

Supplement of Clim. Past Discuss., 11, 2239–2279, 2015  
<http://www.clim-past-discuss.net/11/2239/2015/>  
doi:10.5194/cpd-11-2239-2015-supplement  
© Author(s) 2015. CC Attribution 3.0 License.



*Supplement of*

## **Climate–vegetation modelling and fossil plant data suggest low atmospheric CO<sub>2</sub> in the late Miocene**

**M. Forrest et al.**

*Correspondence to:* J. T. Eronen ([jussi.t.eronen@helsinki.fi](mailto:jussi.t.eronen@helsinki.fi))

The copyright of individual parts of the supplement might differ from the CC-BY 3.0 licence.

1 Table S1 PFT Specific Parameters

2 PFT characteristics and parameter values used in this study.  $T_{c,min}$  = Minimum coldest-month temperature for survival and establishment;  $T_{c,max}$  =  
3 maximum coldest-month temperature for establishment;  $GDD_5$  = Minimum accumulated degree-day sum of days above 5°C for establishment;  
4  $r_{fire}$  = Fraction of individuals surviving fire;  $a_{leaf}$  = leaf longevity;  $a_{ind}$  = individual maximum, non-stressed longevity;  $Tr_{leaf}$  = Leaf turnover rate;  
5  $Br$  = Base respiration rate at 10°C;  $T_{opt}$  = Optimal temperature range for photosynthesis. Full PFT names: BNE = boreal needle-leaved evergreen  
6 tree; BINE = boreal shade intolerant needle-leaved evergreen tree; BNS = boreal needle-leaved summergreen tree; BIBS = boreal shade  
7 intolerant broad-leaved summergreen tree; TeBS = temperate broad-leaved summergreen tree; TeIBS = temperate shade intolerant broad-leaved  
8 summergreen tree; TeBE = temperate broad-leaved evergreen tree; TeNE = temperate needle-leaved evergreen tree; TrBE = tropical broad-  
9 leaved evergreen tree; TriBE = tropical shade intolerant broad-leaved evergreen tree; TrBR = tropical broad-leaved raingreen tree; C3G = C<sub>3</sub>  
10 grass; C4G = C<sub>4</sub> grass.

11  
12  
13  
14

| PFT   | Phenology | Shade tolerance class | Leaf Type     | Growth Form | $T_{c, min}$ (°C) | $T_{c, max}$ (°C) | $GDD_5$ (°C day) | $r_{fire}$ | $a_{leaf}$ (year) | $A_{ind}$ (year) | $Tr_{leaf}$ (year <sup>-1</sup> ) | $Br$ (gC gN <sup>-1</sup> day <sup>-1</sup> ) | $T_{opt}$ (°C) |
|-------|-----------|-----------------------|---------------|-------------|-------------------|-------------------|------------------|------------|-------------------|------------------|-----------------------------------|---|----------------|
| BNE   | evergreen | tolerant              | needle-leaved | tree        | -32.5             | -2                | 600              | 0.3        | 3                 | 500              | 0.33                              | 2   | 10-25          |
| BINE  | evergreen | intolerant            | needle-leaved | tree        | -32.5             | -2                | 600              | 0.3        | 3                 | 500              | 0.33                              | 2   | 10-25          |
| BNS   | deciduous | intolerant            | needle-leaved | tree        | -                 | -2                | 350              | 0.3        | 0.5               | 300              | 1                                 | 2   | 10-25          |
| BIBS  | deciduous | intolerant            | broad-leaved  | tree        | -                 | -2                | 350              | 0.1        | 0.5               | 200              | 1                                 | 2   | 10-25          |
| TeBS  | deciduous | tolerant              | broad-leaved  | tree        | -17               | 15.5              | 1200             | 0.1        | 0.5               | 400              | 1                                 | 1   | 15-25          |
| TeIBS | deciduous | intolerant            | broad-leaved  | tree        | -17               | 15.5              | 1200             | 0.1        | 0.5               | 200              | 1                                 | 1   | 15-25          |
| TeBE  | evergreen | tolerant              | broad-leaved  | tree        | 3                 | 18.8              | 1200             | 0.3        | 3                 | 300              | 0.33                              | 1   | 15-25          |
| TeNE  | evergreen | intolerant            | needle-leaved | tree        | -2                | 22                | 900              | 0.3        | 3                 | 300              | 0.33                              | 1   | 15-25          |
| TrBE  | evergreen | tolerant              | broad-leaved  | tree        | 15.5              | -                 | -                | 0.1        | 2                 | 500              | 0.5                               | 0.15  | 25-30          |
| TriBE | evergreen | intolerant            | broad-leaved  | tree        | 15.5              | -                 | -                | 0.1        | 2                 | 200              | 0.5                               | 0.15  | 25-30          |
| TrBR  | deciduous | intolerant            | broad-leaved  | tree        | 15.5              | -                 | -                | 0.3        | 0.5               | 400              | 0.5                               | 0.15  | 25-30          |
| C3G   | -         | -                     | -             | grass       | -                 | -                 | -                | 0.5        | 0.5               | -                | 1                                 | 1   | 10-30          |
| C4G   | -         | -                     | -             | grass       | 15.5              | -                 | -                | 0.5        | 0.5               | -                | 1                                 | 0.15  | 20-40          |

1 Supplementary Figures

2

3 Figure S1. a) The modelled present-day vegetation distribution using LPJ-GUESS  
4 classified into biomes (see Appendix B) compared to a map of potential natural  
5 vegetation (data as Hickler et al. 2006, modified from Haxeltine and Prentice 1996).

6 b) The dominant PFTs of modelled present-day vegetation distribution using LPJ-  
7 GUESS

8

9

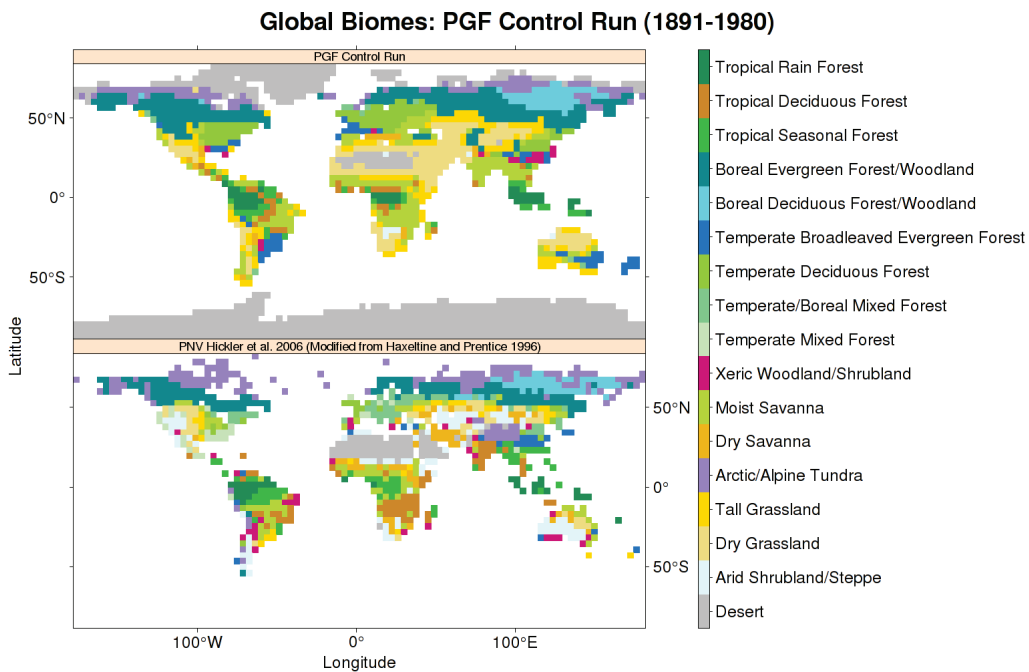
10 Figure S2. Agreement Index difference between the 280 ppm and 450 ppm runs.

11

12

Figure S1

A



B

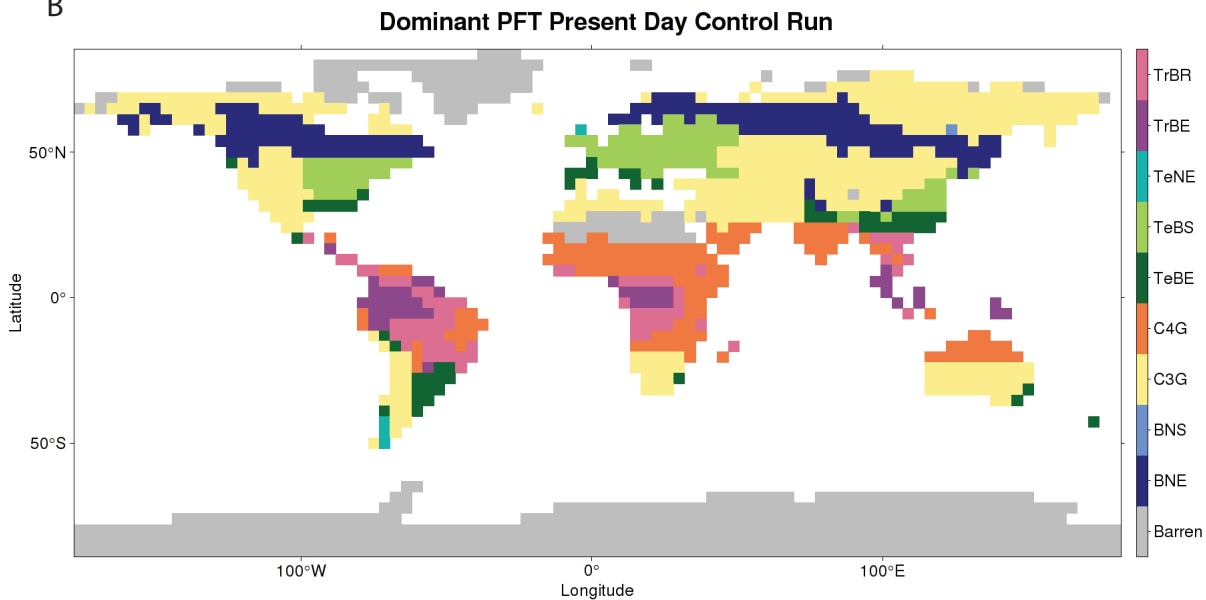
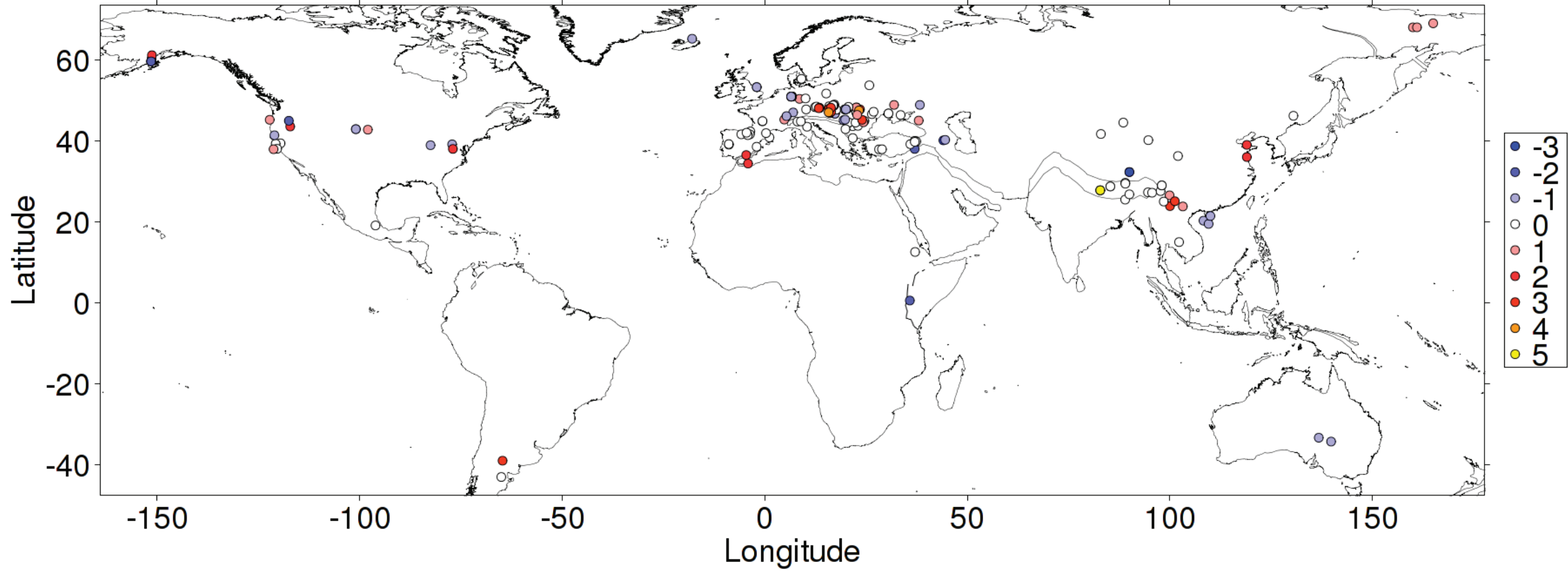


Figure S2

# AI Difference: 280 ppm - 450 ppm



Supplementary Data: all palaeobotanical sites used in the study

North America

| <i>Longitude</i> | <i>Latitude</i> | <i>Region</i>                  | <i>Locality Code</i>  |
|------------------|-----------------|--------------------------------|-----------------------|
| -151.5           | 59.6            | North America                  | Lower Homerian AK     |
| -151.5           | 59.6            | North America                  | Middle Homerian AK    |
| -151.5           | 59.6            | North America                  | Upper Homerian AK     |
| -151.4           | 60.2            | North America                  | Lower Clamgulchian AK |
| -151.3           | 61.12           | Cook Inlet Region, Alaska, USA | Chuitna River         |
| -122.22          | 45.19           | Northern America               | Faraday               |
| -121.27          | 37.93           | North America                  | Neroly CA             |
| -121.06          | 41.37           | California, USA                | Upper Cedarville Pit  |
| -120.75          | 39.28           | California, USA                | Remington Hill        |
| -120.38          | 38.03           | California, USA                | Table Mountain        |
| -119.55          | 39.38           | Nevada, USA                    | Chalk Hills           |
| -117.5           | 44.95           | Oregon, USA                    | Unity Or              |
| -117.16          | 43.53           | Eastern Oregon, USA            | Succor Creek          |
| -100.96          | 42.88           | North America                  | Kilgore               |
| -100.96          | 42.88           | North America                  | Kilgore (pollen)      |
| -98              | 42.75           | Antelope County, Nebraska, USA | Antelope Ne           |
| -96.11           | 19.12           | Mexico                         | Paraje Solo Fm        |
| -82.52           | 38.92           | USA                            | Gray Sinkhole         |
| -77.18           | 39.13           | North America                  | Bryn Mawr             |
| -77              | 38              | South Maryland, USA            | Brandywine Mar        |

South America

| <i>Longitude</i> | <i>Latitude</i> | <i>Region</i> | <i>Locality Code</i> |
|------------------|-----------------|---------------|----------------------|
| -65.05           | -42.94          | Argentina     | Puerto Madryn Fm     |
| -64.74           | -38.92          | Argentina     | Barranca Final Fm    |

Western Eurasia

| <i>Longitude</i> | <i>Latitude</i> | <i>Region</i>              | <i>Locality Code</i>   |
|------------------|-----------------|----------------------------|------------------------|
| -17.939          | 65.187          | Iceland                    | Fnjorskadalur Fm       |
| -8.9             | 39.2            | Portugal                   | Povoa 3                |
| -8.87            | 39.06           | Portugal                   | Azambuja               |
| -5.8             | 41.6            | Duero, Spain               | Abezames               |
| -4.589           | 36.491          | Spain                      | Andalucia G1           |
| -4.5             | 42              | Duero, Spain               | Torrem2                |
| -4.2             | 41.4            | Duero, Spain               | Penafiel               |
| -4.14            | 34.39           | Marocco                    | Taza Guercif           |
| -3.7             | 41.6            | Duero, Spain               | Burgos                 |
| -3.58            | 42.32           | Spain                      | Castrillo del Val      |
| -2.02            | 38.544          | Spain                      | Rambla del Mojon 30 35 |
| -2               | 53.25           | Derbyshire, England        | Derbyshire             |
| -0.6             | 44.8            | Landas, Spain              | Arjuzanx               |
| -0.57            | 44.87           | France                     | Pont de Gail           |
| 0.3              | 41.9            | Pirineo, Spain             | Seo De Urgell          |
| 1.15             | 40.84           | Tarragona, Spain           | Tarragona E2 1         |
| 4.81             | 45.24           | France                     | Andance                |
| 5.35             | 45.95           | France                     | Amberieu S3            |
| 5.35             | 46.1            | France                     | Soblay                 |
| 6.47             | 50.92           | Lower Rhine Basin, Germany | H7FB(F)                |
| 6.509            | 50.9            | Lower Rhine Basin, Germany | H7F(B)                 |

|        |        |  |                               |
|--------|--------|--|-------------------------------|
| 6.509  | 50.9   | Lower Rhine Basin, Germany                 | H7F(F)                        |
| 6.509  | 50.9   | Lower Rhine Basin, Germany                 | H7FT(F)                       |
| 6.691  | 50.954 | Lower Rhine Basin, Germany                 | FO7(F)                        |
| 6.691  | 50.954 | Lower Rhine Basin, Germany                 | FO7O(B)                       |
| 6.691  | 50.954 | Lower Rhine Basin, Germany                 | FO7U(P)                       |
| 6.71   | 50.91  | Germany                                    | FI7O(B)                       |
| 7      | 47     | Switzerland                                | Nebelberg                     |
| 8.05   | 44.75  | Piemonte, Italy                            | Guarene(F)                    |
| 8.57   | 50.35  | Mainz Basin, Germany                       | Dorheim (F)                   |
| 8.9    | 44.8   | Piemonte, Italy                            | Scrvia (F)                    |
| 9.04   | 55.29  | Denmark                                    | Gram clay pit (J11)           |
| 10.05  | 50.45  | Rhön Mountains, Germany                    | Wüstensachsen (F)             |
| 10.2   | 47.75  | Southern Germany                           | Geissertobel(B)               |
| 10.43  | 43.48  | Toscana, Italy                             | Gabbro(F)                     |
| 12.4   | 48.3   | Southern Germany                           | Aubenham (B)                  |
| 12.75  | 48.45  | Southern Germany                           | Lerch(B)                      |
| 13.32  | 48.04  | Austria                                    | Schneegattern (B)             |
| 13.36  | 48.16  | Austria                                    | Grossenreith(B)               |
| 13.42  | 48.15  | Austria                                    | Lohnsburg(B)                  |
| 13.55  | 48.1   | Austria                                    | Ampfelwang (F)                |
| 15.16  | 51.67  | Southwest Poland                           | Godznica(F)                   |
| 15.75  | 47.02  | Steiermark, Kirchberg an der Raab, Austria | Wörth (B)                     |
| 15.83  | 47.92  | Burgenland, Austria                        | Neusiedl(B)                   |
| 15.88  | 48.53  | Vienna Basin, Austria                      | Ebersbrunn (B)                |
| 16     | 46.91  | Austria                                    | Mataschen rev Hably           |
| 16.08  | 46.93  | Steiermark, Neuhaus/Klausenbach, Austria   | Neuhaus(B)                    |
| 16.08  | 46.93  | Steiermark, Neuhaus/Klausenbach, Austria   | Neuhaus rev Hably             |
| 16.27  | 48.17  | Vienna Basin, Austria                      | Laaerberg(B)                  |
| 16.33  | 48.17  | Vienna Basin, Austria                      | Vösendorf(B)                  |
| 16.36  | 47.15  | Hungary                                    | Sé (B)                        |
| 16.364 | 48.023 | Austria                                    | Hennersdorf                   |
| 16.58  | 48.03  | Austria                                    | Goetzendorf                   |
| 16.88  | 48.75  | Czech Republic                             | Postorna                      |
| 16.88  | 48.75  | Czech Republic                             | Postorna Moravska Nova Ves    |
| 17.05  | 48.7   | Slovakia                                   | Moravian Basin F(B)           |
| 17.05  | 48.7   | Slovakia                                   | Moravska N V(B)               |
| 17.17  | 48.97  | Slovakia                                   | Mistrin (B)                   |
| 17.295 | 46.691 | Hungary                                    | Balatonszentgyorgi            |
| 17.635 | 47.684 | Hungary                                    | Gyor Sashegy                  |
| 19.45  | 45.1   | Serbia                                     | Sremska                       |
| 19.75  | 47.75  | Hungary                                    | Rozsaszentmarton (B)          |
| 19.75  | 47.75  | Hungary                                    | Rozsaszentmarton (rev. Hably) |
| 19.84  | 45.23  | Serbia                                     | Sremska Kamenica              |
| 19.917 | 42.883 | Montenegro                                 | Popovici                      |
| 20.032 | 47.776 | Hungary                                    | Visonta(B)                    |
| 20.032 | 47.776 | Hungary                                    | Visonta rev Hably             |
| 20.4   | 47.97  | Hungary                                    | Felsötarkany                  |
| 20.4   | 47.97  | Hungary                                    | Felsotarkany rev Hably        |
| 20.45  | 44.31  | Serbia                                     | Dubona I (B)                  |
| 20.45  | 44.31  | Serbia                                     | Dubona II (B)                 |



|        |        |  |                                  |
|--------|--------|--|----------------------------------|
| 20.63  | 48.38  | Hungary                                | Rudabanya (B)                    |
| 20.75  | 44.52  | Serbia                                 | Durinci (B)                      |
| 21.69  | 43.61  | Serbia                                 | Crveni Breg Grocka               |
| 21.71  | 40.68  | Italy                                  | Vegora                           |
| 22.4   | 44.5   | Serbia                                 | Osojna                           |
| 22.57  | 48.23  | Carpathian area, Ukraine               | Velikaya Began Pontian           |
| 22.58  | 46.97  | Romania                                | Delureni (B)                     |
| 22.67  | 48.23  | Carpathian area, Ukraine               | Velikaya Began N856well          |
| 22.8   | 46.4   | Nagyfeketepatak, Bihor county, Romania | Valea Neagra(B)                  |
| 22.983 | 43.7   | Bulgaria                               | Drenovets Maeotian               |
| 23.25  | 47.5   | Romania                                | Oas Basin                        |
| 23.5   | 47.75  | Romania                                | Chiuzbaia (rev. Hably)           |
| 24.02  | 45.18  | Romania                                | Tanasesti Ramesti                |
| 24.32  | 44.57  | Romania                                | Ramesti                          |
| 24.6   | 44.9   | Romania                                | Porceni                          |
| 25.8   | 53.7   | Belarus                                | Grodno Complex                   |
| 26.44  | 46.58  | Romania                                | Comanesti                        |
| 26.86  | 47.17  | Romania                                | Pau Iasi                         |
| 28.2   | 37.9   | Western Anatolia, Turkey               | Nazilli Haskoy Upper Coal        |
| 28.925 | 37.92  | Turkey, Western Anatolia               | Saraykoy                         |
| 30.52  | 46.75  | Ukraine                                | Emetovka Early Maeotian 1        |
| 30.52  | 46.75  | Ukraine                                | Emetovka Early Maeotian 2        |
| 31.91  | 48.86  | Ukraine, western part, multiple sites  | Western Ukraina (lower Maeotian) |
| 33.53  | 46.37  | Ukraine Plane, Ukraine                 | Chaplinka                        |
| 35.93  | 39.17  | Turkey                                 | Sivas Karaozu                    |
| 37     | 38     | Central Anatolia, Turkey               | Sivas Gemerek                    |
| 37     | 40     | Central Anatolia, Turkey               | Duzyayla                         |
| 37.018 | 39.754 | Central Anatolia, Turkey               | Sivas Vasiltepe                  |
| 37.1   | 12.583 | Ethiopia                               | Chilga                           |
| 37.383 | 39.834 | Central Anatolia, Turkey               | Sivas Hafik                      |
| 38     | 45     | Western Georgia                        | Cocchati Complex                 |
| 38.28  | 48.86  | Ukraine, eastern part, multiple sites  | Eastern Ukraina (lower Maeotian) |
| 44.09  | 40.11  | Armavir region, Armenia                | Hoktemberya                      |
| 44.53  | 40.24  | Armenia                                | Hrazdan/2                        |

Eastern Eurasia

| <i>Longitude</i> | <i>Latitude</i> | <i>Region</i>            | <i>Locality Code</i>      |
|------------------|-----------------|--------------------------|---------------------------|
| 82.81            | 27.8            | Nepal                    | Surai Khola 11-8 Ma       |
| 82.81            | 27.8            | Nepal                    | Surai Khola 6-5 Ma        |
| 82.81            | 27.8            | Nepal                    | Surai Khola 8-6 Ma        |
| 82.97            | 41.683          | North Western China      | Kuqa Xinjiang             |
| 85.3             | 28.75           | China                    | Danzengzhukang Fm         |
| 85.3             | 28.75           | China                    | Lower Woma Fm             |
| 88.5             | 44.5            | North Western China      | Southern Junggar Xinjiang |
| 88.96            | 25.5            | Bangladesh               | Dupi Tila                 |
| 89               | 29.43           | China                    | Wulong                    |
| 89               | 29.65           | Tibet                    | Nanmulin Wulong Fm        |
| 90               | 26.8            | Eastern Himalaya, Bhutan | Bhutan M, Siwalik         |
| 90               | 32.3            | China                    | Lunpola Basin             |
| 90               | 32.3            | Tibet                    | Lunpola Basin Dinquing 2  |
| 94.6             | 27.3            | India                    | Assam Miocene             |
| 94.683           | 40.167          | Northwestern China       | Dunhuang                  |

|         |        |  |                             |
|---------|--------|--|-----------------------------|
| 95.6    | 27.2   | India                                      | Deomali                     |
| 97.7    | 27.6   | India                                      | Arunachal Pradesh           |
| 98      | 29     | Tibet                                      | Markam Lavula 1             |
| 98      | 29     | Tibet                                      | Markam Lavula a pollen      |
| 98.49   | 25.02  | China                                      | Tengchong                   |
| 99.92   | 26.55  | China                                      | Jianchuan                   |
| 100.017 | 23.9   | China                                      | Lincang                     |
| 101.22  | 25.1   | Southern China                             | Luehe Chuxiong              |
| 102     | 36.25  | North Western China                        | Xining Minhe Basin          |
| 102.267 | 15.016 | Thailand                                   | Khorat                      |
| 103.198 | 23.812 | Yunnan, China                              | Xiaolongtan (Pre)           |
| 108.3   | 20.3   | North continental shelf of South China Sea | Beibuwan 3                  |
| 109.56  | 19.5   | Coastal site South China Sea               | Fushan depression Fushan 3  |
| 110     | 21.45  | Coastal site South China Sea               | Leizhou Peninsula Leizhou 3 |
| 119     | 36     | Northern China                             | Bozhong Basin               |
| 119     | 39     | Northern China                             | Bohai Gulf Basin            |
| 130.5   | 46.17  | North Eastern China                        | Huanan Heilongjiang         |
| 136.75  | -29.75 | Australia                                  | Stuart Creek                |
| 139.8   | -30.7  | Australia                                  | Woltana1 Well 93,5          |
| 160     | 68     | Siberia                                    | Bayokov H1172               |
| 161     | 68     | Siberia, Russia                            | Yanran H3690                |
| 165     | 69     | Siberia, Russia                            | Nekkeiveem H3658 I mio      |

Africa

| <i>Longitude</i> | <i>Latitude</i> | <i>Region</i> | <i>Locality Code</i> |
|------------------|-----------------|---------------|----------------------|
| 35.8             | 0.6             | Kenya         | Tugen                |