Supplement of

Factors controlling natural subsidence in the Po Plain

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Supplementary data

Radiocarbon dates

Chronological constrain for core correlation is provided by 28 published $^{14}$C ages (Sheets 204 and 222 of the Geological Map of Italy to scale 1:50000; Amorosi et al., 2005; Amorosi et al., 2017; Bruno et al., 2017) and from 48 $^{14}$C dates carried out at the KIGAM Laboratory (Korea Institute of Geoscience and Mineral Resources, Daejeon, Republic of Korea). Conventional $^{14}$C ages (S1) were calibrated using OxCal 4.2 (Bronk Ramsey & Lee, 2013) with the IntCal 13 and Marine13 curves (Reimer et al., 2013).

| Core | Sample depth (m) | Sample code | C14 age | Cal year BP (mean value) | Material | References | Figure |
|------|------------------|-------------|---------|--------------------------|----------|------------|--------|
| B2   | 5.8              | KGM-TWd180568b | 320±20  | 380±40                   | Peat     | This paper | 4      |
|      | 11.15            | KGM-TWd180570a | 650±30  | 610±40                   | Wood     | This paper | 3,4    |
|      | 12.35            | KGM-TWd180571a | 730±20  | 680±10                   | Wood     | This paper | 4      |
|      | 13.8             | KGM-TWd180572a | 960±40  | 860±50                   | Wood     | This paper | 3,4    |
|      | 15.3             | KGM-TWd180574a | 1190±20 | 1120±40                  | Peat     | This paper | 3,4    |
|      | 16.6             | KGM-TWd180575a | 2730±30 | 2820±30                  | Wood     | This paper | 3      |
|      | 17.6             | KGM-TWd180576a | 3820±30 | 4220±60                  | Peat     | This paper | 3      |
|      | 19.2             | KGM-Tc1800070a | 5030±30 | 5530±40                  | Shell    | This paper | 3,4    |
|      | 20.25            | KGM-TWd180577a | 5390±30 | 6210±60                  | Wood     | This paper | 3,4    |
|      | 21.6             | KGM-TWd180578a | 7150±30 | 7970±20                  | Peat     | This paper | 3,4    |
|      | 22.05            | KGM-TSa180035a | 9500±40 | 10840±130                | Bulk sediment | This paper | 3,4    |
|      | 29.8             | KGM-TSa180036a | 246300±90 | 28660±120               | Bulk sediment | This paper | 3,4    |
| B3   | 3.55             | KGM-TWd190145 | 2120±20 | 2090±40                  | Peat     | This paper | 3,4    |
|      | 3.95             | KGM-TWd190146 | 3020±30 | 3210±60                  | Peat     | This paper | 4      |
|      | 4.35             | KGM-TWd190147 | 4250±40 | 4830±70                  | Wood     | This paper | 4      |
|      | 5.95             | KGM-TWd190148 | 4500±30 | 5170±80                  | Wood     | This paper | 3,4    |
|      | 6.6              | KGM-TWd190149 | 4910±30 | 5630±30                  | Wood     | This paper | 3,4    |
|      | 6.95             | KGM-TWd190150 | 5330±30 | 6110±60                  | Peat     | This paper | 3,4    |
|      | 7.9              | KGM-TWd190151 | 6280±30 | 7210±30                  | Plant fragment | This paper | 3,4    |
|      | 8.5              | KGM-TWd190152 | 6480±30 | 7380±40                  | Peat     | This paper | 4      |
|      | 8.67             | KGM-TWd190153 | 6780±30 | 7630±20                  | Peat     | This paper | 4      |
|      | 9.08             | KGM-TWd190154 | 7130±40 | 7960±40                  | Peaty clay | This paper | 4      |
|      | 9.2              | KGM-TSa190025 | 8870±50 | 10000±120                | Bulk sediment | This paper | 3,4    |
|      | 12.6             | KGM-TSa190026 | 23750±140 | 27820±130              | Bulk sediment | This paper | 3,4    |
|      | 15.6             | KGM-TSa190028 | 28590±200 | 32630±370            | Organic Clay | This paper | 3,4    |
| B4   | 5.15             | KGM-TWd190155 | 1780±20 | 1700±50                  | Peat     | This paper | 3,4    |
|      | 6.05             | KGM-TWd190156 | 2770±30 | 2860±40                  | Peat     | This paper | 3,4    |
| Sample ID | Material | Age Range | Comment |
|-----------|----------|-----------|---------|
| 6.36      | KGM-TWd190157 | 3230±30 3450±40 | Wood | This paper |
| 6.9       | KGM-TWd190158 | 4070±30 4560±90 | Wood | This paper |
| 8.4       | KGM-TWd190159 | 4180±30 4720±60 | Wood | This paper |
| 9.58      | KGM-TWd190161 | 5240±30 5980±70 | Peat | This paper |
| 10.1      | KGM-TWd190162 | 5290±30 6080±60 | Peat | This paper |
| 10.9      | KGM-TWd190163 | 6120±30 7000±70 | Peat | This paper |
| 11.85     | KGM-TWd190164 | 6440±30 7370±40 | Wood | This paper |
| 12.4      | KGM-TWd190165 | 6470±30 7380±30 | Wood | This paper |
| 15.5      | KGM-TWd190166 | 8710±40 9650±80 | Wood | This paper |
| 15.6      | KGM-TSa190029 | 9780±60 11200±70 | Organic Clay | This paper |
| 21.3      | KGM-TWd190167 | 22710±90 27080±170 | Peat | This paper |
| 24.96     | KGM-TSa190030a | 28660±210 32740±380 | Organic Clay | This paper |
| 30.85     | KGM-TSa190031 | 40130±450 43760±420 | Organic Clay | This paper |
| 3.75      | KGM-OWd150177 | 2680±40 2970±110 | Peat | Amorosi et al., 2017 |
| 9.50      | KGM-OWd150178 | 4190±40 4690±85 | Plant fragment | Amorosi et al., 2017 |
| 11.30     | KGM-OWd150179 | 5630±40 6150±130 | Shell | Amorosi et al., 2017 |
| 11.40     | KGM-OWd150180 | 5340±40 6105±110 | Wood | Amorosi et al., 2017 |
| 13.30     | KGM-OWd150181 | 6340±50 7250±85 | Plant fragment | Amorosi et al., 2017 |
| 16.50     | KGM-OWd160062 | 7040±50 7870±50 | Peat | Amorosi et al., 2017 |
| 17.85     | KGM-OWd150182 | 7340±50 8125±105 | Wood | Amorosi et al., 2017 |
| 18.40     | KGM-OWd160063 | 7730±50 8510±50 | Peat | Amorosi et al., 2017 |
| 18.70     | KGM-OSn150001 | 9950±60 11430±195 | Organic clay | Amorosi et al., 2017 |
| 25.3      | KGM-TSa180006 | 22190±100 26400±160 | Wood | This paper |
| 26.90     | KGM-OWd150183 | 22200±120 26450±390 | Wood | Amorosi et al., 2017 |
| 30.1      | KGM-TSa180007 | 27810±150 31520±190 | Peaty clay | This paper |
| 5.45      | OWd160064 | 4890±50 5630±50 | Wood | Bruno et al., 2017 |
| 7.3       | OWd160065 | 5800±40 6600±50 | Wood | Bruno et al., 2017 |
| 22.4      | OWd160066 | 7950±40 8820±100 | Wood | Bruno et al., 2017 |
| 7.95      | KGM-TCa180071 | 1860±30 1270±40 | Shell | Amorosi et al., 2019 |
| 15.90     | KGM-TCa180072 | 2340±30 1800±50 | Shell | Amorosi et al., 2019 |
| 19.75     | KGM-TWd180579 | 2570±20 2070±60 | Wood | Amorosi et al., 2019 |
| 25.85     | Beta Analytic-187 S1_25.85 | 8250±60 9230±100 | Plant fragment | CARG Project, Sheet 187 |
| 50.05     | Beta Analytic-187 S1_50.05 | 41750±1000 45700±1900 | Peat | CARG Project, Sheet 187 |
### S1. List of radiocarbon dates

| 204 S4 | 21 | ENEA-204 S4_26.8 | 35500±3000 | 41730±6620 | Organic clay | CARG Project, Sheet 204 | 3 |
|--------|----|------------------|------------|------------|--------------|--------------------------|---|
|        | 8.50 | KGM-OWd170593-1 | 3910±30 | 4345±50 | Plant fragment | Bruno et al., 2019 | 4 |
|        | 9.30 | KGM-OWd170594-1 | 4390±30 | 4955±60 | Plant fragment | Bruno et al., 2019 | 3 |
|        | 10.30 | KGM-OWd170595-1 | 5140±30 | 5620±30 | Plant fragment | Bruno et al., 2019 | 3 |
|        | 16.95 | ETH-204S5_16.95 | 7735±70 | 8520±70 | Wood | Amorosi et al., 2005 | 3 |
|        | 22.70 | ETH-204S5_22.7 | 23320±210 | 27545±155 | Peat | CARG Project, Sheet 204 | 4 |

| 204 S5 | 12.8 | KGM-OWd170597-1 | 3850±30 | 4270±70 | Plant fragment | This paper | 3,4 |
|--------|------|------------------|------------|------------|--------------|-----------|---|
|        | 13.40 | KGM-OWd170598-1 | 3930±30 | 4370±60 | Plant fragment | This paper | 4 |
|        | 14.75 | KGM-OWd170599-1 | 5170±30 | 5630±30 | Plant fragment | This paper | 3,4 |
|        | 14.95 | KGM-OWd170600-1 | 5530±30 | 6100±60 | Plant fragment | This paper | 4 |
|        | 17 | KGM-OWd170601-1 | 6840±30 | 7670±30 | Plant fragment | This paper | 3,4 |

| 204 S17 | 7.0 | Beta Analytic-222 S2_7.0 | 340±60 | 400±40 | Peat | CARG Project, Sheet 222 | 3 |
|---------|------|-------------------------|-----------|------------|--------------|--------------------------|---|
|        | 17.0 | Beta Analytic-222 S2_17.0 | 6000±60 | 6850±40 | Peat | CARG Project, Sheet 222 | 3 |
|        | 20.9 | Beta Analytic-222 S2_20.9 | 7420±60 | 8270±40 | Organic Clay | CARG Project, Sheet 222 | 3 |
|        | 26.2 | Beta Analytic-222 S2_26.2 | 19770±150 | 23660±490 | Peat | CARG Project, Sheet 222 | 3 |

### Decompaction model

Decompaacted thickness $H_0$ of a soil column presently comprised between depth $z_1$ and $z_2$ can be computed as (Gambolati et al., 1998):

$$H_0 = (1 + e_0) \int_{z_1}^{z_2} \frac{dz}{1 + e(z)}$$

where $e_0$ initial void index and $e(z)$ is the void index at depth $z$. The behavior of $e(z)$ in virgin loading conditions is given by

$$e(z) = e_0 - C_c \log {\sigma_z}$$

with $C_c$ the compression index and $\sigma_z$ the intergranular effective stress.

### Application of decompaction model to core B4

The above described decompaction model was applied to core B4 (S2) where six depositional facies association were identified. The reader is referred to Amorosi et al. (2005 2017a, b), Bruno et al. (2017) and Giacomelli et al. (2018) for detailed description. A brief description is provided in S3, together with geotechnical parameters $e_0$ and $C_c$. 
S2. Stratigraphic log of core B4

Geothechnical characterization of facies associations was based on; (i) loss on ignition and bulk density determination carried out on 6 undisturbed samples from core B4 (ii) 22 oedometer tests carried out on nearby cores from the database of the Geological Seismic and Soil Survey of Regione Emilia Romagna.
| Depositional system | facies association | lithology | Accessory material, sedimentary structures | PP | e0 | cc |
|---------------------|-------------------|-----------|--------------------------------------------|-----|----|----|
| Lowed delta plain – outer estuary | Lagoon | silty clay | Brackish fossils | < 1.2 | 1.56 | 0.15 |
| Upper delta plain – inner estuary | Swamp | peat | Wood, plant debris | - | 2.29 | 0.86 |
| | | clay | Freshwater to low brackish fossils, plant debris | < 1.2 | 1.56 | 0.15 |
| Poorly drained floodplain | silty clay | Parallel lamination | 1.2 – 1.8 | 0.99 | 0.23 |
| Alluvial Plain | Floodplain | clayey silt | carbonate concretions, Fe and Mn oxides | > 1.8 | 0.84 | 0.12 |
| | Crevasse and levee | silty sand | Parallel and cross lamination | - | 0.42 | 0.17 |

S3. Geomechanical parameters $e_0$ and $C_c$ used to decompact the units of core B4. PP = pocket penetrometer.

A simplified stratigraphy was used for decompact of core B4 (S4). The deformation of each unit is computed as $(H_0 - H)/H_0$, with $H$ the actual thickness of the unit. The higher compaction is associated with the peat horizons.

| Facies association | $H$ (m) | $H_0$ (m) | Deformation (%) |
|--------------------|---------|-----------|-----------------|
| Crevasse and levee | 4.15    | 5.14      | 19.26           |
| Swamp peat         | 0.10    | 0.19      | 47.09           |
| Swamp clay and lagoon | 4.23 | 4.76      | 11.13           |
| Swamp peat         | 0.10    | 0.21      | 51.92           |
| Lagoon             | 1.32    | 1.50      | 12.00           |
| Crevasse and levee | 0.95    | 1.26      | 24.60           |
| Swamp clay         | 2.25    | 2.57      | 12.45           |
| Poorly drained floodplain | 1.40 | 1.87      | 25.13           |
| Floodplain         | 5.30    | 6.22      | 14.79           |
| Swamp peat         | 0.55    | 1.56      | 64.74           |
| Poorly drained floodplain | 3.50 | 4.93      | 29.01           |
| Floodplain         | 6.00    | 7.16      | 16.20           |

S4. Result of the decompaction model for each unit of core B4. Boulder line marks the Pleistocene/Holocene boundary.

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