**Supplementary information**

**Tab. S.1.** List of selected references used to compile tab.1 divided per locality.

|  |  |  |
| --- | --- | --- |
| Italy (Bonarelli Level) | Umbria-Marche | Capasso (2007) |
| Sicily | Rindone (2008), Carnevale and Rindone (2011) and references therein |
| Morocco | Jbel Tselfat | Vullo et al. (2016), Khalloufi et al. (2017) and references therein |
| Agoult |
| Goulmima |
| Dinarids | Komen-Kras | Forey et al. (2003) and references therein |
| Portugal | Portugal | Forey et al. (2003) and references therein |
| England | Chalk | Guinot et al. (2012a,b), Guinot et al. (2013); Friedman et al. (2016) and references therein |
| France | Chalk and other localities | Vullo et al. (2007), Vullo et al. (2018) and references therein |
| Germany | Westphalia | Diedrich (2012) |
| Saxony | Müller and Diedrich (1991); Licht et al.(2016), Fischer et al., (2017); Stumpf et al. (2019) |
| Middle East | Israel (Ein Yabrud, etc.) | Forey et al., (2003), Cawley and Kriwet (2018) |
| Hakel | Forey et al. (2003), Bannikov and Bacchia (2005), Gayet et al., (2012), Bannikov (2015), Cawley and Kriwet (2019) and references therein |
| Hajoula |
| Nammoura |
| North America | Western Interior Seaway (Greenhorn, etc.) | Williamson et al., (1993), Shimada et al. (2006), Cumbaa et al. (2010), Underwood and Cumbaa (2010), Gallardo et al. (2012), Nagrodsky et al. (2012), Bice et al. (2013) and references therein |
| Mexico | Agua Nueva Fm. | Bannikov (2015), Gonzalez-Rodriguez et al. (2016), Alvarado-Ortega et al. (2019) and references therein, Than-Marchese et al. (2020), Baños-Rodríguez et al. (2020) |
| Boquillas Fm. |
| El Doctor Fm. |
| Cintalapa Fm. |
| Eagle Ford Fm. |

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**PCA ‘Fish’ (Bony fishes+chondrichthyans)**

**Summary**

PC Eigenvalue % variance

1 5.5824 20.033

2 4.23472 15.197

3 2.67353 9.5944

4 2.45279 8.8022

5 2.08842 7.4946

6 1.7435 6.2568

7 1.29138 4.6343

8 1.12601 4.0408

9 1.11033 3.9846

10 0.773031 2.7741

11 0.72237 2.5923

12 0.690964 2.4796

13 0.602364 2.1617

14 0.476014 1.7082

15 0.459444 1.6488

16 0.427453 1.534

17 0.377928 1.3563

18 0.356453 1.2792

19 0.294358 1.0563

20 0.233387 0.83754

21 0.123435 0.44296

22 0.0253363 0.090923

**Scores PCA ‘Fish’**

 PC 1 PC 2 PC 3 PC 4 PC 5 PC 6 PC 7 PC 8 PC 9 PC 10 PC 11 PC 12 PC 13 PC 14 PC 15 PC 16 PC 17 PC 18 PC 19 PC 20 PC 21 PC 22

NE Italy (this study) -1.1788 -0.18887 -0.34794 0.061194 1.6917 2.3679 0.42395 2.6725 -1.7107 -0.14031 1.9581 -0.44988 0.41951 -0.39924 0.038684 0.062852 -0.10567 0.34232 0.32918 -0.094922 -0.019859 -0.0047338

Umbria-Marche -0.75273 -0.81236 -0.36453 0.023028 0.74925 0.43313 -0.19391 0.88358 -0.12975 0.23968 -0.236 -0.25962 -0.57217 0.43222 -0.51354 -0.20448 0.80255 -0.62565 -2.0621 0.33016 0.066582 0.018973

Sicily -0.61415 -0.96125 -0.81738 0.010374 1.1047 0.7259 0.11638 0.86093 0.82846 -0.040751 -1.2309 0.63296 0.018452 -0.076424 -0.1415 -1.4092 1.2624 -0.96555 1.0994 -0.043061 0.019476 0.008878

Jbel Tselfat -0.74086 -1.173 -1.1022 0.051278 1.39 1.1209 0.23641 1.298 1.4163 -0.33946 -1.9682 1.2847 0.45871 0.036504 0.25082 1.1046 -0.95015 0.70457 -0.17693 0.086808 0.027134 0.0091637

Agoult -0.44708 -0.78252 -0.28829 0.012189 -0.35746 -1.0129 -0.42059 0.015582 0.23343 0.31909 -0.080652 -0.72095 -0.70585 -0.65468 -2.234 1.193 0.53511 0.41806 0.60766 0.34606 0.11953 0.03634

Goulmima (Tur) -0.37205 -0.80824 -0.35865 0.013944 -0.31507 -0.82285 -0.32212 -0.090149 0.093593 0.089005 -0.0025438 -0.21405 0.03498 -0.39496 -0.058408 -0.032989 -0.22829 -0.14716 -0.23565 -1.8229 0.76661 0.11056

Komen-Kras 0.098206 -0.96492 -0.61068 0.039585 0.2671 -1.0654 4.8545 -0.97622 -0.88226 -0.065471 -0.049894 0.05347 -0.10808 0.22477 0.036099 0.1147 0.024015 -0.037536 0.0080544 0.056265 0.026011 0.0095828

Portugal -0.29483 -0.83412 -0.43027 -0.0094375 -0.21956 -0.89878 -0.28522 -0.42451 -0.024943 0.33745 -0.0199 0.17836 0.017244 -1.0009 -0.23432 -1.9481 -0.5989 1.5007 -0.31235 0.4793 0.13418 0.038794

Chalk -3.4479 8.6151 -0.82295 0.059194 -0.83802 -0.66669 0.35075 0.51371 0.36748 0.14922 -0.17543 0.077155 0.030122 0.017815 -0.0070872 -0.044517 -0.014159 -0.011167 -0.027142 0.0035227 0.0013546 0.00064491

Chalk and other localities (FR) -0.56814 -0.31586 0.31452 -0.045263 -0.32633 -1.1745 -0.66138 -0.28626 -0.072418 -3.7536 0.63496 0.51299 -0.08954 0.35122 -0.01248 -0.016655 0.15051 0.019096 -0.0062101 0.16583 0.062495 0.020717

Saxony -1.0587 0.37465 0.58644 -0.017559 0.43942 0.49804 -1.3499 -1.3462 -3.8714 0.26995 -1.4718 0.49415 -0.060393 0.30475 0.10607 0.20331 -0.061579 -0.032879 0.19195 0.050669 0.026635 0.0096147

Westphalia -1.4477 0.66752 -0.98535 0.021309 2.4947 2.9031 -0.32864 -3.2556 1.3363 -0.024806 0.84067 -0.42843 -0.037644 -0.037891 -0.011399 0.10951 -0.023196 -0.010429 -0.012841 -0.0082196 -0.0014618 0.00010028

Israel (Ein Yabrud, etc.) -0.33266 -0.92523 -0.45963 0.16315 -0.58215 -1.1723 -0.64343 -0.26756 0.2432 1.3561 1.7963 2.7637 -0.083205 0.63624 0.10077 0.32384 0.1995 -0.11874 0.095785 0.14361 0.062865 0.021735

Hakel (Lebanon) 7.803 2.1353 0.52406 4.4187 1.3548 -0.34069 -0.22513 0.090856 0.019512 0.0099181 -0.012287 -0.043559 0.016994 0.001415 0.0016176 0.016813 -0.0072551 -0.0029415 -0.0050514 0.003794 0.0020012 0.00089045

Hajoula (Lebanon) 6.2008 1.537 -0.012096 -5.7565 0.025269 0.33654 -0.096733 0.070878 0.029531 0.039253 0.021046 0.031441 0.003562 0.029824 0.0055149 0.03236 0.0016924 -0.0043461 -0.0054879 0.01228 0.0058925 0.0023088

Namoura (Lebanon) 1.163 -0.62965 -0.11362 1.0874 -5.3521 3.3003 0.38822 -0.14079 0.14313 -0.13988 -0.13129 0.055284 -0.12923 0.038868 -0.0043391 -0.026555 0.057863 0.036349 -0.01144 0.024622 0.013358 0.005299

WIS (Greenhorn, etc.) -1.473 0.06994 7.2524 -0.26598 0.36818 0.28622 0.43011 0.095845 0.77069 0.28015 -0.059008 0.095654 -0.06615 -0.076052 0.048825 -0.016825 -0.02888 0.033682 0.020201 -0.019457 -0.0034305 -0.00034865

Agua Nueva Fm. (MEX) -0.55913 -0.88412 -0.4779 0.022909 0.087121 -0.50476 -0.46708 0.60964 0.44745 0.40909 0.025472 -1.2654 -2.0108 1.8731 0.58777 -0.26696 -0.67652 0.26635 0.51101 0.070085 0.049449 0.018218

Boquillas Fm. (MEX) -0.35993 -0.77354 -0.33426 0.012911 -0.28764 -0.73704 -0.27677 -0.075593 0.078267 0.068071 -0.0019035 -0.15773 0.024422 -0.2441 -0.035294 -0.018957 -0.11846 -0.072099 -0.090093 -0.40278 -0.3626 -0.68287

El Doctor Fm. (MEX) -0.42243 -0.9159 -0.12059 0.031425 -0.55489 -0.99246 -0.45172 -0.15169 0.32238 0.43808 -0.021475 -1.2246 2.7013 1.3233 0.1168 0.081607 0.55446 0.4332 0.067041 0.17685 0.078251 0.026398

Cintalapa Fm. (MEX) -0.40166 -0.86575 -0.25563 0.035046 -0.44967 -0.76782 -0.34652 0.035969 0.087496 0.17717 0.21745 -0.54452 0.61863 -0.67527 -0.074379 -0.054983 -1.6131 -1.7728 0.11708 0.69132 0.17341 0.047566

Eagle Ford Fm. (MEX) -0.42735 -0.7736 -0.42938 0.017715 -0.38855 -1.0383 -0.43342 -0.05072 0.189 0.2449 -0.030584 -0.68943 -0.50956 -1.4088 2.0778 0.82168 0.9941 0.14375 0.028251 0.40992 0.1282 0.03831

**Scree plot**

