

[Supplementary material]

Boom and bust in Bronze Age Britain: major copper production from the Great Orme mine and European trade, c. 1600–1400 BC

R. Alan Williams^{1,*} & Cécile Le Carlier de Veslud²

¹ *Department of Archaeology, Classics and Egyptology, University of Liverpool, 12–14 Abercromby Square, Liverpool L69 7XZ, UK*

² *UMR 6566 CReAAH, Laboratoire Archéosciences Bat. 24–25, Porte 009, Université de Rennes 1-Campus de Beaulieu, Rennes Cedex 35042, France*

** Author for correspondence (Email: r.a.williams@liverpool.ac.uk)*

Table S1. New lead isotope data using MC-ICP-MS. All analyses carried out by Jane Evans and Vanessa Pashley at NERC Isotope Geosciences Laboratory, Keyworth, UK (2013–2015) except for Tréboul hoard analyses, which were carried out by E. Ponzevera at Ifremer, Brest, France (2016). Existing data that was also used in the study were from Northover and Gale (1983); Rohl (1996); Rohl & Needham (1998); Northover and Salter (1999); Joel *et al.* (2003); Ling *et al.* (2014).

| Material | Location | Ref. number | 206/204 | 2 σ | 207/204 | 2 σ | 208/204 | 2 σ | 207/206 | 2 σ | 208/206 | 2 σ |
|---|-----------------------------------|-------------|---------|------------|---------|------------|---------|------------|---------|------------|---------|------------|
| Copper ores | | | | | | | | | | | | |
| Chalcopyrite with malachite-goethite | Underground: main mine | GO 15 | 19.917 | 0.012 | 15.697 | 0.014 | 38.664 | 0.017 | 0.788 | 0.003 | 1.941 | 0.0064 |
| Malachite-goethite + chalcopyrite | U-G Roman shaft: Gallery B | GO 32 | 19.444 | 0.013 | 15.680 | 0.008 | 38.761 | 0.012 | 0.806 | 0.008 | 1.993 | 0.013 |
| Malachite-goethite & calcite | Underground: main mine | GO 04 | 19.198 | 0.013 | 15.669 | 0.008 | 38.406 | 0.011 | 0.816 | 0.008 | 2.001 | 0.013 |
| Malachite-goethite | Underground: main mine | GO 33 | 19.147 | 0.006 | 15.674 | 0.008 | 38.702 | 0.010 | 0.819 | 0.003 | 2.021 | 0.0050 |
| Malachite-goethite | Opencast | OC 37 | 19.181 | 0.013 | 15.669 | 0.008 | 38.780 | 0.012 | 0.817 | 0.008 | 2.022 | 0.013 |
| Malachite only | Underground: main mine | GO 55 | 18.600 | 0.013 | 15.643 | 0.008 | 38.422 | 0.012 | 0.841 | 0.008 | 2.066 | 0.013 |
| Malachite-goethite & azurite & chalcopyrite | Underground, Roman shaft area R4 | GO 20 | 18.415 | 0.013 | 15.637 | 0.008 | 38.380 | 0.012 | 0.849 | 0.008 | 2.084 | 0.013 |
| Malachite-goethite | Underground: main mine | GO 50 | 18.432 | 0.013 | 15.637 | 0.008 | 38.424 | 0.012 | 0.848 | 0.008 | 2.085 | 0.013 |
| Malachite-goethite | Opencast | OC 31 | 18.356 | 0.013 | 15.635 | 0.008 | 38.363 | 0.012 | 0.852 | 0.008 | 2.090 | 0.013 |
| Malachite-goethite | Underground, Roman shaft area R14 | GO 30 | 18.344 | 0.013 | 15.633 | 0.008 | 38.351 | 0.012 | 0.852 | 0.008 | 2.091 | 0.013 |
| Malachite-goethite | Underground: main mine | GO 67 | 18.336 | 0.012 | 15.630 | 0.007 | 38.338 | 0.011 | 0.852 | 0.008 | 2.091 | 0.013 |
| Malachite-goethite | Opencast | GO E2 | 18.318 | 0.013 | 15.632 | 0.009 | 38.345 | 0.012 | 0.853 | 0.008 | 2.093 | 0.013 |
| Malachite-goethite | Opencast | GO E1 | 18.317 | 0.007 | 15.632 | 0.009 | 38.344 | 0.010 | 0.853 | 0.003 | 2.093 | 0.0050 |
| Lead ores | | | | | | | | | | | | |
| Galena | In situ vein | GO 50 | 18.310 | 0.013 | 15.627 | 0.009 | 38.325 | 0.012 | 0.853 | 0.008 | 2.093 | 0.013 |
| Bronze fragments excavated in the mine | | | | | | | | | | | | |
| Irregular bronze fragment | Underground: location 21 | 8318 | 18.410 | 0.013 | 15.637 | 0.008 | 38.424 | 0.012 | 0.849 | 0.008 | 2.087 | 0.013 |
| Irregular bronze fragment | Underground: location 21 | 8321 | 18.407 | 0.013 | 15.637 | 0.009 | 38.423 | 0.012 | 0.849 | 0.008 | 2.087 | 0.013 |
| Irregular bronze fragment | Underground: location 21 | 8335 | 18.402 | 0.014 | 15.635 | 0.010 | 38.415 | 0.013 | 0.850 | 0.008 | 2.088 | 0.013 |

| | | | | | | | | | | | | |
|---|---|-------|--------|-------|--------|-------|--------|-------|-------|-------|-------|--------|
| Irregular bronze fragment | Underground: location 21 | 8348 | 18.406 | 0.013 | 15.638 | 0.008 | 38.427 | 0.012 | 0.850 | 0.008 | 2.088 | 0.013 |
| Pentrwyn copper prills from smelting | | | | | | | | | | | | |
| Copper prill | Pentrwyn excavation 1998 (analysed in 2011) | 98-1h | 20.385 | 0.013 | 15.737 | 0.008 | 38.624 | 0.012 | 0.772 | 0.008 | 1.895 | 0.013 |
| Slag (with small copper prills) | Pentrwyn excavation 2011 | P12b | 20.204 | 0.013 | 15.735 | 0.009 | 38.676 | 0.013 | 0.779 | 0.008 | 1.914 | 0.013 |
| Copper prill | Pentrwyn excavation 2011 | P16c | 19.874 | 0.006 | 15.708 | 0.008 | 38.731 | 0.010 | 0.790 | 0.003 | 1.949 | 0.0050 |
| Copper prill | Pentrwyn excavation 2011 | P27 | 19.859 | 0.014 | 15.718 | 0.009 | 38.611 | 0.013 | 0.791 | 0.008 | 1.944 | 0.013 |
| Copper prill | Pentrwyn excavation 2011 | P16a | 19.470 | 0.012 | 15.689 | 0.009 | 38.593 | 0.011 | 0.806 | 0.010 | 1.982 | 0.0092 |
| Copper prill | Pentrwyn excavation 2011 | P13 | 18.979 | 0.007 | 15.667 | 0.009 | 38.589 | 0.011 | 0.825 | 0.003 | 2.033 | 0.0052 |
| Copper prill | Pentrwyn excavation 2011 | P05 | 18.458 | 0.013 | 15.639 | 0.009 | 38.394 | 0.013 | 0.847 | 0.008 | 2.080 | 0.013 |
| Tréboul hoard metalwork data | | | | | | | | | | | | |
| Brittany, France. | | | | | | | | | | | | |
| Hache à rebords | | 5-8 | 18.317 | 0.001 | 15.627 | 0.001 | 38.352 | 0.002 | 0.853 | | 2.094 | |
| Fragment de hache | | 16-3 | 18.327 | 0.001 | 15.628 | 0.001 | 38.356 | 0.002 | 0.853 | | 2.093 | |
| Fragment de lame d'épée | | 89 | 18.741 | 0.001 | 15.653 | 0.001 | 38.466 | 0.002 | 0.835 | | 2.052 | |
| Fragment de lame d'épée | | 93 | 18.337 | 0.001 | 15.634 | 0.001 | 38.377 | 0.002 | 0.853 | | 2.093 | |
| Boutons et jets de coulées | | 101-1 | 18.316 | 0.001 | 15.625 | 0.001 | 38.347 | 0.002 | 0.853 | | 2.094 | |

Table S2. Great Orme ore analyses prior to normalising to 100 per cent copper. The main analytical methods used were MP-AES (Microwave plasma, Agilent), WD-XRF, ICP-AES and pXRF. Symbol '<' means below detection limit. For further details, see Williams (2018).

| Sample no. | Ore type | Key minor and trace elements (ppm) | | | | | | | | | | Key major elements (%) | |
|------------|--------------------|------------------------------------|------|-----|-----|-----|------|-----|-----|----|----|------------------------|-------|
| | | As | Ni | Ag | Sb | Pb | Co | Zn | Bi | Au | Sn | Cu | Fe* |
| GO 13 | Malachite-goethite | 4188 | 651 | 243 | 79 | 796 | 66 | 58 | 13 | 1 | < | 23.68 | 21.78 |
| GO 15 | Malachite-goethite | 5737 | 1679 | 271 | 109 | 76 | 506 | 68 | 19 | 12 | < | 26.76 | 21.28 |
| GO 16 | Malachite-goethite | 3723 | 1750 | 301 | 80 | 573 | 1148 | 258 | 17 | 11 | < | 26.45 | 23.29 |
| GO 20 | Malachite-goethite | 2422 | 1138 | 39 | 71 | 461 | 327 | 242 | 14 | < | < | 16.94 | 16.57 |
| GO 22 | Malachite-goethite | 1477 | 662 | 281 | 57 | 41 | 297 | 954 | 125 | < | < | 18.73 | 19.34 |
| GO 24 | Malachite-goethite | 600 | 540 | 57 | 30 | 36 | 242 | 225 | < | < | < | 20.75 | 24.11 |

| | | | | | | | | | | | | | |
|------------|--------------------|------|------|-----|-----|-------|------|------|----|----|---|-------|-------|
| GO 30 | Malachite-goethite | 2251 | 989 | 34 | 130 | 826 | 301 | 353 | 72 | < | < | 19.05 | 21.16 |
| GO 32 | Malachite-goethite | 6437 | 2658 | 130 | 31 | 156 | 692 | 588 | 59 | < | < | 22.95 | 16.38 |
| GO 34 | Malachite-goethite | 3313 | 1142 | 27 | 37 | 202 | 423 | 59 | 15 | 8 | < | 14.66 | 20.63 |
| GO 37 (E1) | Malachite-goethite | 1124 | 1567 | 132 | 184 | 9111 | 521 | 200 | 74 | < | < | 29.24 | 24.36 |
| GO 38 (E2) | Malachite-goethite | 1587 | 2944 | 66 | 147 | 19344 | 1970 | 14 | 21 | < | < | 27.61 | 21.19 |
| GO 39 (E3) | Malachite-goethite | 2440 | 2700 | 115 | 158 | 5166 | 1966 | 26 | 15 | 7 | < | 27.63 | 18.02 |
| GO 40 | Malachite-goethite | 2520 | 1252 | 201 | 49 | 767 | 397 | 179 | 17 | < | < | 15.78 | 20.78 |
| GO 42 | Malachite-goethite | 4423 | 2472 | 79 | 20 | 105 | 675 | 19 | 21 | < | < | 18.91 | 13.74 |
| GO 44 | Malachite-goethite | 1700 | 880 | 146 | 42 | 198 | 362 | 418 | < | < | 9 | 23.48 | 24.55 |
| GO 50 | Malachite-goethite | 6285 | 1343 | 317 | 34 | 562 | 466 | 969 | 29 | 11 | < | 26.39 | 23.10 |
| GO 59 | Malachite-goethite | 2805 | 765 | 172 | 46 | 271 | 469 | 443 | 34 | < | < | 22.03 | 7.91 |
| GO 60 | Malachite-goethite | 3746 | 1619 | 172 | 46 | 619 | 560 | 152 | 15 | < | < | 17.54 | 19.95 |
| GO 63 | Malachite-goethite | 4154 | 1164 | 292 | 72 | 622 | 266 | 689 | 57 | < | < | 23.51 | 23.01 |
| GO 64 | Malachite-goethite | 1573 | 1597 | 34 | 22 | 269 | 556 | 114 | 10 | 2 | < | 38.04 | 4.99 |
| GO 65 | Malachite-goethite | 3550 | 598 | 124 | 103 | 682 | 442 | 88 | 13 | 4 | < | 21.47 | 16.66 |
| GO 67 | Malachite-goethite | 2914 | 2134 | 65 | 77 | 2633 | 1353 | 1729 | 54 | < | < | 19.22 | 20.11 |
| GO 68 | Malachite-goethite | 3993 | 644 | 120 | 26 | 623 | 252 | 263 | < | 10 | < | 12.30 | 14.35 |
| GO 71b | Malachite-goethite | 2121 | 1101 | 122 | 26 | 97 | 343 | 174 | 64 | < | < | 41.96 | 9.88 |
| GO 72 | Malachite-goethite | 2435 | 1377 | 122 | 26 | 97 | 453 | 38 | < | 9 | < | 35.14 | 15.54 |
| OC 0 | Malachite-goethite | 2297 | 871 | 174 | 83 | 465 | 248 | 147 | < | < | < | 18.84 | 17.95 |
| OC 3 | Malachite-goethite | 3638 | 707 | 307 | 264 | 1507 | 214 | 65 | < | 17 | < | 28.90 | 23.98 |
| OC 6 | Malachite-goethite | 960 | 500 | < | < | 40 | < | < | < | < | < | 28.77 | 5.24 |
| OC 8 | Malachite-goethite | 1000 | 440 | 146 | 15 | 33 | 349 | 285 | < | < | 7 | 20.48 | 21.28 |
| OC 12 | Malachite-goethite | 2185 | 499 | 279 | 19 | 1300 | 31 | 1195 | < | 7 | < | 18.36 | 21.09 |
| OC 15 | Malachite-goethite | 500 | 210 | 119 | 11 | 44 | 21 | 874 | < | < | 6 | 21.73 | 29.34 |
| OC 16 | Malachite-goethite | 1704 | 1049 | 210 | 30 | 773 | 103 | 267 | < | 3 | < | 24.89 | 17.36 |
| OC 22 | Malachite-goethite | 1797 | 784 | 2 | 8 | < | 1635 | 398 | < | 3 | < | 35.39 | 9.24 |
| OC 25 | Malachite-goethite | 3490 | 570 | 102 | 52 | 15 | 82 | 1367 | < | < | 6 | 24.39 | 30.85 |
| OC 31 | Malachite-goethite | 3696 | 1945 | 35 | 166 | 800 | 972 | 12 | < | 1 | < | 23.27 | 20.53 |

| | | | | | | | | | | | | | |
|--------|--------------------|------|------|-----|----|-----|------|------|----|----|---|-------|-------|
| OC 37 | Malachite-goethite | 2460 | 2399 | 71 | 35 | 100 | 1663 | 75 | 21 | < | 4 | 24.63 | 23.79 |
| OC 38 | Malachite-goethite | 5115 | 5549 | 177 | 81 | 488 | 1099 | 1935 | < | < | 7 | 25.12 | 19.89 |
| OC 39 | Malachite-goethite | 1291 | 1547 | 54 | 52 | 327 | 457 | 10 | < | < | < | 23.98 | 15.88 |
| OC 44 | Malachite-goethite | 1001 | 852 | 142 | 43 | 199 | 331 | 157 | 33 | < | < | 22.27 | 23.87 |
| OC 49 | Malachite-goethite | 759 | 588 | 88 | 9 | 10 | 115 | 555 | 90 | < | < | 22.89 | 25.41 |
| OC 51 | Malachite-goethite | 3695 | 585 | 111 | 97 | 701 | 66 | 474 | < | 18 | < | 24.78 | 24.29 |
| OC 52 | Malachite-goethite | 5399 | 3781 | 156 | 51 | 475 | 949 | 840 | < | < | < | 20.29 | 19.44 |
| | | | | | | | | | | | | | |
| GO 26 | Malachite only | 285 | 356 | < | 18 | 54 | 72 | 13 | 8 | 3 | 1 | 18.12 | 3.69 |
| GO 55 | Malachite only | 177 | 275 | 4 | 4 | 36 | 216 | 9 | 34 | < | < | 25.76 | 0.80 |
| GO 62 | Malachite only | 498 | 401 | < | 3 | 34 | 190 | 44 | < | < | < | 23.61 | 0.63 |
| GO 71a | Malachite only | 442 | 286 | < | < | 7 | 109 | 11 | < | < | < | 51.32 | 2.30 |
| OC 40 | Malachite only | 60 | 290 | 7 | 2 | 137 | 2890 | 623 | < | < | < | 45.35 | 0.78 |
| GO 61 | Azurite-only | 623 | 283 | 1 | 2 | 4 | 74 | 120 | 3 | 8 | 7 | 14.38 | 2.56 |

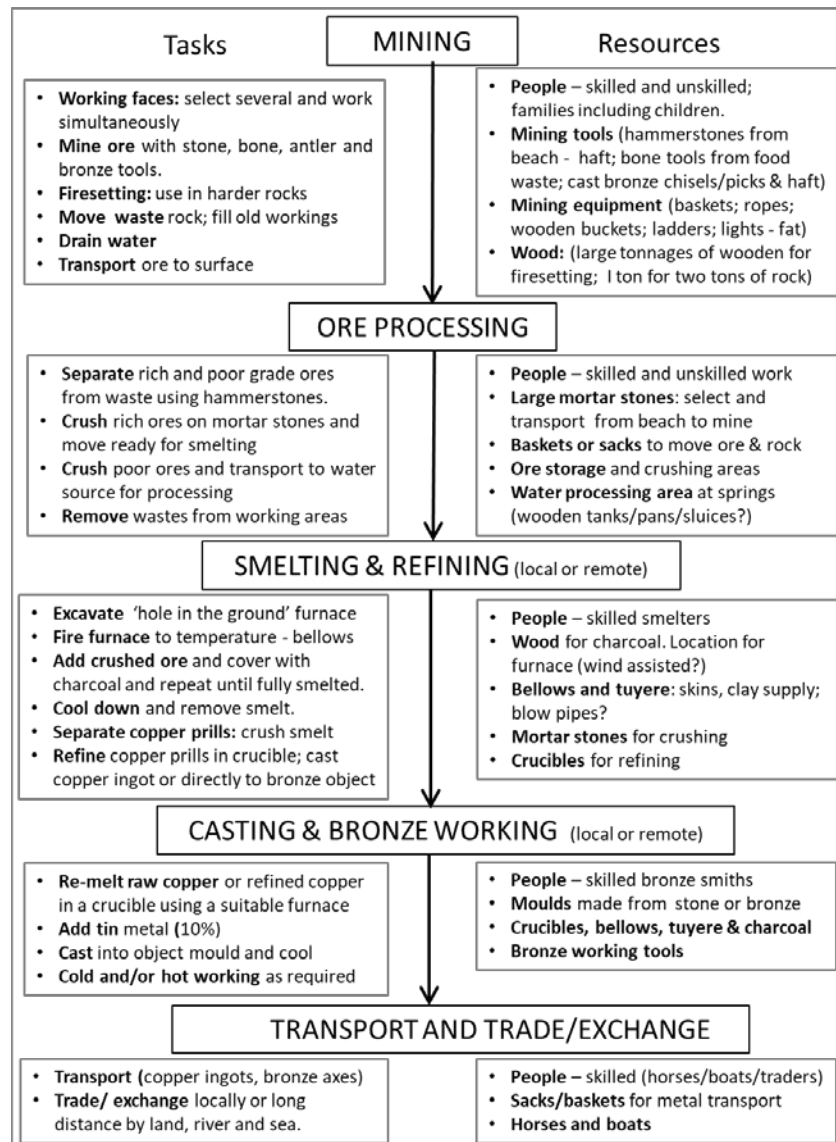


Figure S1. Tasks and resources for mining, ore processing, casting and trade/exchange (from Williams 2018).

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