Additional INFORMATION

Table S1: Summary of the recipes used to prepare the madder and cochineal pigments. In most cases, adaption of recipes consists in adapting the temperature of reaction to the dyestuff source (70 - 80 ⁰C for madder and 40 - 50 ⁰C for cochineal). Ca-containing substrates were made by using standard madder and cochineal recipes but substituting the alkali used for CaCO3.

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|  | | **Pigment** | **Recipe Summary** | **Source and date** |
| **COCHINEAL** | C-Std M-R | | Raw material; aqueous extraction at ~70°C; addition of alkali (K2CO3)then alum; Tprecipitation = 40⁰-50°C. | Adapted from ML-pot-Al recipe in Kirby *et al*.(1), p.97-98.; not historical, but representative of a cochineal lake made from raw insects (16th to 17th century). |
| C-Std M-Ca | | Raw material; aqueous extraction at ~70°C; alum added then alkali (CaCO3 used as alkali); Tprecipitation = 40⁰-50°C. | Adapted from ML-Std recipe in Kirby *et al*.(1), p.96-97, using CaCO3 as alkali; earlier than 18th century, not common for cochineal. |
| C-Std M-Ca excess | | Raw material; aqueous extraction at ~70°C; alum added then alkali (CaCO3 used as alkali, added in excess to act as extender); Tprecipitation = 40⁰-50°C. | Adapted from ML-Std recipe in Kirby *et al*.(1), p.96-97, using CaCO3 as alkali; earlier than 18th century, not common for cochineal. |
| C-Std M | | Raw material; aqueous extraction at ~70°C; addition of alum then K2CO3; Tprecipitation = 40⁰-50°C. | Adapted from ML-Std recipe in Kirby *et al*.(1), p.96-97; not historical, but representative of a cochineal lake made from raw insects (16th to 17th century). |
| C-Std M-Al ex. | | Raw material; alum extraction at ~70°C; K2CO3 as alkali for precipitation; Tprecipitation = 40⁰-50°C. | Adapted from ML-EBAl recipe in Kirby *et al*.(1), p.98; not historical, but representative of a cochineal lake made from raw insects (16th to 17th century). |
| C-Sn | | Raw material; extraction in very weak alum solution (0.064g alum in 300mL H2O) at boiling point; tin(IV) chloride (provide formula) saturated solution added drop by drop to dyestuff + alum solution; Tprecipitation = 40⁰-50°C. | From Kirby *et al*.(1), p.101, 19th century. |
| C-Al | | Raw material; extraction in distilled water at boiling point; addition of alum followed by continued boiling; left to stand for a week to precipitate. | From Homberg, 1695, in Kirby *et al*. (2), p. 94. |
| C-Silk | | Dyed alum mordanted silk as source; digestion in 0.1M K2CO3 solution; extraction at boiling point; alum added for precipitation; Tprecipitation = 40⁰-50°C.. | From Kirby *et al*.(1), p.100, 15th century.  Silk dyed following procedure in Kirby *et al.* (1), p. 50 & 62 (no potash was added; wool substituted for silk). |
| C-Fleece | | Dyed alum mordanted wool as source; alkaline extraction at 50-60°C in 0.3M KOH solution; alum added for precipitation; Tprecipitation = 40⁰-50°C.. | Adapted from ML-Fleece recipe in Kirby *et al*.(1), p.98.; 16th or 17th century, but dyed silk more commonly used for cochineal.  Wool dyed following procedure in Kirby *et al.* (1), p. 50 & 62 (no potash was added). |

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| **MADDER** | M-Std | Raw material; aqueous extraction at 70°C; addition of alum then alkali; Tprecipitation=70-80°C | ML-Std recipe in Kirby *et al*.(1), p.96-97.; 19th century. |
| M-Std-R | Raw material; aqueous extraction at 70°C; addition of alkali then alum; Tprecipitation= 70-80°C | ML-pot-Al recipe in Kirby *et al*.(1), p.97-98.; earlier than 18th century, but dyestuff usually extracted from dyed wool instead of directly from root. |
| M-Std-Al ex. | Raw material; alum extraction at 70°C; addition of alkali after extraction; Tprecipitation= 70-80°C | ML-EBAl recipe in Kirby *et al*.(1), p.98.; 18th century. |
| M-Std-Ca | Raw material; aqueous extraction at 70°C; addition of alum then alkali; CaCO3 used as alkali; Tprecipitation= 70-80°C | Adapted from ML-Std recipe in Kirby *et al*.(1), p.96-97, using CaCO3 as alkali; recipe used since Antiquity, although the use of CaCO3 was more common for brazilwood and yellow lakes. |
| M-Std-Ca excess | Raw material; aqueous extraction at 70°C; alum added then alkali; CaCO3 used as alkali, added in excess to act as extender; Tprecipitation= 70-80°C | Adapted from ML-Std recipe in Kirby *et al*.(1), p.96-97, using CaCO3 as alkali; recipe used since Antiquity, although the use of CaCO3 was more common for brazilwood and yellow lakes. |
| M-Silk | Dyed alum mordanted silk as source; alkaline extraction at 50°C in 0.1M K2CO3 solution; Tprecipitation= 40°C; no potash used in the bath. | Adapted from cochineal from dyed silk recipe in Kirby *et al*.(1), p.100.; 14th to 17th century but dyed wool more commonly used for madder.  Silk dyed following procedure in Kirby *et al.* (1), p. 50 & 55 (substituting wool for silk). |
| M-Fleece | Dyed alum mordanted wool as source; digestion in 0.3M KOH; extraction at 50°C; Tprecipitation= 40°C | ML-Fleece recipe in Kirby *et al*.(1), p.98.; 14th to 17th century.  Wool dyed following procedure (code M-Std) in Kirby *et al.* (1), p. 50 & 55. |

Table S2 Summary of procedure used to make paints using linseed oil, gum Arabic, yolk and beeswax. No additives were added to any of the paints to avoid interference with analysis and to build a reference database of mixtures containing just the binder and the pigment.

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| **Binder** | **Procedure** | | **Source** | |
| Linseed oil | | Equal parts by volume of linseed oil and pigment were mixed in an agate pestle and mortar until pigment was sufficiently dispersed in the binder, with no large particles. | | Adapted from Gottsegen (32), p. 205-215.  Linseed oil was purchased from Kremer Pigments (#73054) |
| Gum Arabic | | 100 g of gum Arabic grains were added to twice its volume of boiled distilled water, while still warm, and left to stand overnight. It was filtered the next day, before it was ready for use.  Equal parts by volume of gum Arabic and pigment were mixed in an agate pestle and mortar until pigment was sufficiently dispersed in the binder, with no large particles. If the mixture started to dry out, drops of distilled water were added to restore consistency. | | Adapted from Gottsegen (32), p. 216-217.  Gum Arabic was purchased from Kremer Pigments (#63320) |
| Yolk | | Equal parts by volume of egg yolk, distilled water and pigment were mixed in an agate pestle and mortar until pigment was sufficiently dispersed in the binder, with no large particles. If the mixture started to dry out, drops of distilled water were added to restore consistency. | | Adapted from Gottsegen (32), p. 226-231. |
| Beeswax | | Approximately six beads of 100% pure beeswax were melted on a glass plate at 60 °C using a hot plate. Then an amount equivalent to approximately a third of the volume of beeswax was added of pigment. The mixture was mixed with a metal spatula and used immediately. | | Adapted from Gottsegen (32), p. 232-236.  Beeswax beads were purchased from Kremer Pigments (#62200). |