TRADE IN ARTISTS' MATERIALS

MARKETS AND COMMERCE IN EUROPE TO 1700

EDITED BY JO KIRBY, SUSIE NASH AND JOANNA CANNON

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Tracing White: A Study of Lead White Pigments found in Seventeenth-Century Paintings using High Precision Lead Isotope Abundance Ratios

Daniel Fabian and Giuseppino Fortunato

Alchemists believed that lead played an important role in experiments to find the philosophers' stone, a substance that would transmute base metals into gold. Their high aim has yet to be reached; however, in this project we look into another transmutation – from a heavy, dark, silvery-grey looking rock to the colour of purest white.

Lead white, a basic lead carbonate, has been used as an artists' pigment since antiquity and is found in almost every painting in Western art throughout the centuries. Excellent covering power, durability and lightfastness, together with its capacity for rapid drying when used in combination with a drying oil, such as linseed or walnut oil, are its outstanding characteristics. Towards the last quarter of the eighteenth century, zinc oxide became available as a white pigment[1] and by the first quarter of the twentieth century commercially produced titanium white had begun to replace the toxic lead white pigment.[2] Today lead white is used by a few artists only.

High-precision lead isotope ratio analysis shows great promise for distinguishing between cisalpine and transalpine lead ores,[3] the primary raw material of metallic lead, by examining the abundance of each lead isotope present. The potential for tracing the origins of lead white according to these isotope ratios prompted our interest. Like a fingerprint, the data can be traced back from the pigment to its raw form of metallic lead and to the lead ore. For example, it can be determined if a lead white sample originates from a northern or southern source. Geochemical properties, such as the trace element content and isotope abundance ratios form a recognised tool used to establish the provenance of artefacts,[4] although relying on trace elements alone may have several drawbacks since an artefact is rarely made up of a chemically homogenous material. Lead isotope ratios themselves are not noticeably altered by processing lead ores to give metallic lead or lead white pigment. This is a key factor when using lead isotope abundance ratios for provenance studies.

The suitability of artists chosen for this study was determined primarily by the artist having a well-documented *curriculum vitae* and oeuvre, and having worked on both sides of the Alps. The two major Flemish artists of the northern Baroque epoch, Peter Paul Rubens and Anthony van Dyck, were ideal candidates. Both were much travelled artists working on both sides of the Alps, visiting Italy, Spain and England among other countries and both had well-documented works of art commissioned by the great European courts.

The study presented here concentrates mainly on paintings that were created in Antwerp, one of the most important ports and art centres in Europe at that time. The data compiled from works by these two artists and some of their contemporaries are compared to the data from Italian paintings, as well as to data obtained from works of art painted in Italy by northern artists and those by southern artists working in the north. The focus was primarily on the origins of the pigments – where they were mined and manufactured into pigments – and the ensuing trade routes, and secondarily on a particular artist's working method. Our goal is to set up a database of lead isotope ratio values yielding a recognisable trend that can be used as a baseline for further research.

We were intrigued by several questions. First, did artists use lead white originating from local sources or were imported pigments used? Secondly, when working abroad, did artists obtain pigments locally or did they bring along their own materials from home? Thirdly, was the pigment imported as a finished product or was the metallic lead imported and the pigment produced locally? Lastly, can the geographical source of the raw material from which the pigment was produced be located?

METHOD OF ANALYSIS FOR THE DETERMINATION OF THE ORIGIN OF LEAD PIGMENTS

The element lead (chemical symbol Pb) has four naturally occurring, stable isotopes, ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb, found in different concentrations in the soil and in rocks. The last three isotopes are radiogenic; that is, they derive partly

from radioactive decay, specifically decay of the nuclides of uranium (^{238}U and ^{235}U) and thorium (^{232}Th). The use of lead isotope ratios for authentication and provenance investigations depends on a two-fold coincidence. Although ^{206}Pb, ^{207}Pb and ^{208}Pb are radiogenic and their concentrations vary between rocks in different places, ^{204}Pb is not radiogenic and therefore its concentration is constant in time. The isotope ratios can be plotted as a graph using ^{206}Pb / ^{204}Pb as the x-axis and ^{207}Pb / ^{204}Pb as the y-axis; this is a standard procedure used by geochronologists. Geologically, lead is one of the few chemical elements that varies markedly in its isotopic composition. The parameters upon which the isotopic composition primarily depends are the age and the uranium/lead (U/Pb) and thorium/lead (Th/Pb) content ratios of the rock units from which, over time, fluids extracted lead to form ore deposits.[5]

The multiple-collector inductively coupled plasma mass spectrometer (MC–ICP–MS) is an instrument that permits isotope ratios to be measured with very small measurement uncertainties. This sophisticated method of analysis, in which only a minute sample size of one microgram (μg or one-millionth of a gram) is required to identify the lead isotope successfully, is thus suitable for old master paintings from which, due to their unique and precious nature, taking samples has to be restricted to an absolute minimum.

Table 1 lists the system check of the lead isotope ratio index (LIRI) of modern lead white reference samples and of old paintings.[6] The lead isotope ratio index was introduced by Bernard Keisch and Robert C. Callahan and published in 1976 in order to obtain a better visualisation and clustering of the isotope abundance ratios which can be calculated using the three ratios ^{206}Pb/^{204}Pb, ^{207}Pb/^{206}Pb and ^{208}Pb/^{206}Pb.[7] Table 1 shows a significant difference between the values for 'modern' and 'historical' lead white, allowing the very precise LIRI to be a valuable clue when questions of the age of lead white arise.

TABLE 1. Comparison of lead isotope ratio index values for modern and historical lead white samples.

Sample	Lead isotope ratio index
Historical pigment sample 1	*18.28*
Historical pigment sample 2	*18.30*
Historical pigment sample 3	*18.30*
Historical pigment sample 4	*18.31*
Modern pigment reference 1	16.95
Modern pigment reference 2	17.82
Modern pigment reference 3	17.92
Modern pigment reference 4	17.14

SAMPLING PROCEDURE AND PREPARATION

Due to the unique and fragile nature of paintings the samples were kept as small as possible and restricted to areas agreed upon by joint consent of the collection manager, curator and conservators, such as existing damages and the edges of paintings.[8] Microgram quantities of pigment were taken from the paintings using a scalpel, in most cases under a stereo light microscope. Experience has shown that the best results can be obtained from relatively pure lead white paint such as highlights, where exceptionally small samples (5–10 μg) yield enough material for successful analysis. The samples were analysed using mass spectrometry (MS), scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). The high precision lead isotope abundance ratios were measured by multiple-collector inductively coupled plasma mass spectrometry as discussed above.[9]

FROM ORE TO METAL

Native metallic lead is rarely found but we came across one reference describing lead as having been found as particles of a very small size in Sweden (Langban).[10] The ancient process of smelting galena (lead sulphide), the lead ore, was straightforward and does not seem to vary much from region to region.[11] 'Smelting' is the term used to describe a reaction taking place at high temperature between a metal ore and another substance, such as carbon, in order to extract the metal from the ore.[12] Lead was one of the first metals to be extracted from ore since it could be smelted at relatively low temperatures, not much more than 300 °C. Simple hearths consisted of a low circular wall of stones, built on a slope, with a channel to direct the molten metal. Detailed descriptions of the technology of mining and metallurgy are given by Georgius Agricola,[13] the sixteenth-century German medical doctor, apothecary and scientist.

USES OF LEAD

Prior to the Roman empire, lead appears to have been excavated primarily for silver production as the two metals often occur together. The ability of lead to couple with silver and gold and its low melting point increased demand for the ever-growing technology to extract precious metals. After smelting silver-rich lead ores, silver was extracted using cupellation, a process whereby a molten mixture of metals is separated into its constituents, thereby purifying one of the metals, in this case the precious silver.[14] The usefulness of lead as a material in its own right came later.[15] Lead was used for cisterns, coins, seals, piping, anchors, weights, roofing, bullets, cannonballs, the lining of coffins, statuettes, medicine, cosmetics, jewellery, crosses, musical instruments, glazing, plumbing, kitchenware and, of course, pigments.[16]

FROM METALLIC LEAD TO LEAD WHITE

From antiquity, lead white was produced by placing thin shavings of lead over a vessel of acetic acid – vinegar; the vinegar fumes attacked the lead to give a white product, which could drop down from the lead. The collected material was dried, powdered and sifted. It was then re-moistened with vinegar, made into tablets and dried in the summer sun.[17] Another old (fifteenth-century) method of lead white manufacture is given by Harley,[18] whereby strips

of lead were suspended above tightly sealed barrels filled with vinegar and left for eight weeks. The white lead could then be scraped off the lead strips. In this process the acetic acid attacks the oxidised outer surface of the lead strips. The resulting lead acetate is converted to basic lead carbonate by the action of moist carbonic acid gas, and the acetic acid goes on to convert further metallic lead.[19]

Little changed in the method of production over the centuries. In the 'Dutch' or stack process, metallic lead was exposed to acetic acid in clay pots. The pots were placed in tiers in a shed with tanbark or manure separating them. Manure was a source of warmth and carbon dioxide, which was released during its fermentation, allowing the manufacture to take place in colder periods and regions. In a closed environment lead was transformed to basic lead carbonate by the combined action of acetic vapours, heat, carbon dioxide and water vapour.[20] Venice was the major centre of production and had a reputation for producing the best quality of lead white. The process was adopted by the rapidly growing trading nations, Holland followed by England. In England the first monopoly for making white and red lead was granted in 1622, while the Dutch dominated the European output in the seventeenth century. The Venetian lead white seems to have been replaced in many markets by the Dutch – manufacturers used the simple expedient of adulterating their product with chalk to cut costs. As a result the Venetian lead white retained a small quality market for artists.[21] A purer and whiter lead white was produced in Austria by the late eighteenth century.[22]

OCCURRENCE AND TRADE

Lead was mined throughout Europe and other regions from the earliest times: the first written references to trade in lead are found in inscriptions in temples of the eighteenth Egyptian dynasty. In Roman times lead bars were traded from Spain to Italy by way of rivers and across the Mediterranean. Various means of transport were used: across the sea, by river or overland (Fig. 1).[23]

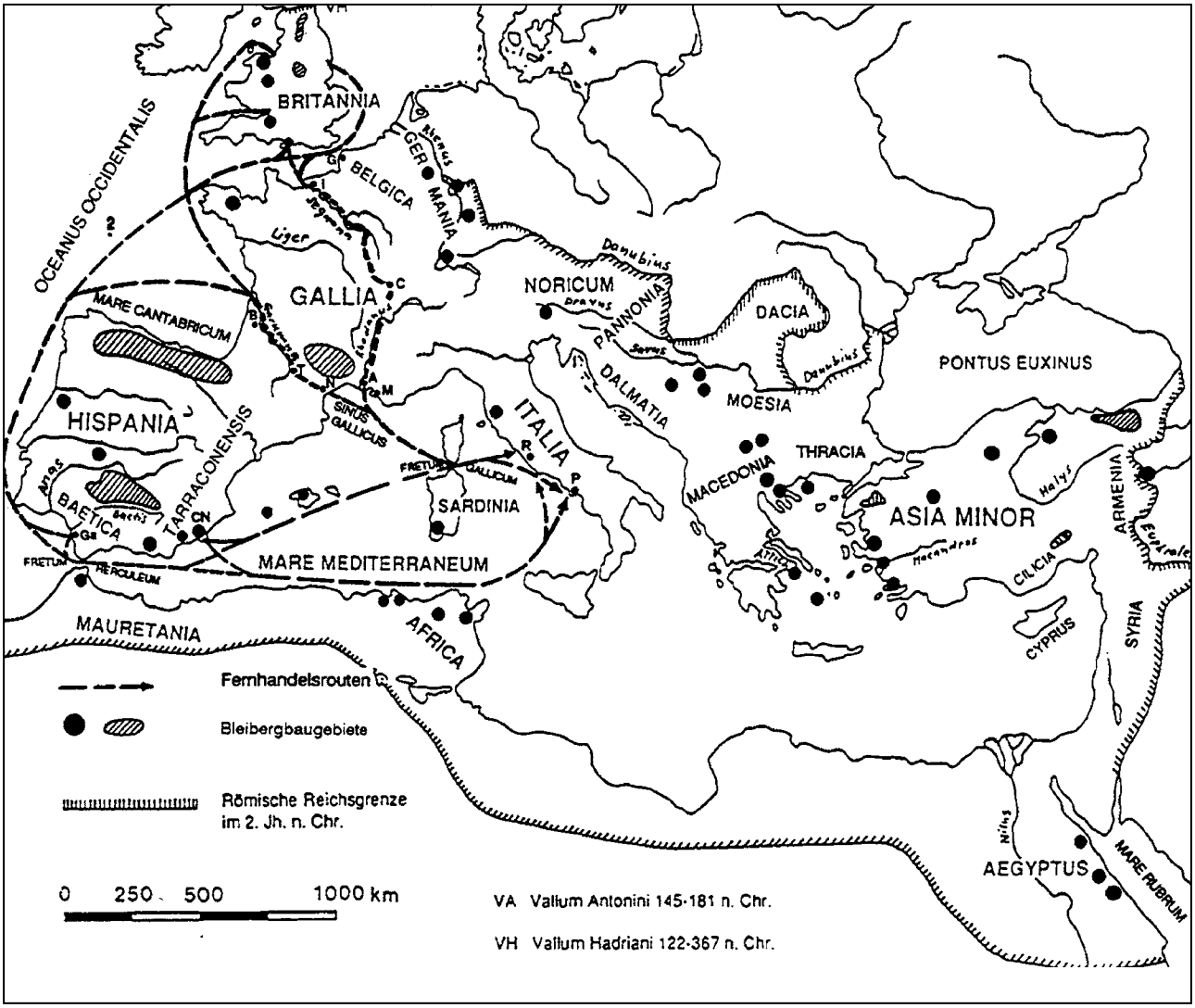

FIGURE 1. Lead trade routes and locations of lead exploitation in Roman times. *Key*: A: Arles; B: Bordeaux; C: Châlon-sur-Saône; CN: Cartagena; GA: Cádiz; G: Boulogne; I: Lillebonne; M: Marseille; N: Narbonne; P: Pozzuoli; R: Rome; T: Toulouse. Black dots indicate regions of lead exploitation. From S.W. Meier (1995) 'Blei in der Antike: Bergbau, Verhüttung, Fernhandel', PhD dissertation, University of Zurich; map reproduced by kind permission of the author.

The possible sources for the ore from which the pigment could be produced are therefore complicated. In this project, analysis was done on samples from major European lead mining areas (as shown in Table A-1 in the Appendix), as well as samples from paintings. More than 200 paint samples, from paintings mostly by seventeenth-century artists, from Italy, Flanders, the Netherlands, Germany, Switzerland, England and other parts of Europe, were examined, analysing at least one representative lead white sample. Brief details of the paintings sampled are given in Table A-2 (in the Appendix). Wherever possible, a sample of pure lead white paint – from a highlight, for example – was used for the examination. Published data as well as our own were included in the resulting scatter plots of lead ore isotope ratios.[24]

RESULTS

The distribution of lead isotope ratio values for lead ores from the northern (England, Wales, Ireland, Scotland), the central (Belgium, Germany, Poland, the Alps) and some of the southern parts of Europe (Tuscany, Sardinia) reveals a complicated pattern (Fig. 2).[25] Some of the mining areas can be divided quite clearly; others, such as mining areas in Great Britain and the Harz region of Germany, overlap and cannot be separated using lead isotope ratios alone. As long as few data concerning the distribution and its function are known, one has to be aware of possible overlaps due to the facts described in the literature on this field.[26] Lead isotope ratio data can therefore only be used as indications of origin and not as full proof in many cases. Although there is some reference to early lead smelting in Virginia in the United States, in 1621,[27] we have not included data from the New World.

As expected, the EDX determinations of the elements present in the samples reveal that, for most of the samples, lead is the main inorganic component, emphasising the exclusive use of white lead as a white pigment during the sixteenth and seventeenth centuries. Calcium is also regularly found and in some samples traces of silicon, tin, barium and iron could be identified. Calcium carbonate is the main ingredient of the ground layers in northern panel paintings, which would explain the frequency of its appearance to some extent. Southern grounds for panel paintings are typically made using gypsum (calcium sulphate). As mentioned earlier, however, lead white pigments were also adulterated with calcium carbonate to cut costs. It has to be borne in mind, therefore, that a low or absent calcium content could be related to a better quality of lead white pigment.

The lead isotope abundance ratio values measured for the pigments from paintings by Peter Paul Rubens and Anthony van Dyck exhibit precisions (2s) for $^{206}Pb/^{204}Pb$,

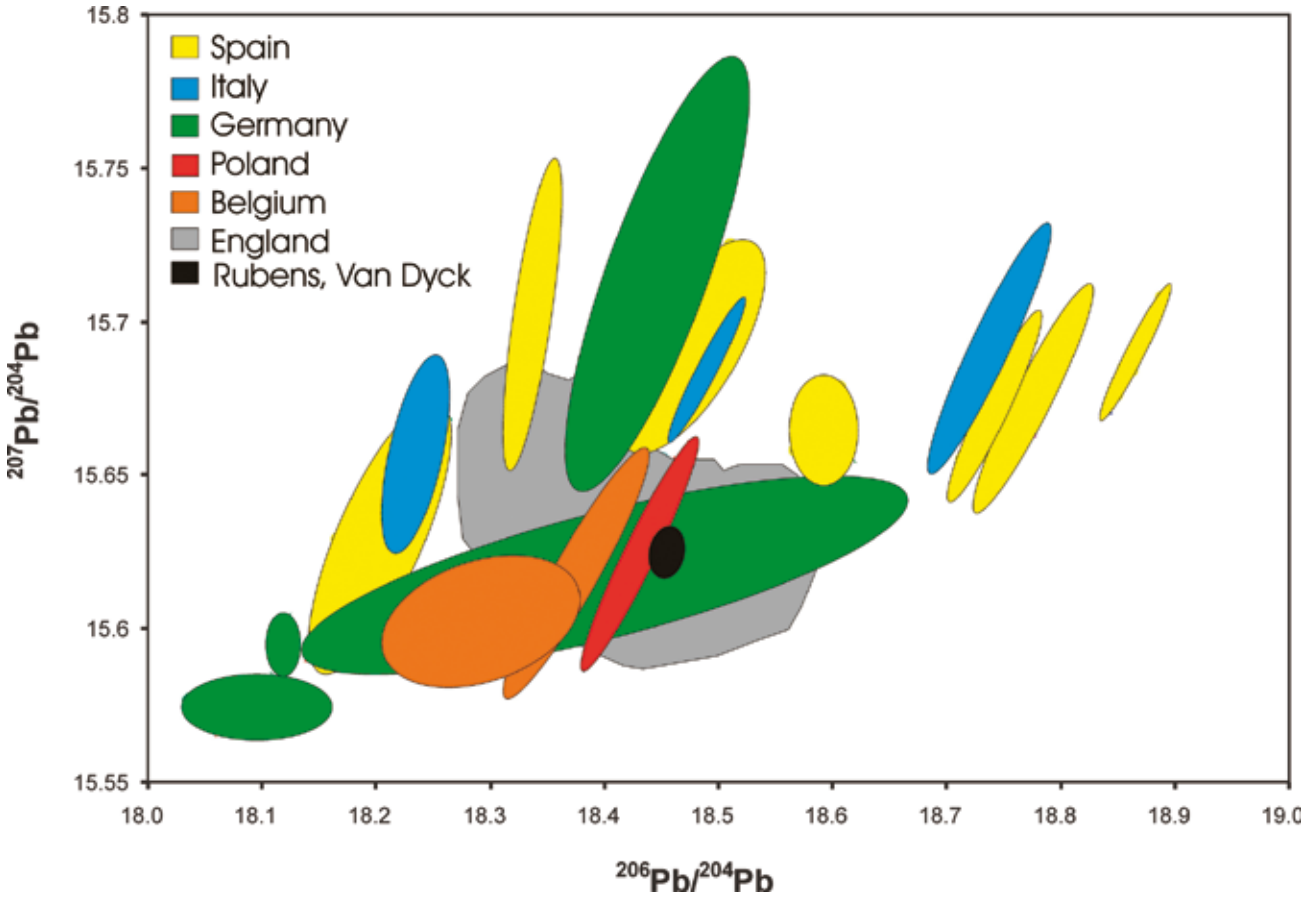

FIGURE 2. The distribution of lead isotope ratio values of the main European mining areas.

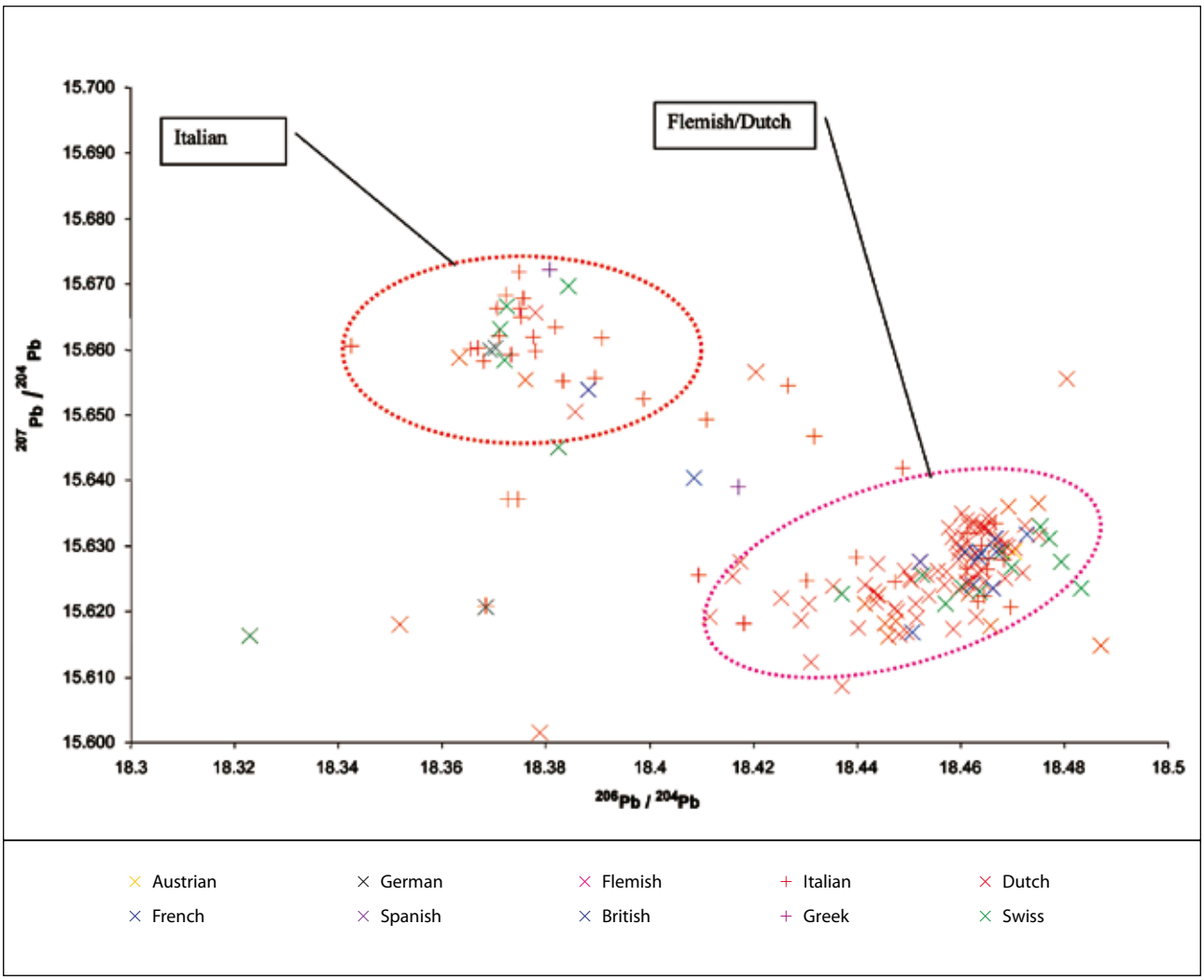

FIGURE 3. An overview of lead isotope ratio comparison values for lead white samples from cis- and transalpine paintings showing 'Italian' and 'Dutch/Flemish' clusters. *Pattern code*: +: 'southern' painting sample (Italian, Spanish, Greek); ×: 'northern' painting sample. Dotted circles show the trend line for southern (Italian, Spanish, Greek) and northern (Flemish, Dutch, Swiss and other) artists.

$^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ in the range of 0.01–0.05%. The range of the measured lead isotope abundance values for the 'Antwerp' pigments (Flemish and Dutch paintings) lies – compared to modern white lead values – in a narrow field forming a cluster ranging from 18.41 to 18.48 for the isotope abundance ratio $^{206}Pb/^{204}Pb$ and from 15.61 to 15.64 for the isotope abundance ratio $^{207}Pb/^{204}Pb$.

It came as no surprise that the pigments used by Rubens and Van Dyck are very similar indeed. Figure 3 clearly shows the distinct grouping of 'Italian' isotope ratios in the red circle and the 'Flemish and Dutch' isotope ratios in the pink-coloured circle. The 'Italian' values lie between 18.36 and 18.40 for the isotope abundance ratio $^{206}Pb/^{204}Pb$ and from 15.64 to 15.68 for the isotope abundance ratio $^{207}Pb/^{204}Pb$.

Results of analysis of lead white pigment samples from paintings by Rubens and Van Dyck dating from the Antwerp periods lie within close parameters. The combination of lead ore and pigment isotope ratio data gives a clear overlap of Italian lead ores and Italian paint samples. Dutch and Flemish paint samples mainly overlap with ores from Germany, Great Britain and also Poland.[28] The first three areas (Italy, Germany, Great Britain) are known to have been exploited since ancient times.[29] Poland has been an important source of lead ore since the Middle Ages.[30] Data from Spanish ores lie in between the dense clusters of 'Flemish' and 'Italian' paint samples, as illustrated in Figure 4. Since we have only included a few Spanish paintings, no interpretations can be made at this time, but it seems that ores from Spain are also a possible source which has to be studied very carefully since the values overlap some of the Spanish, Italian and Flemish paint samples.

The suggested use of English, German, Polish and Spanish ores to manufacture the lead white pigment poses interesting questions. Why does the Flemish ore only overlap marginally with samples from Flemish/Dutch paint samples, where we expected a better overlap? Does this mean that mainly German, British or Polish lead ore was used to produce the metallic lead from which the lead white pigment was obtained? In order to find some

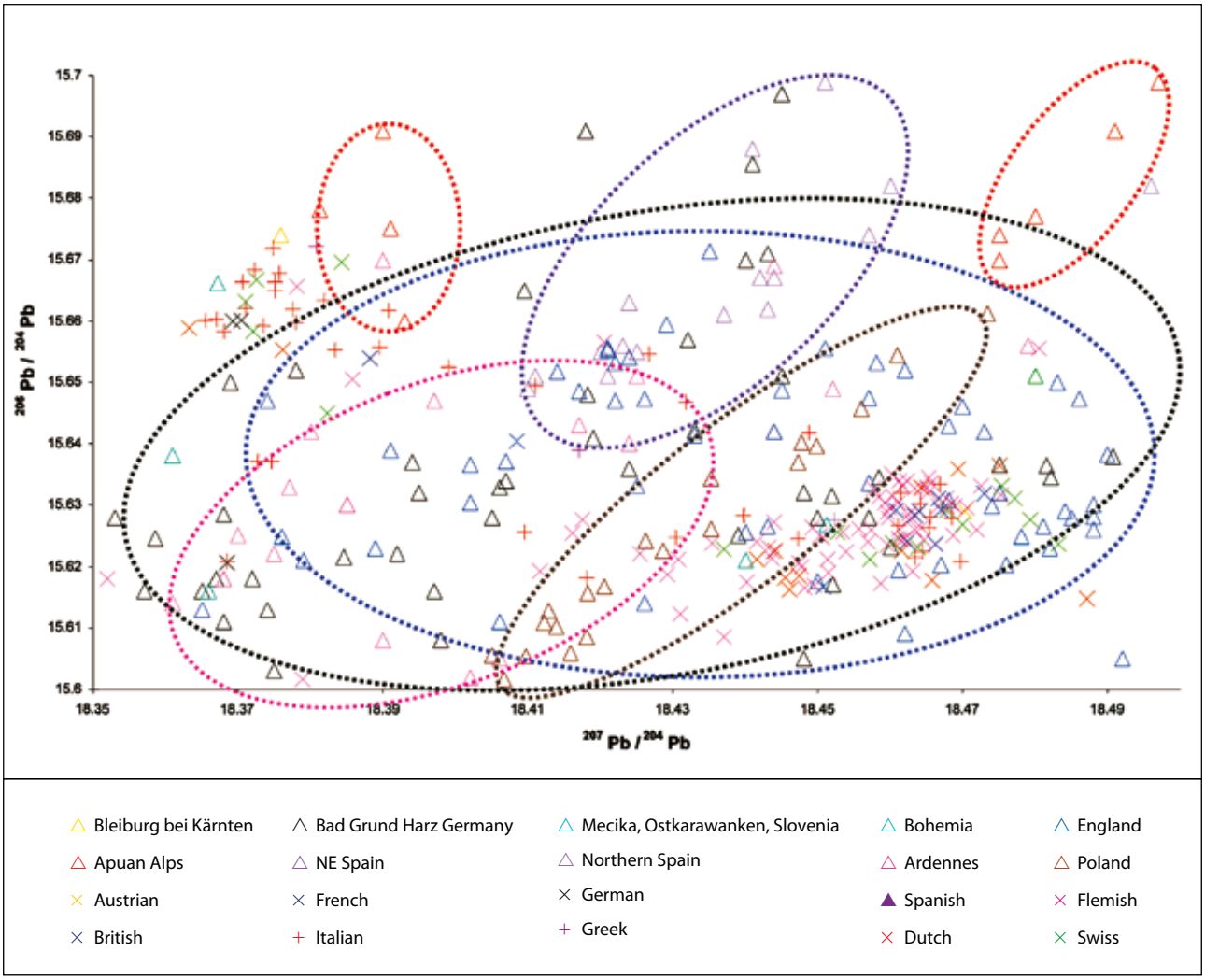

FIGURE 4. An overview of lead isotope ratio comparison values for lead ores and lead white paint samples. *Pattern code*: Δ: ore; +: 'southern' painting sample; ×: 'northern' painting sample. Dotted circle: outline ore sample: pink circle: Flemish ore; black circle: German ore; blue circle: British ore; red circles: Italian ore; brown circle: Polish ore; lilac circle: Spanish ore.

answers, we began by comparing paintings by Van Dyck and others produced in England.[31] Since there is no clear distinction between German and British ore, could this mean that there is possibly a common source for the production of lead white? In other words, was the lead white used in Antwerp and London possibly made from the same metallic lead? And if this is the case, could it have come from a British source? There is, of course, a very old tradition of trading lead, as mentioned earlier. During the Roman empire, Spain's dominance as a source of lead was overtaken by Britain as a major exporter of lead.[32] Is it likely that, for a small quality market, British, German, Polish or Spanish lead was exported to Venice for the manufacture of a high quality pigment? Would this hypothesis explain the occurrence of similar lead white in Flemish as well as in Italian paintings, as illustrated in Figure 5?

The data illustrated in Figure 6, which shows a detail of Figure 5, reveal no clear distinction between samples taken from English paintings in the 'Flemish' cluster. This could indeed indicate a common source of English lead ore from which the pigment used by English and Flemish/Dutch artists was derived. As can be seen in the same figure, some Italian samples (taken from Italian paintings) also show up in or near the 'Flemish' cluster. The relevance of these markings has to be investigated further after more research when we hope to focus on Italian artists in greater detail. As pointed out earlier, however, the overlapping lead isotope ratio index is not the only factor to authenticate the source of the lead ore and further research has to concentrate also on trace elements present.

CONCLUSION

Results to date have produced two narrow clusters of data from cisalpine and transalpine paintings: one of Flemish and Dutch and one of Italian works of art. Paintings that have been attributed to the Antwerp period of Peter Paul Rubens and Anthony van Dyck show similar lead

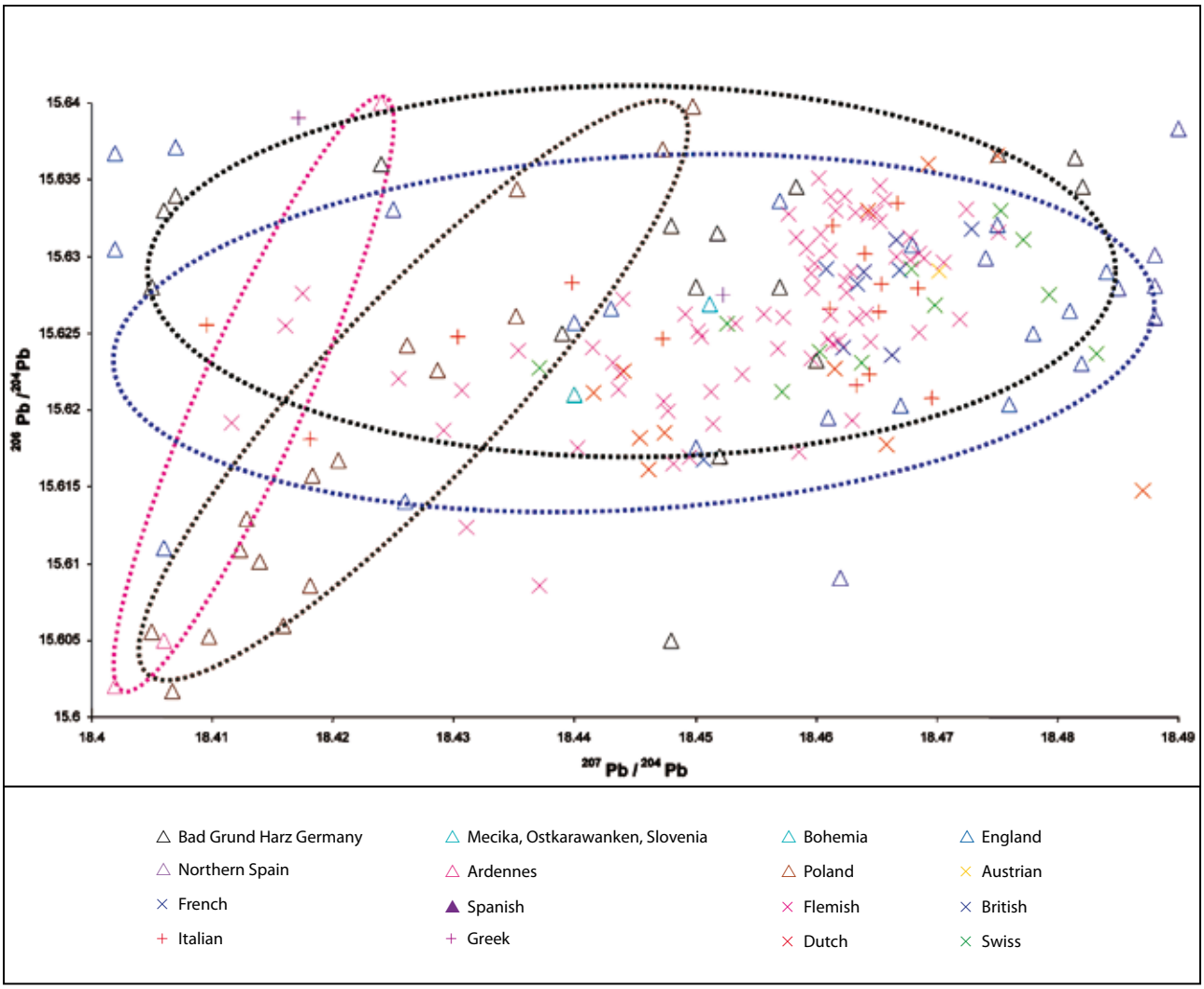

FIGURE 5. Enlarged view of part of Figure 4 showing the Dutch and Flemish data. *Pattern code*: Δ: ore; +: 'southern' painting sample; ×: 'northern' painting sample. Dotted circle: outline ore sample: pink circle: Flemish ore; black circle: German ore; blue circle: British ore; brown circle: Polish ore.

isotope ratios for the lead white pigment used. Pigment data from paintings by Van Dyck, Matthias Stom and also Angelica Kauffmann, which are attributed to their Italian periods, lie within the 'Italian' cluster.[33] Samples taken from later additions can be distinguished, as shown for example in the case of Rembrandt's *Susanna* (The Hague, Mauritshuis), in Figure 6.[34] The data from the sample of original paint from this painting lie well within the Dutch/Flemish cluster and are marked with an orange circle labelled 'Rem'. The sample from the later addition gave data lying outside this cluster; it can be seen in the upper right corner, also marked with an orange circle entitled 'RemRetv758'. This sample comes from a retouching in the addition that must have been applied before 1758.

Lead isotope ratio data from ores originating from known mining areas can be used for distinguishing the source of samples from different regions. Geographically overlapping lead isotope data (Germany, Britain, Poland, Spain) require further analysis. It is now important to broaden the lead white database and to examine the lead ore isotope ratio values in more detail. The manufacturing process has to be further researched in order to establish its role as a variable with regard to purity, composition, general characteristics and the quality of the metallic lead. The content of calcium carbonate found in some of the samples will be investigated later in the project. If calcium carbonate is indeed an adulterant to the pigment and hence an indication of its quality, does the lack of it imply a higher quality pigment? Was it only the better known and wealthier artists who used a more expensive pigment? Can a trend be established? This study shows great promise in broadening our knowledge of a widely used pigment. It is hoped that it will prove to be a hotbed of research between conservators, historians, art historians, archivists and metallurgists. Finding out more about the fascinating history of lead white will help to shed further light in identifying and attributing works of art.

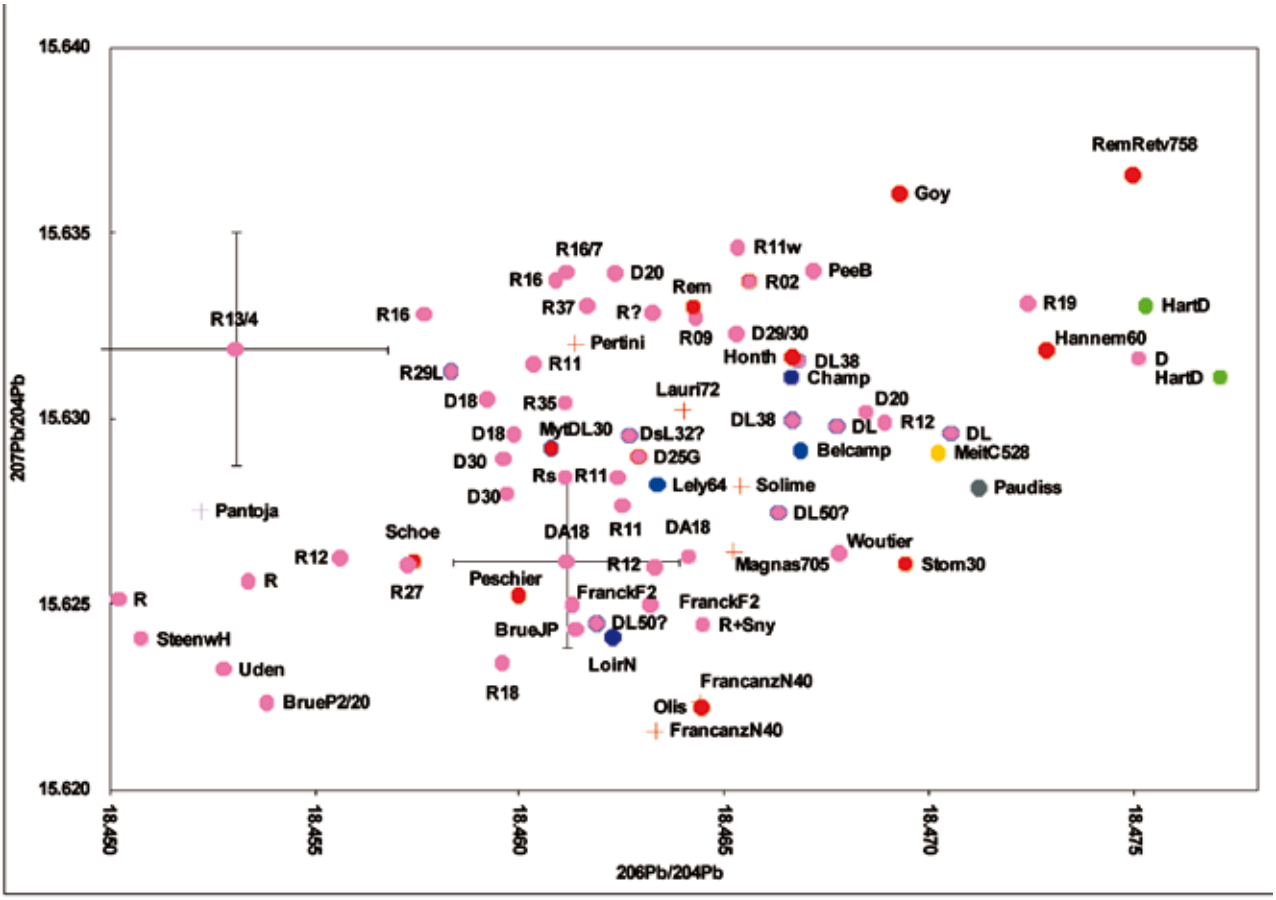

FIGURE 6. Lead isotope ratio comparison data from English and Dutch/Flemish paint samples. *Pattern code*: ũ: 'northern' painter (Flemish, Dutch and so on); +: 'southern' painter (Italian, Spanish and so on). *Colour code*: pink: Flemish; dark blue: British; orange: Dutch; indigo:French; green: Swiss; grey: German; yellow: Austrian; red: Italian; lilac: Spanish; pink with blue outline: Flemish painting executed in Great Britain; orange with blue outline: Dutch painter in Britain, and so on. *Letter and number code*: R: Rubens; D: van Dyck; Rem: Rembrandt; A: painted in Antwerp; L: painted in London; 09: 1609: 758: 1758; s: studio (example: R29L = Rubens, 1629, painted in London).

APPENDIX

TABLE A-1. Composition of lead ores from the principal European lead mining regions.[35]

Country	Location/region/ mine	Composition
Belgium	Theux	Galena, cerussite and anglesite
Belgium	Theux	Cerussite
Belgium	Theux	Cerussite
Belgium	Engis/Lüttich	Galena covered with sphalerite
Belgium	Engis/Lüttich	Galena and wurtzite
Belgium	Theux	Cerussite and galena
Bulgaria	Madan	Galena
Germany	Schauinsland, Black Forest near Freiburg	Galena with sphalerite
Germany	Schauinsland, Black Forest	Galena
Germany	Gute Hoffnung, near St Goar am Rhein	Galena
Germany	Grube Rosenberg, Braubach, Rheinland	Galena
Germany	Holzappel Koblenz region	Galena
Germany	Gosenbach, Siegerland	Galena
Germany	Wildemann, Oberharz, Silberaal, Mine Medingschacht	Galena
Germany	Rammelsberg near Goslar/Harz	Galena
Germany	Rammelsberg near Goslar/Harz	Galena and chalcopyrite
Germany	Bad Grund/Harz	Galena
Germany	Halsbrücke near Freiberg	Galena

Country	Location/region/ mine	Composition
Germany	Freiberg	Galena
Germany	Kleinvoigsberg near Freiberg	Galena
Germany	'Gang der Edlen pit' Brand-Erbisdorf near Freiberg	Galena
Germany	'Gang der Edlen pit' Grube Schmalgraf near Aachen	Galena and sphalerite
Germany	Diepenlinchen near Aachen	Galena, wurtzite, pyrite and calcite
Germany	Mechernich/Eifel	Galena
Germany	Tagebau Kallmuther Berg, Mechernich/Eifel	Galena
Germany	Tagebau Usief, Gey near Düren/Eifel	Galena conglomerate
Germany	Mechernich/Eifel	Cerussite
Germany	Grube Virginia, Mechernich/Eifel	Cerussite
Germany	Ramsbeck/Sauerland	Galena with sphalerite
Germany	Ramsbeck/Sauerland	Galena
Germany	Grube Pfaffenberg Neudorf/Harz	Galena
Germany	Neudorf/Harz	Galena and siderite
Germany	Andreasberg/Harz	Galena and quartz
Germany	Andreasberg/Harz	Galena and siderite
Germany	Bad Gund/Harz	Galena
Germany	Silbernaal near Bad Gund/Harz	Galena and carbonate [*sic*]
Germany	Silbernaal, Medingschacht, Wildemann near Bad Gund/Harz	Galena
Germany	Clausthal-Zellerfeld/ Harz	Galena, sphalerite, carbonate [*sic*]
Germany	Clausthal-Zellerfeld/ Harz	Galena, chalcopyrite and quartz
Germany	Maubach near Düren/Eifel	Galena conglomerate
Germany	Schmalgraf pit, Altenberg near Aachen	Calcite with wurtzite and galena
Germany	Schmalgraf pit, Altenberg near Aachen	Galena, wurtzite, pyrite
Germany	Wiesloch near Heidelberg, Baden-Württemberg	Wurtzite, galena, pyrite
Germany	Wiesloch near Heidelberg, Baden-Württemberg	Galena on wurtzite
Germany	Maubach/Eifel	Cerussite
Greece	Chalkidiki Penisnsula, Modem Lakkos	(Information unavailable)
Great Britain	Yatestoop mine, Winster, Derbyshire	Galena with sphalerite
Great Britain	Hubbadale mine, Derbyshire	Galena and massicot
Great Britain	Leadhills, Lanarkshire	Galena, Sphalerite and carbonate [*sic*]
Great Britain	Nenthead, Alston Moor, Cumberland	Galena, chalcopyrite, arsenopyrite, sphalerite, quartz
Great Britain	Alston Moor, Cumberland	Galena
Great Britain	Parc mine, Llanrwst, Caernarvonshire	Galena, sphalerite, quartz
Italy	Schneeberg, Southern Tyrol	Galena with quartz
Italy	Schneeberg near Sterzing, southern Tyrol	Galena with chalcopyrite
Italy	Del Predil/Raibl	Lead, zinc [*sic*]
Italy	Raibl near Tarvis	Galena
Morocco	Erfoud	Galena
Austria	Bleiberg, Kreuth/Kärnten	Galena
Poland	Okkusz, Boleslaw pit	Galena
Poland	Radzimowice, Altenbarg am Katzbach, Slask	Galena, chalcopyrite, sphalerite with traces of tetrahedrite
Poland	Walbrzyck/Silesia	Galena with baryte
Poland	Grube Neue Fortuna, Bytom/Silesia	Galena
Poland	Gang Bergmannstrost, Radzimowice/Silesia	Galena, pyrite and chalcopyrite
Poland	Gierczyn, Isergebirge/Silesia	Galena
Poland	Grube Boleslaw Olkusz/Silesia	Galena
Poland	Grube Boleslaw Olkusz/Silesia	Galena and dolomite
Romania	Baia Mare	Galena, sphalerite
Romania	Baia Sprie Horizont 11	Galena, pyrite
Romania	Cavnik, Reimura West	Galena, chalcopyrite
Slovenia	Mečica /Ostkarawanken	Galena
Spain	Osor	Galena, low silver content
Czech Republic	Harrachor/ Harrachov	Galena
Czech Republic	Bohutin near Přibram 1100m Sohle	Galena with sphalerite
Czech Republic	Přibram, II. Liegendgang, 14. Lauf, Littschacht	Galena
Czech Republic	Přibram/Miess	Galena

TABLE A-2. Paintings sampled for the lead white isotope project.

Artist	Painting	Painted in	Date	Sample	Collection
Allori, Alessandro	*Portrait of a Woman*	Florence	1590	HUAMF 1957.62	Harvard University Art Museums
Anonymous	*Portrait of David Cunz (1592–1664)*			VA10	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Friedrich Buchmann*			VA13	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Johannes Keller*			VA21	Vadianische Sammlung St Gallen
Anonymous	*Portrait of David Wetter*			VA22	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Eusebius Kleber*			VA23	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Othmar Scheitlin*			VA24	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Christoph Hofmann*			VA25	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Sebastian Högger*			VA27	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Hans Friederich*			VA32	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Joachim Vonwiler*			VA33	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Conrad Locher*			VA34	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Hans Albrecht Schobinger*			VA35	Vadianische Sammlung St Gallen
Anonymous	*Philosophus dives prisca de gente*			VA36	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Ambrosius Schlumpf*			VA38	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Caspar Friedrich (1572–1655)*			VA8	Vadianische Sammlung St Gallen
Anonymous	*Portrait of Hans Hiltbrand (1586–1654)*			VA9	Vadianische Sammlung St Gallen
Asselijin, Jan	*Fortified Tower by the Water*			G308/1	Collections of the Prince of Liechtenstein
Barocci, Federico	*The Nativity*			rc404143	Royal Collection
Bassano, Leandro	*Man with a Statuette*	Italy	1592	rc405988 FCS	Royal Collection
Belcamp, Jan van	*Edward, Prince of Wales*	England	1635	rc404037/1 WCCal	Royal Collection
Belcamp, Jan van	*Louis XIII of France*	France	1636	rc404098a/1WCCal	Royal Collection
Berchem, Nicolaes	*The Death of Dido*			G142/1	Collections of the Prince of Liechtenstein
Berchem, Nicolaes (C.P.)	*Herdsmen and Animals in an Italian Landscape*			KA 126 3021	Koller Auktionen Zurich
Blin de Fontenay, Jean-Baptiste	*Still Life with Flowers*			KA 126 3050	Koller Auktionen Zurich
Bramer, Leonaert	*Baptism of the Chamberlain*			K3023	Koller Auktionen Zurich
Bruegel, Pieter the Elder	*Landscape with the Flight into Egypt*		1563	CIA: 1237	Courtauld Institute of Art, London
Brueghel, Jan the Younger	*The Virgin Mary with the Christ Child*			K3038/1	Koller Auktionen Zurich
Brueghel, Jan the Younger	*Venus in Vulcan's Smithy*			KA 126 3006/1	Koller Auktionen Zurich
Brueghel, Jan the Younger	*Allegory of War*			K3031	Koller Auktionen Zurich
Brueghel, Jan Pieter	*The Element of Water*			K3015/1	Koller Auktionen Zurich
Brueghel, Jan Pieter	*The Element of Air*			K3015/2	Koller Auktionen Zurich
Brueghel, Pieter the Younger	*The Sermon of John the Baptist*			KA3010/1	Koller Auktionen Zurich
Cagnacci, Guido	*Jacob peeling the Rods*	Venice	*c.*1650	rc(ML364)/1 HCP	Royal Collection
Campi, Vincenzo	*Kitchen Interior*			KA 126 3003	Koller Auktionen Zurich
Caracciolo, Giovanni Battista (called Battistello)	*The Martyrdom of Saint Sebastian*	Naples	1625	HUAMF 1924.31	Harvard University Art Museums
Champaigne, Philippe de	*Portrait of Cardinal Richelieu*			rc404757/1WCCal	Royal Collection
Claesz, Pieter	*Still Life*		*c.*1632	KHZ32 KS 12	Kunsthaus Zurich Betty u. David Koetser Stiftung

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TABLE A-2. Paintings sampled for the lead white isotope project *cont'd*.

Artist	Painting	Painted in	Date	Sample	Collection
Coninck, David	*Still Life with Flowers, Fruit and a Monkey*		*c.*1685	KHZ3 KS 16	Kunsthaus Zurich Betty u. David Koetser Stiftung
D'Artois, Jacques	*Departure of the Hunt with Falcons*			K3075	Koller Auktionen Zurich
Dacin di Capella, Francesco called 'Il Daggiù'	*Susanna Bathing*		1745–50	KHZ 31 869	Kunsthaus Zurich Zürcher Kunstgesellschaft
Domenichino	*Landscape with the Baptism of Christ*		1603	KHZ 12 KS52	Kunsthaus Zurich Betty u. David Koetser Stiftung
Dyck, Anthony van	*Madonna and Child with Angels Playing Music*		1630–32	Y 1945.357	Yale University Art Gallery
Dyck, Anthony van	*Portrait of a Young Man*		1620	G 66	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Portrait of a Young Woman*		1620	G 68_1	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Portrait of an Older Man*		1618	G 95_2	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Saint Jerome*		1615	G56	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Maria Theresias de Tassis*		1629	G58	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Portrait of a Young Woman*		1620	G63	Collections of the Prince of Liechtenstein
Dyck, Anthony van	*Golgotha*		1630	IRPA 10	Royal Institute for Cultural Heritage Brussels
Dyck, Anthony van	*The Balbi Children*		1625	NGL 6502	The National Gallery London
Dyck, Anthony van	*Triumphal Procession of Bacchus with Children*		1626	KHZ 2 KS 39	Kunsthaus Zurich Betty u. David Koetser Stiftung
Dyck, Anthony van (after?)	*Lady d'Aubigny*		1650?	rc401360(OM177)/2 FCS	Royal Collection
Dyck, Anthony van	*Henry, Prince of Wales*	London	1638	rc404320a/1FCS	Royal Collection
Dyck, Anthony van	*Mary*			rc404436/2WCCal	Royal Collection
Dyck, Anthony van	*Portrait of a Man*	Antwerp	1618–20	rc407188(OM160)/ 1FCS	Royal Collection
Dyck, Anthony van	*Filippo Francesco d'Este, Third Marchese di Lanzo*			KMW	Kunsthistorisches Museum Vienna
Dyck, Anthony van	*Mystic Betrothal of the Blessed Hermann Joseph and the Virgin Mary*		1630	KMW	Kunsthistorisches Museum Vienna
Dyck, Anthony van	*Capture of Samson*		1628–30	KMW	Kunsthistorisches Museum Vienna
Dyck, Anthony van (studio)	*Sir Kenelm Digby*	London	1632?	rc402903(OM171) WCCal	Royal Collection
Dyck, Anthony van (after)	*Prince Thomas of Savoy-Carignan*		1635	rc404011(OM184)/1 WCCal	Royal Collection
El Greco	*Crucifixion (after Tintoretto)*			KHZ 9	Kunsthaus Zurich Private Loan
El Greco	*The Apostle Paul*			S945/1	Stucker Auktionen Zurich
Fels, Elias	*Portrait of Melchior Locher*			VA26	Vadianische Sammlung St Gallen
Forabosco, Girolamo	*David with the Head of Goliath*			G38/1	Collections of the Prince of Liechtenstein
Francanzano, Francesco	*The Drunken Silenus*	Naples	1640s	HUAMF 1932.70.1	Harvard University Art Museums
Francanzano, Francesco	*The Virgin and Saint Peter appear to the First Companions of Saint Bruno*		1637	KHZ 7KS50	Kunsthaus Zurich, Betty u. David Koetser Stiftung
Francken, Frans the Younger	*Virgin and Child*			KA3013/ 2	Koller Auktionen Zurich
Frank, Daniel	*The Linen Trader Klaus Gugger*		1615	HMSG21404	Historisches Museum St Gallen
Gennari, Benedetto	*Danaë receiving the Shower of Gold*		*c.*1676	rc402934 (ML497)	Royal Collection
Ghisolfi, Giovanni	*Roman Ruins*	Milan		GE219/1	Collections of the Prince of Liechtenstein

Artist	Painting	Painted in	Date	Sample	Collection
Ghisolfi, Giovanni	*Roman Ruins with the Three Columns of the Temple of Vespasian*	Milan		GE214/1	Collections of the Prince of Liechtenstein
Giordano, Luca	*The Pool of Bethesda*	Naples	1684–5	HUAMF 1954.84	Harvard University Art Museums
Giordano, Luca	*Translation of the Body of Saint Restituta*		After 1692	KHZ 17 48	Kunsthaus Zurich Bequest David Hess im Beckenhof
Goyen, Jan van	*View over a Wide Landscape*			K3034/1	Koller Auktionen Zurich
Hagenbuch, Caspar	*Portrait of Joachim von Watt*			VA37	Vadianische Sammlung St Gallen
Hagenbuch, Kaspar (attrib.)	*Portrait of Christoph Schappler*			VA30	Vadianische Sammlung St Gallen
Hals, Frans	*Portrait of a Man*			B151/1	Sammlung E. G. Bührle Zurich
Hanneman, Adriaen	*Mary, Princess of Orange*	The Hague(?)	1660	rc(OM212)	Royal Collection
Hartmann, Daniel	*Portrait of Tobias Schobinger*		1684	VAPA10	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Hans Joachim Haltmeier*		1660	VAPB 8	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Otmar Appenzeller*		1683	VAPB10	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Johannes Spengler*		1687	VAPB11	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Ulrich Weyermann*		1702	VAPB12	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Laurenz Werder*		1702	VAPB13	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Dr. med. Bartholomäus Schobinger*		1662	VAPA8	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Christian Huber, Dean*		1692	VAPD10/1	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Jacob Hofmann, Dean*		1685	VAPD8	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Bartholomäus Schobinger*		1566?	HMSG	Collections of the Prince of Liechtenstein
Hartmann, Daniel	*Portrait of a Girl*		1697	HMSG 12458	Historisches Museum St Gallen
Hartmann, Daniel	*Portrait of a Girl*			HMSG 13565	Historisches Museum St Gallen
Hartmann, Daniel	*Portrait of Peter Fels*			HMSG 7354	Historisches Museum St Gallen
Hartmann, Daniel	*Portrait of Joachim Morss*		1666	VAPA9	Vadianische Sammlung St Gallen
Hartmann, Daniel	*Portrait of Leonhard Harmann, Mathematician*			VA3	Vadianische Sammlung St Gallen
Hartmann, Daniel (circle of)	*Portrait of Joachim von Watt, Bürgermeister of Vadian,*			VA7	Vadianische Sammlung St Gallen
Hartmann, Hans Anton	*Portrait of Hans Jacob Rietmann*			VA20	Vadianische Sammlung St Gallen
Hartmann, Hans Anton	*Portrait of Johannes Jacob Scherrer*			VA29	Vadianische Sammlung St Gallen
Hartmann, Hans Anton	*Portrait of Christoph Hochreutiner*			VAV18	Vadianische Sammlung St Gallen
Hoffmann, Samuel	*Portrait*	Frankfurt?		KHZ29	Kunsthaus Zurich
Honthorst, Gerrit van	*Sophia, Electress of Hannover*			rc404105/2FCS	Royal Collection
Huchtenburg, Jan van	*Cavalry Skirmish*			KHZ30	Kunsthaus Zurich
Huysmans, Cornelis	*Landscape*			K3074	Koller Auktionen Zurich
Jordaens, Jacob	*The Musical Contest between Apollo and Pan*		589	KHZ28	Kunsthaus Zurich Loan Gottfried Keller Stiftung
Kalf, Willem	*Still Life*			B155/1	Sammlung E. G. Bührle Zurich
Kauffmann, Angelica	*Ariadne presents Theseus ...*			K3096/1	Koller Auktionen Zurich
Kessel, Jan van	*Wreath of Flowers with Cartouche*			KA 126 3031	Koller Auktionen Zurich
Lauri, Filippo	*Jacob fleeing from Laban*		1672–9	rc406356 FCS	Royal Collection
Lely, Peter	*Eleanor Needham, Lady Byron*		1664	rc404089(OM253)/ 1WCCal	Royal Collection
Lievens, Jan	*Portrait of a Man*		1650	HUAMF 1972.38	Harvard University Art Museums

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TABLE A-2. Paintings sampled for the lead white isotope project *cont'd*.

Artist	Painting	Painted in	Date	Sample	Collection
Lint, Hendrick Frans van	*Landscape with Figures*			K3073/1	Koller Auktionen Zurich
Lisse, Dirk van der	*Sleeping Nymph*			KA 126 3028	Koller Auktionen Zurich
Loir, Nicolas	*The Virgin and Child with the Infant Saint John the Baptist*	Paris?		HUAMF 1938.86	Harvard University Art Museums
Magnasco, Alessandro, Peruzzini Antonio Francesco and Ricci, Marco	*View of a Town with Vagabonds*		*c.*1716–1718	KHZ 15 KS 54	Kunsthaus Zurich, Betty u. David Koester Stiftung
Magnasco, Alessandro	*Monks by the Fire*		1725	KHZ 24 2601	Kunsthaus Zurich, Zürcher Kunstgesellschaft
Magnasco, Alessandro	*Six Monks praying in a Landscape*		1705	HUAMF 1920.6	Harvard University Art Museums
Malo, Vincente	*Madonna and Child with Saint John*			rc406058/2HCP	Royal Collection
Mancadan, Jacob Sibrandi	*Scene with Fishermen*	Friesland		KHZ25 R15	Kunsthaus Zurich Ruzicka Stiftung
Maratta, Carlo (circle of)	*Virgin and Child*			K3066/1	Koller Auktionen Zurich
Marcos (Armenian School)	*Portrait of a Persian Man*	Isfahan	1660–70	rc407811	Royal Collection
Meit, Conrat (attrib.)	*Archduchess Margaret, Regent of the Netherlands* (painted terracotta bust)			KMW	Kunsthistorisches Museum Vienna
Michaud, Theobald	*View of a Farm*			K3022/1	Koller Auktionen Zurich
Momper, Joos de and Teniers, David the Younger.	*River Scene with Fortune-Telling Gypsies*		*c.*1630	KHZ6 KS 17	Kunsthaus Zurich Betty u. David Koetser Stiftung
Mytens, Aert	*Cleopatra*			rc406053/1HCP	Royal Collection
Mytens, Daniel	*Jeffery Hudson*	London	1630	rc402812(OM125)	Royal Collection
Neer, Aert van der	*Riverscape*		*c.* 1644–1650	KHZ26 R21	Kunsthaus Zurich Ruzicka Stiftung
Netscher, Caspar	*Portrait of a Nobleman*			KA 126 3040	Koller Auktionen Zurich
Olis, Jan	*Guardhouse with Soldiers*			K3032	Koller Auktionen Zurich
Palamedesz, Anthonie	*In a guardhouse*			G 512	Collections of the Prince of Liechtenstein
Palma il Giovane	*Self-Portrait*	Venice		HUAMF 1919.562	Harvard University Art Museums
Pantoja de la Cruz, Juan	*Portrait of an Evangelist*			K3064/1	Koller Auktionen Zurich
Paudiss, Christoph	*Kitchen Still Life*			K3033	Koller Auktionen Zurich
Pedrini, Giovanni	*Female Half Length*			K3009/1	Koller Auktionen Zurich
Peeters, Bonaventura	*Ship in a Storm*			K3035/1	Koller Auktionen Zurich
Peschier, N. L.	*Vanitas Still Life*			K3049	Koller Auktionen Zurich
Petrini, Giuseppe Antonio	*St. Luke painting the Madonna*		*c.*1740	KHZ 23 1968/20	Kunsthaus Zurich Gottfried Keller Stiftung
Poussin, Nicolas	*Sleeping Venus surprised by Satyrs*		*c.*1625	KHZ21 2480	Kunsthaus Zurich
Preti, Mattia	*Christ and the Adulteress*		1635–40	KHZ 11 KS 51	Kunsthaus Zurich Stiftung Betty u. David Koetser
Procaccino, Ercole the Younger	*Christ washing the Disciples' Feet*			K3046	Koller Auktionen Zurich
Rembrandt	*Saskia van Uylenburgh*			B163/1	Sammlung E. G. Bührle Zurich
Rembrandt	*Susanna and the Elders*	Amsterdam	1636	MH147-2E	Mauritshuis, The Hague
Rembrandt: *Later addition*	*Susanna and the Elders*		pre-1758 (estim.)	MH147-2D	
Rembrandt, Circle of	*Minerva in her Study*		1628–31	MH626-G	Mauritshuis, The Hague
Rembrandt (?)	*Hunt Still Life*			B164/1	Sammlung E. G. Bührle Zurich

Artist	Painting	Painted in	Date	Sample	Collection
Reni Guido	*The Magdalen*			G 10	Collections of the Prince of Liechtenstein
Ricci, Sebastiano	*Nessus abducts Deianeira*		*c.*1700	KHZ 8 KS 56	Kunsthaus Zurich, Betty u. David Koetser Stiftung
Roos, Jacob	*Three Shepherds with their Flock*			K3089/1	Koller Auktionen Zurich
Rosa, Salvator	*Landscape with Pythagoras and the Fishermen*		1662	KHZ 16 KS 53	Kunsthaus Zurich, Betty u. David Koetser Stiftung
Rosa, Salvator	*Landscape with Pythagoras and the Fishermen*		1662	KHZ 13	Kunsthaus Zurich, Betty u. David Koetser Stiftung
Rubens, Peter Paul	*Saint Augustine*		*c.*1620	B160/1	Sammlung E. G. Bührle Zurich
Rubens, Peter Paul	*Saint Augustine*		*c.*1620	B160/2	Sammlung E. G. Bührle Zurich
Rubens, Peter Paul	*The family of Jan Breughel the Elder*		1612–13	CIA: 1524	Courtauld Institute of Art London
Rubens, Peter Paul	*Portrait of Jan Monfort*		1635	CIA: 1526, red	Courtauld Institute of Art London
Rubens, Peter Paul	*The Virgin adorned with Flowers*		1609–10	G 116_2	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Three Music-making Angels*		1613	G 136	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Lamentation of Christ*		1614–15	G 62_1	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Lamentation of Christ*		1614–15	G 62_2	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Henry IV seizes the Opportunity to Conclude Peace*		1628	G100	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Victory of Henry IV at Coutras*		1628	G101	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Portrait of Clara Serena Rubens*		*c.*1623	G105	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Apollo in the Chariot of the Sun*		1621–5	G109	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Study of the Head of a Bearded Man*		1616	G113	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*St Francis of Assisi before the Crucified Christ*		1614–15	G60	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Assumption of the Virgin*		1635	G80	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Portrait of the Marchese Ambrogio Spinola*		1627	Haum B/85/3	Herzog Anton-Ulrich-Museum Brunswick
Rubens, Peter Paul	*Judith with the head of Holofernes*		1616	Haum B/87/2	Herzog Anton-Ulrich-Museum Brunswick
Ruben, Peter Pauls	*Conversion of St. Bavo*			IRPA 1	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Descent from the Cross*		1612–14	IRPA 12	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Resurrection of Christ*		1611–12	IRPA 13	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	Resurrection of Christ		1611–12	IRPA 14	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Resurrection of Christ*		1611–12	IRPA 15	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Resurrection of Christ, wing*		1611–12	IRPA 16	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Purgatory*		1635	IRPA 3	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Purgatory*		1635	IRPA 4	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Descent from the Cross*		1612–14	IRPA 7	Royal Institute for Cultural Heritage Brussels
Rubens, Peter Paul	*Faun and Countrywoman*			IRPA 8	Royal Institute for Cultural Heritage Brussels

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TABLE A-2. Paintings sampled for the lead white isotope project *cont'd*.

Artist	Painting	Painted in	Date	Sample	Collection
Rubens, Peter Paul	*Adoration of the Kings*			KA 126 3009/1	Koller Auktionen Zurich
Rubens, Peter Paul	*Saint Ambrose and the Emperor Theodosius*		1618–20	KMW	Kunsthistorisches Museum Vienna
Rubens, Peter Paul	*Portrait of Helena Fourment*			MH0251-41	Mauritshuis, The Hague
Rubens, Peter Paul	*Portrait of Helena Fourment*			MH0251-42	Mauritshuis, The Hague
Rubens, Peter Paul	*Peace and War*		1629–30	NGL 46	The National Gallery London
Rubens, Peter Paul	*Samon and Delilah*		1609	NGL 6491	The National Gallery London
Rubens, Peter Paul	*Decius Mus preparing for Death*		1618	R11	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Conversion of Saul*		1602	R31	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*The Discovery of the Infant Erychthonius*		1615	R41	Collections of the Prince of Liechtenstein
Rubens, Peter Paul	*Saint Augustine*		*c.*1620	S160/1	Stucker Auktionen Zurich
Rubens, Peter Paul	*Cimon and Iphigenia*		*c.*1617	KMW	Kunsthistorisches Museum Vienna
Rubens, Peter Paul (?)	*The Holy Family*			KA 126 3054	Koller Auktionen Zurich
Rubens, Peter Paul (School of)	*Saint Ambrose denied*			KHZ 22	Kunsthaus Zurich
Rubens, Peter Paul and Snyders, Frans	*The Christ Child with the Infant Saint John the Baptist and Angels*			HUAMF 1958/85/1	Harvard University Art Museums
Rubens, Peter Paul, and Breughel, Jan the Elder	*The Return from War: Mars Disarmed by Venus*		*c.*1610–12	GM1	J. Paul Getty Museum
Rubens, Peter Paul (copy)	*Portrait of a Man*		18th or 19th century	rc401073	Royal Collection
Rubens, Peter Paul, School of (copy)	*Saint Ambrose denies Emperor Theodosius entrance into the Cathedral of Milan*			2153	Kunsthaus Zurich, Bequest Dr. R. Schwarzenbach
Ruisdael, Jacob Isaaks. van	*Landscape with Waterfall*			KA 126 3013	Koller Auktionen Zurich
Saenredam, Pieter	*Interior of the Grote Kerk (St. Bavo)*			B165/1	Sammlung E. G. Bührle Zurich
Schoeff, Johannes P.	*Landscape with Rider*			K3059/1	Koller Auktionen Zurich
Sofonisba, Anguissola	*Portrait of an Old Woman*			KHZ 33	Kunsthaus Zurich
Simonini, Francesco Antonio, circle of	*Council of War of the Commanders*			KHZ 20 134	Kunsthaus Zurich Zürcher Kunstgesellschaft
Steenwyck, Hendrik van	*Interior of a Church in Antwerp*			K3062	Koller Auktionen Zurich
Stimmer, Tobias (circle of?)	*Portrait of Bartholomäus Schobiger*			VA31	Vadianische Sammlung St Gallen
Stom, Matthias	*The Deliverance of Peter*		1632	KHZ14 KS 49	Kunsthaus Zurich Stiftung Betty u. David Koetser
Stom, Matthias	*Christ and the Woman of Samaria*		1630	KHZ10 KS 48	Kunsthaus Zurich Betty u. David Koetser Stiftung
Stom, Matthias	*Young Couple at their Evening Meal*			KHZ19 1992/2	Kunsthaus Zurich Zürcher Kunstgesellschaft
Streeck, Julian van	*Still Life*		1672	KHZ18 R36	Kunsthaus Zurich Ruzicka Stiftung, Zürger Kunstgesellschaft
Thiele, Johann Alexander	*[Information unavailable]*			Thiele0285/1	Herzog Anton-Ulrich-Museum Brunswick
Thiele, Johann Alexander	*[Information unavailable]*			Thiele0285/2	Herzog Anton-Ulrich-Museum Brunswick
Tintoretto, Domenico	*Portrait of a Nobleman with his Son*	Venice		G230/1	Collections of the Prince of Liechtenstein

Artist	Painting	Painted in	Date	Sample	Collection
Tintoretto, Domenico	*The Mocking of Christ*	Venice		HUAMF 1926.5	Harvard University Art Museums
Titian	*Landscape with Shepherds and Flocks*			rc405735(JS295)HCP	Royal Collection
Torregiani, Bartolomeo	*Landscape with Shepherds*	Rome		G496/2	Collections of the Prince of Liechtenstein
Trotti, Giovanni Battista called 'Il Malosso'	*Portrait of Cattolica Barbo Anguissola as an Old Woman*		*c.*1590	KHZ 33 585	Kunsthaus Zurich Loan Gottfried Keller Stiftung
Uden, Lucas van	*Winter*			G488	Collections of the Prince of Liechtenstein
Veyel, Sylvester	*Portrait of David Stäheli*			VAV19	Vadianische Sammlung St Gallen
Veyel, Sylvester	*Portrait of Michael Schlatter*			V28	Vadianische Sammlung St Gallen
Voss, Cornelis de	*Diogenes looks for a Man*			KA 126 3030	Koller Auktionen Zurich
Wautier, Michaelina	*Portrait of a Young Man*			K3052	Koller Auktionen Zurich
Wedig, Gottfried von	*Still Life with a Candle*			K3027	Koller Auktionen Zurich
Wouwerman, Philips	*Landscape with Bathers*			G432	Collections of the Prince of Liechtenstein
Wyck,Thomas	*Italian Harbour Scene*			G573/1	Collections of the Prince of Liechtenstein

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NOTES

1. Zinc oxide: http://webexhibits.org/pigments/indiv/history/zincwhite.html (accessed 6 June 2009).
2. Titanium dioxide: http://webexhibits.org/pigments/indiv/history/tiwhite.html (accessed 6 June 2009).
3. Cisalpine meaning this side of the Alps as seen with reference to Rome, hence transalpine is the region north of the Alps.
4. Gale, N.H. and Stos-Gale, Z.A (2000) 'Lead isotope analyses applied to provenance studies', in E. Ciliberto and G. Spoto (eds) *Modern Analytical Methods in Art and Archeometry*, Chemical Analysis vol. 155, New York: John Wiley & Sons, pp. 503–69; Wedepohl, K. and Baumann, A. (1997) 'Isotope composition of medieval lead glasses reflecting early silver production in Central Europe', *Mineralium Deposita*, 32, pp. 292–5; Rosman, K.J.R., Chisholm, W., Hong, S., Candelone, J.P. and Boutron, C.F. (1997) 'Lead from Carthaginian and Roman Spanish mines isotopically identified in Greenland ice dated from 600 BC to 300 AD', *Environmental Science and Technol*ogy, 31, pp. 3413–16; De Wannemacker, G., Vanhaecke, F., Moens, L., Van Mele, A. and Thoen, H. (2000) 'Lead isotopic and elemental analysis of copper alloy statuettes by double focusing sector field ICP mass spectrometry', *Journal of Analytical Atomic Spectrometry*, 15, pp. 323–7; De Readt, I., Janssens, K., Veeckman, J., Vincze, L., Vekemans, B. and Jeffries, T.E. (2001) 'Trace analysis for distinguishing between Venetian and facon-de-Venise glass vessels of the 16th and 17th century', *Journal of Analytical Atomic Spectrometry*, 16, pp. 1012–17; Niederschlag, E., Pernicka, E., Seifert, T. and Bartelheim, M (2003) 'The determination of lead isotope ratios by multiple collector ICP–MS: a case study of early Bronze Age artefacts and their possible relation with ore deposits of the Erzgebirge', *Archaeometry*, 45, pp. 61–100; Junk, S.A. and Pernicka, E. (2003) 'An assessment of osmium isotope ratios as a new tool to determine the provenance of gold with platinum-group metal inclusions', *Archaeometry*, 45, pp. 313–31; Fortunato, G., Mumic, K., Wunderli, S., Pillonel, L., Bosset, J.O. and Gremaud, G. (2004) 'Application of strontium isotope abundance ratios measured by MC–ICP–MS for food authentication', *Journal of Analytical Atomic Spectrometry*, 19, pp. 227–34.
5. Faure, G. (1986) *Principles of Isotope Geology*, 2nd edn, New York: John Wiley & Sons.
6. Ritter, A. (2000) P.P. Rubens *The Consecration of Decius Mus*, 1616/17 oil on canvas (Liechtenstein Museum Vienna, Inv. No. G 49) Untersuchungsbericht 411'253 EMPA St Gallen.

7. Keisch, B. and Callahan, R.C. (1976) 'Lead isotope ratios in artists' lead white: a progress report', *Archaeometry*, 2, pp. 181–93.
8. To state the obvious, this means when the condition of a painting is in a perfect state of preservation, without apparent damages at the locations where sampling would be required, no sampling is performed.
9. After determination of the sample weight, its morphology, the inorganic matrix and the layer structure, 4 mL of a 1:1 diluted sub-boiled concentrated nitric acid (puriss. pa, Fluka, CH) was used to perform the decomposition. The samples and solutions were kept under clean room conditions (class 100) during manipulation to avoid any contamination.

   For the lead isotope abundance ratio determinations, the samples were diluted using sub-boiled 2% nitric acid (puriss. pa, Fluka, CH) achieving a lead amount content of approximately 200 μg kg^{-1}. All weighing operations were performed in a class E2 environment (according to the Organisation Internationale de Metrologie Legale (OIML)) with stabilised air temperature and relative air humidity as well as monitored air pressure. All weighing was done on a micro-analytical balance (UMT5 Mettler-Toledo, Greifensee, Switzerland). The balance was regularly checked by the use of class E2 reference weights traced back to the Swiss National Metrology References. Scanning electron microscope (SEM) images were acquired using an Amray ECO-SEM 3200 C (Amray, USA), using a BSE detector (backscattering electrons) operating in a low pressure vacuum mode (150 mTorr) and 20 keV accelerating voltage. The X-ray spectrum acquisition for elemental analysis was done at 20 keV by an EDX Oxford LINK ISIS 300 (Oxford Instruments, UK). The spectra were acquired in a single mode and in a 2D mode (element mapping).

   All measurements of the different isotope abundance ratios were performed using the VG AXIOM MC–ICP–MS (Thermo-Elemental, Winsford, Cheshire, UK). The instrument was operated in an air temperature-stabilised (17 °C ±1 °C) clean hood (class 100) laboratory.

   The solutions to be analysed were taken up by free aspiration using a TH1 nebuliser (CETAC, Omaha, USA). The sample uptake rate of the nebuliser was about 100 μL min^{-1}. The wet aerosol was dried by an Aridus (CETAC, Omaha, USA) aerosol desolvating system using approximately 3 L min^{-1} argon and 20 mL min^{-1} nitrogen (temperature 160 °C). The system was cleaned for two minutes before every run by aspirating a 2% HNO_3 solution. The dry aerosol was fed to the torch assembly kept at a voltage of 5000 V. A gain calibration of the multiple collector system was performed once a week. Faraday cup multiple collector detector positions were optimised while a mixture of 200 μg kg^{-1} Pb (SRM 981, NIST) and 50 μg kg^{-1} Tl (SRM 997, NIST) was introduced. Day-to-day variations of the relative multiple collector detector positions were in the order of 0.1 mm at maximum. Isotope abundance ratios of Pb in the digested white lead samples were determined using a 'standard – sample – standard' method: a mixture of 200 μg kg^{-1} Pb (SRM 981) and 50 μg kg^{-1} Tl (SRM 997) – a mixture of sample no. 1 and 50 μg kg^{-1} Tl (SRM 997) – a mixture of sample no. 1 and 50 μg kg^{-1} Tl (SRM 997) – 200 μg kg^{-1} Pb (SRM 981) and 50 μg kg^{-1} Tl (SRM 997) – a mixture of sample no. 2 and 50 μg kg^{-1} Tl (SRM 997) and so on up to 200 μg kg^{-1} Pb (SRM 981) and 50 μg kg^{-1} Tl (SRM 997). The SRM 997 thallium isotopic standard was added volumetrically to the samples. Between each measurement the wash sequence with 2% HNO_3 solution lasted for two minutes. The mass discrimination correction was performed using the values of natural thallium (internal calibration) and an exponential model equation, giving overlap of the corrected isotope abundance ratio value for the SRM 981 (NIST, USA) certificate and published values.
10. Krysko, W.W. (1979) *Lead in History and Art – Blei in Geschichte und Kunst*, Stuttgart: Riederer Verlag, p. 15.
11. Pulsifer, W.H. (1888) *Notes for a History of Lead and an Inquiry into the Development of the Manufacture of White Lead and Lead Oxides*, New York: D. Van Nostrand.
12. Krysko 1979 (cited in note 10), pp. 13ff.
13. Agricola, G. (1556) *De re metallica libri XII*, Basel.
14. Henderson, J. (2000) *The Science and Archaeology of Materials: An Investigation of Inorganic Materials*, London: Routledge, p. 238.
15. International Lead Association, Publications, On-line fact book: *Lead: The Facts*, annex, 'Historical production and uses of lead' (pdf file); http://www.ila-lead.org/factbook/annex.pdf (accessed 9 June 2009), pp. 177–84.
16. Rowe, D.J. (1983) *Lead Manufacturing in Britain*, London and Canberra: Croom Helm, p. 2.
17. Clay, R.M. (1950) 'From blue lead to white lead', *Country Life*, 108, p. 1903.
18. Harley, R.D. (1982) *Artists' Pigments c.1600–1835*, 2nd edn, London: Butterworth Scientific, pp. 166–72, citing MS Sloane 122 (London, British Library).
19. Rowe 1983 (cited in note 16), p. 4.
20. Gettens, R.J. and Stout, G.L. (1942) *Painting Materials: A Short Encyclopaedia*, New York: D. Van Nostrand Company, pp. 172–3.
21. Rowe 1983 (cited in note 16), p. 5.
22. Gettens, R.J., Kühn, H. and Chase, W.T. (1993) 'Lead white', in A. Roy (ed.) *Artist's Pigments: A Handbook of their History and Characteristics*, vol. 2, Washington, DC: National Gallery of Art; New York and Oxford: Oxford University Press, pp. 67–81; p. 68.
23. Meier, S.W. (1995) 'Blei in der Antike: Bergbau, Verhüttung, Fernhandel', PhD dissertation, University of Zurich, pp. 228 ff.
24. Scaife, B. (2003) Lead isotope ratios for Mediterranean ores, http://www.brettscaife.net/lead/data/index.html (accessed 6 June 2009); Scaife, B., Barreiro, B.A., McDonnell, J.G. and Pollard, A.M. (2001) Lead isotope ratios of 36 galenas from the northern Pennines, http://www.brettscaife.net/lead/npennine/npennine.html, updated version of 22 July 2008 (accessed 6 June 2009); Dejonghe, L. (1998) 'Zinc-lead deposits of Belgium', *Ore Geology Reviews*, 12, pp. 329–54.
25. Haggerty, R., Rohl, B.M., Budd, P.D. and Gale, N.H. (1996) 'Pb-isotope evidence on the origin of the West Shropshire orefield, England', *Geological Mag*azine, 133, pp. 611–17; Niggli, M. (1988) 'Geochemische Untersuchungen metamorpher Pb-Zn-Lagerstaetten und ihrer Nebengesteine', dissertation Nr. 8404, Eidgenössische Technische Hochschule, Zurich; Rohl, B.M. (1996) 'Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 2, galena from Britain and Ireland', *Archaeometry*, 38, pp. 165–80; Large, D., Schaeffer, R. and Hohndorf, A. (1983) 'Lead isotope data from selected galena occurrences in the North Eifel and North Sauerland, Germany', *Mineralium Deposita*, 18, pp. 235–43; Dejonghe 1998 (cited in note 24); Gottschalk, R. and Baumann, A. (2001) 'Material provenance of late Roman lead coffins in the Rheinland, Germany', *European Journal of Mineralogy*, 13, pp. 197–205; Stos-Gale, Z., Gale, N.H., Houghton, J. and Speakman, R. (1995) 'Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 1, ores from the western Mediterranean', *Archaeometry*, 37, pp. 407–15; Ludwig, K.R., Vollmer, R., Turi, B., Simmons, K.R. and Perna, G. (1989) 'Isotopic constraints on the genesis of base-metal ores in southern and central Sardinia', *European Journal of Mineralogy*, 1, pp. 657–66; Boni, M. and Koeppel, V. (1985) 'Ore-lead isotope pattern from the Iglesiente-Sulcis area (SW Sardinia) and the problem of remobilization of metals', *Mineralium Deposita*, 20, pp. 185–93.
26. Baxter, M.J. (1999) 'On the multivariate normality of data arising from lead isotope fields', *Journal of Archaeological Science*, 26, pp. 117–24; Reedy, C.L. and Reedy, T.J. (1988) 'Lead isotope analysis for provenance studies in the Aegean region: a re-evaluation', in E.V. Sayre, P. Vandiver, J. Druzik and C. Stevenson (eds) *Materials Issues in Art and Archaeology*, Materials Research Society Symposium Proceedings 123, Pittsburgh: Materials Research Society, pp. 65–70.
27. Krysko 1979 (cited in note 10), p. 30.

28. Polish ore might have found its way into the production of lead white following the same trade routes known to have been used for the trade in oak panels, often found in Flemish paintings, by way of the Baltic Sea: see Molenda, D. (1984) 'Der polnische Bleibergbau und seine Bedeutung für den europäischen Bleimarkt vom 12. bis 17. Jahrhundert', in W. Kroker and E. Westermann (eds) *Montanwirtschaft Mitteleuropas vom 12. bis 17. Jahrhunderts: Stand, Wege und Aufgaben der Forschung*, *Der Anschnitt*, Beiheft 2, Bochum: Vereinigung der Freunde von Kunst und Kultur in Bergbau e.V., Deutsches Bergbau Museum, pp. 187–98. Lead from the Goslar region in the German Harz mountains was in high demand for the cupellation process of the smelting plants of Thuringia, Mansfield and Saxony and the whole of the east German trade. The crisis of 1552 led to a reduction in the Goslar lead production. Since 1528 Polish lead had been traded in the markets in Dresden, Leipzig and Freiberg, Saxony, as well as in Nuremberg. The merchant Heinrich Cramer von Clausbruch from Leipzig imported lead from Olkusz via Breslau/Posen. By 1582 members of lead trading cooperatives included burgers of Braunschweig, Hamburg, Schwaben and Goslar. The complex trading routes and international relations show the possibilities of Polish lead being used for pigment-making. This path has to be evaluated further and promises to be a valuable resource of information. See also Kraschewski, H.-J. (1984) *Der Bergbau des Harzes im 16. und zu Beginn des 17. Jahrhunderts*, in Kroker and Westermann (cited above), pp. 134–43.
29. Jockenhövel, A. (ed.) (1996) *Bergbau, Verhüttung und Waldnutzung im Mittelalter: Auswirkungen auf Mensch und Umwelt. Ergebnisse eines Internationalen Workshops (Dillenburg, 11.-15. Mai 1994. Wirtschaftshistorisches Museum 'Villa Grün')*, Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte – Beihefte vol. 121, Stuttgart: Franz Steiner Verlag; Shepherd, R. (1993) *Ancient Mining*, London: Elsevier Applied Science; Blanchard, I. (1995) *International Lead Production and Trade in the 'Age of the Saigerprozess', 1460–1560*, Zeitschrift für Unternehmensgeschichte – Beihefte, 85, Stuttgart: Franz Steiner Verlag.
30. Molenda 1984 (cited in note 28).
31. Jan van Belcamp, *Edward, Prince of Wales*, *c.*1635, Royal Collection Inv. no. 404037; Anthony van Dyck, studio, *Portrait of Lady d'Aubigny*, *c.*1650 Royal Collection Inv. no. 401360; Anthony van Dyck, studio, *Sir Kenelm Digby*, *c.*1632, Royal Collection Inv. no. 402903; Anthony van Dyck, *Portrait of Henry, Prince of Wales*, 1638, Royal Collection Inv. no. 404320; Adriaen Hanneman, *Mary, Princess of Orange*, 1660, Royal Collection Inv. no. 404436 (probably painted in The Hague); Peter Lely, *Portrait of Eleanor Needham, Lady Byron*, 1664, Royal Collection Inv. no. 404089; Daniel Mytens, *Jeffrey Hudson*, 1630, Royal Collection Inv. no. 402812.
32. Meier, S.W. (1997) 'Blei-Fernhandel in römischer Zeit (2.Jh. v. Chr. – 4. Jh. n. Chr.)', *Helvetia Archaeologica*, 28, pp. 2–14.
33. Fabian, D. and Fortunato, G. (2004) 'Bleiweiss-Isotopenanlayse an Gemäldeproben des 17. Jahrhunderts; Zwischenbericht eines laufenden Projektes', *Zeitschrift für Kunsttechnologie und Konservierung*, 17, pp. 371–9.
34. Noble, P. and van Loon, A. (2005) 'New insights into Rembrandt's Susanna: changes of format; smalt discoloration; identification of vivianite; fading of yellow and red lakes; lead white paint', *ArtMatters: Netherlands Technical Studies in Art*, 2, pp. 76–96.
35. All the lead ore samples and their description of the composition were obtained from the Technische Universität, Bergakademie Freiberg, Fakultät Geowissenschaften, Geotechnik und Bergbau, Geowissenschatliche Sammlung.