Plate 1 Follower of Quinten Massys, *Saint Luke painting the Virgin and Child* (NG 3902), *c.*1525. Oak, 113.7 × 34.9 cm.

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Front cover: Jan Gossaert, *The Adoration of the Kings* (detail of Plate 65)

Methods and materials of Northern European painting in the National Gallery, 1400–1550

Early in the 1950s, as part of the urge for renewal and reassessment following the devastation of the Second World War, one of the most extensive cataloguing projects ever undertaken was set up by the Centre National de Recherches 'Primitifs flamands' (as it was then called) in Brussels. Its intention was, and is, to catalogue every surviving painting produced in the Southern Netherlands during the fifteenth and early sixteenth centuries; that is, those classified under the general heading 'Early Netherlandish' or *'les Primitifs flamands'*. As part of this project, Hubert and Jan van Eyck's *Adoration of the Lamb* altarpiece in the Cathedral of St Bavo, Ghent, became the subject of detailed technical investigation. It is so complex a work that it has a volume to itself in the series published by the Centre 'Primitifs Flamands'; it is also, with Dieric Bouts's *Altarpiece of the Blessed Sacrament* (Louvain, St Peter's), one of the first paintings to be studied in depth in this way.[1]

Since this time, the results of the scientific examination of many individual Northern European paintings, carried out both at the National Gallery and elsewhere, have been published; the opportunities for the investigation of a number of paintings together have, however, been limited.[2] It is, of course, perfectly possible to obtain an overall impression by comparing the published results of individual examinations, but there are considerable advantages to be gained by studying a number of paintings as a group. If each has been examined by the same range of methods of examination under similar conditions, the results from one can be interpreted in the light of those obtained from the others: some of the elements of uncertainty involved in comparing results from different campaigns of analysis are thus absent. A general survey is of particular value, partly because it provides a general framework within which the specific examples can be fitted, but also because it is thus possible to see how a particular painter's practice fits into the context of Early Netherlandish (or German, or any other chosen geographical subdivision) painting as a whole. What is perhaps of greater interest and importance is that it may enable one to examine the practice of a workshop; to compare the methods of one painter with another, more or less closely associated; and to elucidate the ordinary, everyday methods by which paintings were produced.

It is necessary to consider how far the National Gallery collection of Early Netherlandish and German paintings is representative of the work of these schools as a whole. The collection comprises a wide range of both religious and secular works, including panels from complex altarpieces, small altarpieces and devotional works and portraits. From this point of view, its content is entirely characteristic of the interests of those times and the products of the painters' workshops. The vast majority of the paintings are (or were originally) on panel. Paintings on canvas were produced in Northern Europe during the fifteenth century, the so-called *Tüchlein* (discussed below); very few have survived and the National Gallery is indeed fortunate to have two, both in reasonable condition considering their fragility: *The Entombment* (NG 664), painted by Dieric Bouts perhaps during the 1450s, and *The Virgin and Child with Saints Barbara and Catherine* (NG 3664), painted by Quinten Massys probably about 1515–25.

There are certain more or less significant omissions and imbalances in this sample of paintings, however. Partly because fifteenth- and sixteenth-century state frontiers were not as they are today, partly because of the nature of the National Gallery collection, there are a number of artists who are difficult or inconvenient to categorise. The collection contains very few pictures by Northern European painters of other schools, such as the French School, of this period. It so happens that the Master of Saint Giles, who worked in Paris around the turn of the sixteenth century, is classified with the Early Netherlandish painters; for the purposes of this discussion the other French School paintings of this period in the collection, such as *Charlemagne, and the Meeting of Saints Joachim and Anne at the Golden Gate* (NG 4092), a panel

from an altarpiece by the Master of Moulins (now identified as Jean Hey), will also be included and referred to as appropriate. There are no British School paintings of the period in the collection and only one or two by Continental artists painting in Britain: the outstanding example is Hans Holbein the Younger's *Jean de Dinteville and Georges de Selve ('The Ambassadors')* (NG 1314) painted in London in 1533. In the case of an artist like Holbein, who worked in more than one country, it is interesting and useful to compare the materials used by the painter in the different localities; differences in painting techniques used by the local artists and the foreign visitor may also become apparent.[3] From the point of view of the technical examination of paintings, much remains to be learned about painting methods and materials used in Britain during this period. Among the German School paintings a large number are of the Cologne School. There are no Early Netherlandish paintings dating from the first quarter of the fifteenth century and very few from the German School before about 1460; the Austrian School painting of *The Trinity with Christ Crucified* (NG 3662) dates from around 1410, the Master of Saint Veronica's *Saint Veronica with the Sudarium* (NG 687) from about 1420, and Stephan Lochner's *Saints Matthew, Catherine of Alexandra and John the Evangelist* (NG 705) from about 1445. Lastly, some major artists are poorly represented or unrepresented in the collection: for example Hugo van der Goes, Jan van Scorel and Mathis Grünewald (Neithardt-Gothardt).

Many Northern European altarpieces were in part sculpted, perhaps with a sculpted central scene and painted wings; the sculptures themselves were frequently painted.[4] While the collection contains none of the sculpted elements of such altarpieces, it is possible that some of the panels may derive from the wings of altarpieces whose central portions were of this type. A number of the German School paintings are panels from what would certainly have been quite substantial altarpieces, now dismembered, such as those from the high altarpiece of the Benedictine Abbey at Liesborn, in Westphalia, painted by the Master of Liesborn probably between 1470 and 1480 (NG 256–61). The Gallery is less fortunate as far as its Early Netherlandish paintings are concerned: very few are from large altarpieces or are themselves particularly large. One of the largest is Jan Gossaert's *Adoration of the Kings* (NG 2790, Plate 65), painted in about 1510–15. Jan van Eyck, Dieric Bouts and Hans Memling are represented by exquisite, but relatively small, paintings. Against these, the figures in Hans Memling's panels of *Christ as Source of Grace with Angel Musicians* of the late 1480s (Antwerp, Koninklijk Museum voor Schone Kunsten), painted for Santa María la Real, Nájera, Castile, are almost life-sized. However, Rogier van der Weyden's panel of *The Magdalen Reading* (NG 654, Plate 37) is a fragment of what would have been a large work and many extant Early Netherlandish panels are of a similar size and scale to Gossaert's *Adoration of the Kings*.

In most respects, the National Gallery collection of well over 200 Northern European paintings can thus be taken as a reasonably typical sample for the purposes of technical examination. It could be said that it is not entirely representative as far as quality is concerned; the law of averages suggests that a sizeable proportion of the painted works produced over the fifteenth and sixteenth centuries would have been rather mediocre, aesthetically speaking, while a great many of the Northern European paintings (particularly those of the fifteenth century) in the collection are very fine. It must be remembered that many paintings were entirely workshop pieces, often reproductions of an original painted by the master of the shop which was then reproduced as required, but upon which the master himself might not have laid a brush. If the piece had been commissioned there might be minor modifications of the original design, to accommodate the client's wishes, but works were also reproduced because the theme depicted was popular.[5] Undoubtedly a number of the pictures in the National Gallery collection are of this type.

Documentary sources for painting methods and materials

Information on the methods of production of paintings and polychromed sculptures may be gleaned from a surprisingly wide range of sources: those dealing with legal and administrative aspects of the painter's working life – guild regulations, contracts, accounts, inventories and

correspondence; those commenting on or describing the workshop in written or pictorial form; artists' accounts and correspondence; and technical treatises describing the preparation or use of materials. It should be pointed out that in guild statutes and contracts far more attention is devoted to polychromed sculpture than to easel painting. This is not surprising: such works were technically and structurally complex and there was plenty of scope for cutting corners in the workmanship or for falsification of materials. It was also desirable to specify very precisely what the final appearance of the gilding, for example, was to be in the particular site where the item was to be placed, allowing for conditions of lighting, the depth of the structure itself and so forth. The contracts for such works and the appropriate clauses in guild regulations are thus far more informative, but the information they contain may not always be applicable to easel painting as well. In order to become a master in the Tournai painters' guild, it was possible to submit a masterpiece either in the form of a conventional easel painting, '*pourtraiture*', or in gilding and polychromy.[6] Far more attention is devoted to details concerned with the gilding and polychromy category: the work was in itself more complex and needed stricter control. It can be seen that this could lead to a degree of division of labour between painting and gilding in an altarpiece, even where no polychromy was involved.

Guild regulations

The guild in which a painter was enrolled was not necessarily concerned with painters alone; at this time it was very common in both the Netherlands and Germany for painters to be enrolled in a guild with craftsmen working in other, more or less related, trades. Guild regulations effectively controlled most aspects of how painters practised their trade: the permitted number of apprentices and journeymen and the length of apprenticeship; the conditions to be fulfilled to become a master; the position of foreign workers; demarcation disputes with other members; obligations to be fulfilled on feast days; the care of a painter's dependants.[7] While these statutes varied in detail and in strictness from one town to another, most of the differences lie in the clauses relating to administrative matters; clauses relating to materials and to the production of the article varied remarkably little. The concern of the guilds rested principally with the quality of the finished product and thus in the supply and quality of the materials used, particularly with reference to expensive items like gold leaf and the wood used as a support. The 1371 statutes of the Cologne painters' guild, for example, proscribed the selling of pigments in secret and contained a clause forbidding the use of saffron or a similar alternative to colour a cheaper metal foil where the work was intended to be gilded, on pain of payment of a fine. Later statutes, drawn up in 1449, contained many more clauses concerned with the day-to-day business of the workshop: it is generally the case that guild regulations increased in number, detail and rigour with the passage of time, in part reflecting past disputes and circumventing moves by one group of workers or another to exploit loopholes. One statute defined the boundary between the work of painters and that of glass-workers. A regulation was included prohibiting the purchase of large quantities of pigments in advance of their being needed (secret trade in or stockpiling of materials was a constant and understandable preoccupation of the guilds: both could threaten the livelihood of guild members). Another stated that the work was to be carried out as stipulated: if the use of oil paint had been specified, then water-based paint was not to be used; if fine gold was demanded, *gedeilden gulde* (a cheaper leaf consisting of gold laminated with another metal, usually silver, but possibly tin) could not be substituted.[8]

Some of the guild ordinances concerned with materials are more informative. In the 1470 statutes of the Antwerp Guild of Saint Luke (in which were registered, not only the painters, but also sculptors, glassmakers, illuminators, printmakers and others), directions were given for the thickness of the wood to be used for the various parts of an altarpiece case of eight Antwerp feet (about 229 cm) or less, and also for elements (concerned with the support of the wings) of an altarpiece more than eight feet high. In both instances, the panels of the shutters (wings) were to be one-third of an inch (about 0.87 cm) thick. The wood itself was to be 'dry wood wainscot or oak'.[9] A further regulation incorporated in

1472 emphasised that the wood used for altarpieces, sculpture, tabernacles, panels and so forth should be dry and properly seasoned.[10] The equivalent, considerably more detailed, clauses in the 1493 statutes explained that the frame of an altarpiece case of up to seven feet (about 201 cm) high should be one and a half inches (about 3.9 cm) thick with side walls of the same thickness; the thickness of these elements increased to two inches (5.2 cm) if the altarpiece was higher than seven feet. The thickness of the wing panels varied according to whether the altarpiece had two or four wings, thus ensuring that the weight carried by the hinges was not too great.[11] The 1470 statutes also incorporated a regulation forbidding the painting of sculpture or panels in a frost or in freezing conditions, unless the workshop was frost-free or heated.[12]

As in the Cologne statutes, much attention was paid in the 1470 Antwerp statutes to the quality of the gilding, which was to be of fine gold and not replaced by a gold laminated leaf, silver glazed with a yellow glaze or something similar. If metal foil or *tentvelle* was to be used, it was to be impressed or stamped, filled behind with an appropriate filler – *semente* [literally, cement] – and affixed with gold-coloured paint or priming (*pourmuersel*); it was to be gilded with fine gold. This refers to a method of gilding widely used on polychromed sculpture which gives a pattern in relief for brocade or the borders of garments, for example, widely known as applied relief brocade (discussed below). Another clause stated that no matt gold could be laid without first preparing the ground; the gold was to be laid over gold-coloured pigment. This regulation refers to mordant gilding, which has a matt appearance as it cannot be burnished.[13]

The same methods of gilding are referred to in the statutes of the guild of the painters and glass-workers of Tournai of 1480, which, because of the meticulous detail in which individual clauses were drawn up, are particularly informative about painting materials available at the time. Burnished and matt gold leaf, *or parti* (the laminated leaf referred to above), silver leaf, leaf tinted with a glaze, *foelle molée* ('moulded leaf', described above) and, cheapest of all, *or clainquant* (probably a form of tinsel or pinchbeck, made from brass) are all referred to, for different purposes on every imaginable support, or every decorative purpose, employing any form of tempera or oil.[14] Individual clauses laid down the conditions under which individual branches of the painter's trade, such as the panel painters, glass-painters or manuscript illuminators, could work, or certain types of ephemeral work, such as the painting of playing cards, images on paper or in relief, wooden horses, carts and parrot perches, could be carried out.[15] The cheaper forms of gilding and particular ranges of pigments, including cheaper pigments derived from plant dyestuffs, were deemed suitable for tasks such as these; fine gold, the expensive blue pigments azurite and ultramarine and other dearer pigments not listed could not be used. The highly poisonous brilliant yellow pigment, orpiment (arsenic sulphide, As_2S_3), was permitted for playing cards, but apparently not for parrot perches (fortunately for the parrots). One clause enumerates brushes, other tools of the trade, the different forms of metal leaf and pigments, the use of which was sanctioned by the guild, to be used in oil, varnish, glue, gum or similar materials. Not all the pigments can be identified with certainty, but the list includes different varieties of lead white; other white and black pigments; vermilion, red lead and a number of red lake pigments; varieties of *azur* (high-quality blue pigment, probably including both azurite and ultramarine) and the blue pigment known as ashes (perhaps an artificially prepared copper-containing pigment; the precise nature of this pigment is difficult to identify at this date). Indigo and other fugitive blue pigments derived from plant dyestuffs were also included, together with verdigris, malachite, sap green, massicot (lead-tin yellow 'type I', Pb_2SnO_4), orpiment and yellow and red ochres. It is important to note that not all of these would be used in easel painting: pigments like *lecquemous* (litmus or something similar, derived from species of lichen) were far too fugitive for this purpose. The list is a good indication of the range available, however.[16]

Canvas is mentioned as a possible support for painting in the Tournai statutes, but rarely in the same breath as painting on panel; because of the different purposes for which painted canvas appears to have been used, canvas and those who were primarily employed as canvas painters seem to have had a different status.[17] This was certainly the position in Bruges, which appears to

have been a particularly important centre for canvas painting of all sorts, up to about 1530.[18] Here the painters' branch of the Guild of Saint Luke was subdivided into the panel painters, *schilders*, and the cloth painters, *cleederscrivers*; in spite of the fact that the painters on cloth were apparently almost as numerous as those who painted on panel (some 40% by the latter part of the fifteenth century), they appear not to have had the same rank. As a result, it is not surprising to find that one group sued the other on several occasions over distinctions between the two branches of the trade. From a law suit in 1458, where two cloth painters were sued for exhibiting paintings, something permitted only to panel painters, it appears that, in practice, both *schilders* and *cleederscrivers* were painting on cloth and on panel. The judgement also stated that a cloth painting of more than two ells (just over 140 cm) in length should be on new linen, worked wet, and no more should be primed with glue than could be completed at one time. Old linen could be used for smaller works, provided it had no holes or patches. As a result of the suit, the cloth painters were permitted to paint statues, cloths and panels, but could not exhibit for sale openly. That decision was reversed in another law suit of 1463; but the cloth painters were still forbidden to work in oil: this was the prerogative of the panel painters.[19] At this time, many of the purposes for which canvas was used – decorative projects and as inexpensive, light, easily transported substitutes for tapestries or paintings on panel – were ephemeral, thus cheaper pigments and rapidly drying aqueous media were appropriate. The guild statutes and judicial decisions underline the apparently less prestigious role canvas painters played. Paolo Pino, discussing the different modes of painting in his *Dialogo di pittura* (Venice 1548), was rather dismissive of those who painted in aqueous media, although for a different reason: 'The method of painting *à guazzo* is imperfect and more fragile, and it does not please me, wherefore leave it to the *oltramontani* [literally, 'those who live across the mountains'], who are lacking the true way.'[20] Plainly the technique was one which painters in Flanders practised to a far greater extent than those in Italy and it does seem that canvas appears not to have been much used as a support for oil painting (Pino's 'true way') in the Netherlands, up to the time when Pino was writing. Restrictive practices and controls imposed by the guilds may have played some part in this.

Contracts, accounts and inventories

The earliest extant Early Netherlandish painting for which the associated contract still survives is Dieric Bouts's *Altarpiece of the Blessed Sacrament* (1464–7), painted for the church of St Peter, Louvain.[21] Contracts for paintings, and indeed for sculpted works, vary in the amount of information they contain on the materials to be used; most attention was usually given to the subject matter, the cost and method of payment, and when the completed work was to be delivered. The contract for the *Blessed Sacrament* altarpiece enumerated the scenes to be painted (the painter being advised by two theologians on the details) and ordered that, while occupied with this work, the painter should not paint anything else. Terms of payment were also agreed. In many cases, however, the construction of the work and its frame was also discussed in some detail. In the case of German, and certainly some Early Netherlandish, altarpieces a detailed sketch of the whole complex was produced, which would serve to prevent future misunderstandings.[22] For a large project, the construction of the support might be commissioned separately by the patron: this was an expensive element of the work of art as a whole. The decorative work might also be contracted to more than one workshop, particularly in the case of a complex altarpiece that was part sculpted, part painted. Alternatively, the primary recipient of the contract might subcontract parts of the work, including the construction of the support and any other joinery necessary. It is convenient at this juncture to mention the value of accounts as a source of information, not only for the materials used and their cost, but also for the order in which the construction of the work took place and the type of craftsman involved at each stage. A well-known, but particularly clear illustration is provided by the surviving accounts for another work begun, but not completed, by Dieric Bouts: a *Last Judgement* (now lost) and several large panels on the theme of Justice, commissioned for the Louvain Town Hall in 1468. Two of the latter were painted between 1470 and 1475, one being completed after Bouts's death;

together these are known as the *Justice of Emperor Otto III* (Brussels, Musées Royaux de Beaux Arts). The subject and size of the proposed works are documented; the accounts show that a joiner, Reyner Cocx, was commissioned to go to Antwerp to purchase wood (forty-five planks, twelve feet long – about 344 cm) for the series of paintings and that he was one of several joiners constructing the panels for the Justice paintings during 1469. The panels were kept in a room in the Town Hall until Bouts was ready; payments were then made (November 1469 – January 1470 and again in June 1473) for the panels to be taken to his workshop. A payment made in October 1468 to a locksmith, Janne de Jongen, for fitting four hinges and a lock to the *Last Judgement* shows that the lost picture was a triptych.[23]

Other than the support itself, the painting materials of most interest to the client, and most likely to be specified in the contract (and, for that matter, accounts), were the most expensive: namely, gold and other metals, and the blue pigments ultramarine and azurite. The contract for painting and polychroming the shutters of an altarpiece commissioned by Willem de Busoen from the painter Saladijn de Stoevere for the Franciscan church in Ghent in 1434, for instance, specifies that fine gold, fine azure and 'good oil colours' should be used. It is interesting to note that the colours of the garments of the persons depicted are also specified: the garment of the Virgin was to be gold cloth (perhaps cloth of gold), lined with fine azure glazed with *sinopere*.[24] Great attention was often paid to the gilding; in the contract for an altarpiece for the monastery of 's Hertogendale, to be polychromed by the painter Jan van Molenbeke of Louvain, burnished and matt gold (that is, gold on an oil-based mordant) are specified for different areas of the work.[25] The use of both kinds of gold would have a pronounced visual effect, particularly in the case of polychromed sculpture; in a painting it enables distinction to be made between several areas of gold: liturgical vessels, cloth-of-gold fabrics and a gold background, for example (Plate 3). It is also true that on some occasions the use of burnished gold was specified for the more important areas of the work: this appears to be the case with van Molenbeke's work. The quality of the gold leaf itself might be specified: gold beaten from ducats

Plate 3 Workshop of the Master of the Life of the Virgin, *The Mass of Saint Hubert* (NG 253). Detail showing part of the altarpiece, for which mordant gilding was used, and water-gilded background.

and Rhenish gold (both notably pure) are often mentioned in Northern European contracts, such as one drawn up between the painter Michael Pfender and the parish of Lenzkirch for an altarpiece in 1478.[26] Later contracts, particularly those for polychromed sculpture, are often very detailed indeed; one of 1516 for an altarpiece for the Hôpital de Marvis in Tournai, commissioned from the painter Bonaventura de Thieffries, specified, among other requirements, that cloth-of-gold draperies were to be decorated with good blue and good *sinoppre de Coullongne*; different flesh tones were to be used for the various faces; areas of earth, like Calvary, for example, were to be green; loose stones where Christ was shown carrying the cross were to be gilded in burnished gold, while the higher parts of the terrain were to be fine matt gold and the rest glazed with green in oil.[27]

Far fewer 'unofficial' documentary sources, such as the account books, journals and correspondence of painters or private patrons, have survived, but they provide valuable first-hand written evidence of the practices and materials adopted by a particular painter. From one of Albrecht Dürer's letters to the merchant Jacob Heller, who had commissioned an altarpiece for the Dominican church in Frankfurt-am-Main, we learn that for the central panel of the Assumption and Coronation of the Virgin, which he was contracted to paint himself, Dürer had contracted out the construction of the panel and the frame. The whole structure had then been delivered to an assistant, who had applied the ground and some unspecified colour and would gild it the following week: '*geweist, geferbet und wirdt sie die ander wochen vergulten.*'[28] Presumably the reference to gilding applied to the frame; the reference to colouring is more obscure. Later, while in Antwerp in August 1520 during his trip to the Netherlands, he recorded in his journal a payment of fourteen *stuivers* (*Stübern*) for three small panels and four *stuivers* for applying and preparing the ground. While it is not clear from this if Dürer had the panels made up or bought them ready-made, the reference to the preparation of the ground implies that there were already divisions and specialisations in that part of the painter's trade.[29]

Fig. 1 Crushing and preliminary sieving of ore, from Georgius Agricola, *De re metallica*, Basel 1556. Letters A–F refer to the box-shaped sieve and its use.

As far as the availability of painting materials is concerned, one of the extant inventories of artists' estates is of particular interest: this is the inventory of the possessions of Mathis Neithardt-Gothardt, called Grünewald (*c.*1460–1528), compiled in October 1528, in Frankfurt-am-Main.[30] The list includes fifteen ells of Netherlandish canvas, several grinding stones, books of gold and silver leaf and a number of pigments, not all of which can be identified precisely. These include Armenian bole; ochre; lead white; '*blygel*' (probably lead-tin yellow); minium; two shades of orpiment; vermilion; '*berkgrin*' (malachite); '*shifer-grun*' or '*shefergrün*' (a mineral pigment of uncertain identity); verdigris and another artificial copper green, described in the inventory as '*alchemy grun*'. Three differently valued grades of Paris red, a red lake pigment, appear on the list.[31] Another unnamed red lake pigment is described as being in the form of cone-shaped drops, a very typical appearance for lakes as they would have been manufactured. It is noticeable that the painter possessed over sixteen pounds of one of the blue pigments, four pounds of verdigris and over seventeen pounds in total of lead-tin yellow. Grünewald had an interest in certain branches of hydraulic engineering (the making of fountains) and mining; several records of mining are listed in the inventory and a number of the pigments listed occur as minerals in various parts of Germany (Fig. 1). This and other evidence has led to the suggestion that Grünewald mined and manufactured pigments himself.[32]

Pictorial and literary descriptions of artists' workshops

A number of Northern European fifteenth- and sixteenth-century representations of the painter's workshop are known, both painted and in printed form. One of the most widely reproduced (although perhaps not the most informative) is that in the National Gallery collection, *Saint Luke painting the Virgin and Child* by a follower of Quinten Massys (Plate 1). The illustration shows that the picture on Saint Luke's easel, which is similar in appearance to a modern

three-legged easel, is being painted in its frame and some paintings in the Gallery collection show evidence of having been painted in their frames in this way (discussed below). The ledge upon which Saint Luke's picture rests is supported by movable pegs and is thus adjustable; other representations of easels indicate that this was usually the case. Saint Luke supports his hand on a mahlstick, the padded end of which appears to rest on the frame, rather than on the surface of the painting. His palette is small and roughly rectangular, with a hole for the thumb as in modern palettes; the pigments are arranged in an orderly manner, the reddish tones on one side and the lighter colours and blue on the other. The discrete dabs of paint, the fact that they retain their shape, the distinctive slight blending of the two reds, the presence of the mahlstick, the almost upright position of the panel are all indications that Saint Luke is using oil paint. The brushes (all of the pointed type described as *pinchiaux* in the Tournai statutes discussed above) would have hairs of ermine, or a similar soft hair that would take a point, tied and inserted into quills. Larger, stiffer hogs' hair brushes (*brousses*) appear in other pictures showing an artist at work; one is included in the range of brushes carefully balanced across a support on the chest at the artist's feet in Niklaus Manuel Deutsch's version of *Saint Luke painting the Virgin*, painted in 1515 (Fig. 2). A trough-like container for brushes, seemingly with a sloping bottom and apparently containing liquid, is shown in Colyn de Coter's representation of *Saint Luke painting the Virgin* in Vieure (parish church) of about 1500; the brushes lie with their heads in the liquid to prevent them drying out.[33] A spatula or palette knife and a container of oil or some other liquid, with something to stir or dispense the contents, are shown conveniently placed near the easel in both the versions of Saint Luke's workshop illustrated in Plate 1 and Fig. 2. In the National Gallery picture, the only container for pigment is the mussel shell on the three-legged table, often used to contain powdered gold; Deutsch's painting shows small pots for pigment.[34] It also shows an assistant or apprentice, who has been grinding pigment and medium together on a slab with a muller and now appears to be setting out the paint thus prepared on a palette.

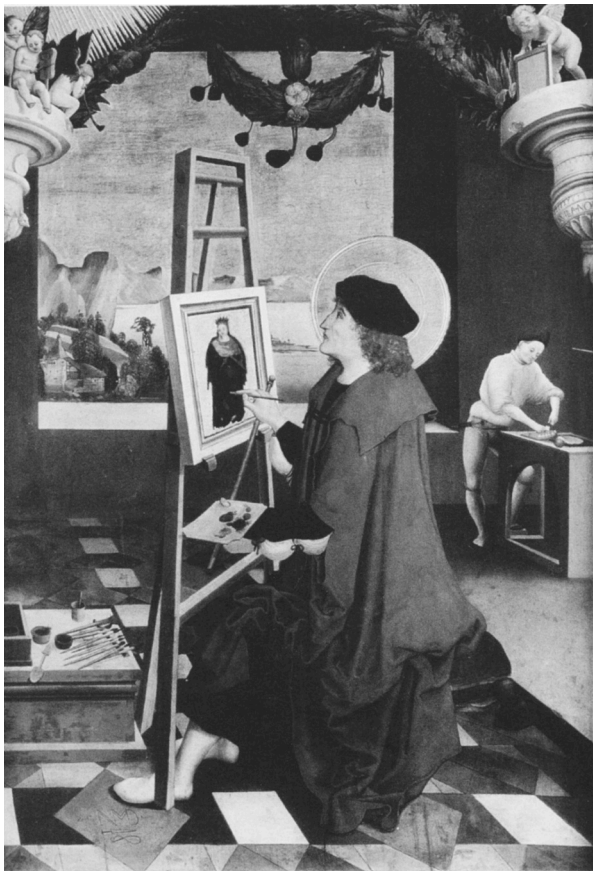

Fig.2 Niklaus Manuel Deutsch, *Saint Luke painting the Virgin*, 1515. Wood, 121.5 × 84.2 cm. Bern, Kunstmuseum.

Contemporary written descriptions of fifteenth- and sixteenth-century artists' studios and materials are very rare; a brief, but remarkably comprehensive, list occurs in *La Couronne Margaritique*, a long narrative poem written by Jean Lemaire de Belges in 1504–5 when he was in the service of Margaret of Austria.[35] There is some indication that Lemaire may have painted miniatures himself;[36] the summary descriptions of the training of an apprentice and the contents of the workshop in *La Couronne Margaritique*, and in *La Plainte du Désiré* of about 1503, show that he was familiar with workshop practice and also that there was a large quantity both of materials and of pictures (in all stages of completion) in the workshop.[37] The pigments listed, including ultramarine from lapis lazuli, powdered gold, mosaic gold (tin sulphide, SnS_2) and an unidentified expensive purple pigment (possibly a lake), would have been entirely suitable for miniature painting: most would also be appropriate for use in easel painting. Brushes and

drawing materials, such as charcoal, *crayons* (presumably black or red chalk), pens and silverpoint are also mentioned, as well as mussel shells, used here for blue and gold.[38] In both poems Lemaire de Belges refers to a *carnation* or flesh colour, which was mixed from other pigments ready for use; in *La Plainte du Désiré* he also states that ultramarine, sinoper, '*lacque*' and other expensive pigments should be kept apart from the rest.[39]

Technical documentary sources

There is a wealth of Northern European technical literature touching on various aspects of the painter's craft in this period, much of it in the form of compilations of 'secrets' in both manuscript and printed form. The sixteenth-century *Kunstbüchlein* are part of this tradition: small handbooks catering for the craftsman or for domestic use on subjects as diverse as assaying, removing stains from clothing, and the preparation of inks and the sort of pigments one might use on paper or for decorative purposes.[40] Precursors of the printed books of 'secrets' may be found in manuscript sources; much of the material they contain is part of a very long, pan-European tradition, going back to Arabic-Greek sources by way of compilations like the *Mappae clavicula*. Alchemical treatises, derived ultimately from Classical Greek, Middle Eastern and Indian sources, introduced methods of preparation and purification of materials which spread across Europe from the thirteenth century onwards. It is thus hardly surprising that the same recipes may be found in manuscript sources, copied from one another with a greater or lesser degree of accuracy, all over Europe.

Like their Italian counterparts, the Netherlandish and German recipes for pigments and inks are primarily intended for use in manuscripts; to some extent, however, they indicate what was available at the time and how the pigments were mixed and used. Some are concerned with manuscript illumination alone.[41] A very few also illustrate the instructions they contain; these were the model- or pattern-books which served the same purpose in the illuminator's workshop as the pattern-books of drawings and motifs in the painter's workshop. One of the best known is the so-called Göttingen model-book, a fifteenth-century manuscript in the Niedersächsische Staats- und Universitätsbibliothek, Göttingen (Cod. MS. 8° Uff. 51 Cim.), which not only includes coloured models for acanthus leaves, borders and other flourishes, but also gives the recipes to prepare the pigments used for painting them.[42] Printed sources include one on manuscript illumination which is of considerable interest for painting in general: Valentin Boltz's *Illuminierbuch*.[43] Of all the handbooks on painting of the period, this must have had the widest circulation: first published in Basel in 1549, the book was not only reprinted many times until the end of the following century, but it was also translated and extracts from it appeared (sometimes unattributed) in books of secrets and other works into the eighteenth century.

More frequently recipes are found in general collections, which also contain instructions for dyeing, preparing oil-based mordants for textile printing and other purposes, glass-making and other 'secrets'. These include the so-called Nuremberg *Kunstbuch*, dating from the second half of the fifteenth century, which was in the possession of the Dominican convent of Saint Katharine in Nuremberg, and a Netherlandish manuscript forming part of the late fifteenth- to early sixteenth-century collection MS Sloane 345, in the British Library, London.[44] One of the most interesting sources for pigment recipes is the sixteenth-century *Traktaat om kleuren te bereiden* in the Plantin-Moretus Museum, Antwerp (MS 253), which has the usual selection of recipes for artificial copper-containing blue pigments, blues from plant dyes, lake pigments, verdigris, lead white and ceruse, vermilion and minium, but also contains a recipe for the preparation of the form of lead-tin yellow known across Northern Europe as massicot, lead-tin oxide (Pb_2SnO_4) or lead-tin yellow 'type I'. In this case it was prepared by calcining three pounds of lead and two pounds of tin, followed by the addition of minium and further heating for twelve hours.[45] This pigment was extremely common; it has been identified in most of the Northern European paintings examined during the present survey, either alone or in mixtures with other pigments, particularly for greens. The inventory of Grünewald's estate (see page 12) lists it several different times, in large quantity, and it was exported to Italy and other parts of Europe.[46]

There appear to be few references to its preparation, but this may be partly because there was a strong relationship between this variety of lead-tin yellow and pottery glazes and recipes should perhaps be sought in the historical literature of that industry.[47]

It has been said that there is no extant treatise on fifteenth-century oil painting practice to complement that of Cennino Cennini on the technique of egg tempera: this is true, but it is not the case that there is no written information at all. The best-known book giving any indication of Netherlandish painting technique is Karel van Mander's *Schilder-Boeck*, first published in Haarlem in 1604.[48] The long poem forming the preface, *Den grondt der edel vry schilderconst*, which was intended to educate young painters on the theory and practice of painting, contains a little on painting practice; in the biographies that follow, the author occasionally gives some information on the practice of Northern European painters. There are also a number of technical treatises, mostly German, of the fifteenth and sixteenth centuries that give fragmentary information on different aspects of oil painting technique. It is important to remember that easel painting was a skilled trade, requiring a thorough training that would have been learned by practice in the workshop rather than from books and it is therefore no surprise to find scanty written information, little more than notes; it is rare to find 'amateurs' practising as easel painters, although this would be possible for the illumination of manuscripts.[49]

The compilation of texts made by Jehan le Begue in Paris in 1431 and the so-called Strasburg Manuscript are today perhaps the best-known fifteenth-century Northern European sources on painting technique. Le Begue's collection contains a range of Northern European sources, including Eraclius's *De coloribus et artibus romanorum* (elements of which derive from earlier writers such as Vitruvius), parts of the *De diversis artibus* of Theophilus and Pierre de Saint Omer's *De coloribus faciendis*, of the twelfth or thirteenth centuries. Le Begue also included recipes collected by Johannes Alcherius in the early years of the fifteenth century; much of this material is connected with manuscript illumination. At the end he inserted some French recipes, including a very typical, and by that time well-known, preparation of drying oil, which he could have derived from Eraclius's recipe.[50] The document as a whole is, perhaps, an unusually sophisticated example of this type of compilation – Le Begue's training appears to have been in the law, not painting; it serves to indicate what was widely known and had passed into the collective consciousness, rather than as a source directly descriptive of fifteenth-century painting technique.

The Strasburg Manuscript is of rather greater value. Written in German, it is much concerned with work in the aqueous media used for manuscript illumination, but it also devotes some attention to oil painting: how to prepare oil for colours, which pigments to use, and how to temper them.[51] It also gives a description of the pigment mixtures suitable for various flesh tones, hair colours and draperies, and describes the making of varnishes. It is now clear that the Strasburg Manuscript has connections with other manuscript collections and also with Boltz's *Illuminierbuch* of the following century: the mixtures for the flesh of young people, for example, are given in both. Two other manuscript sources in German share with the Strasburg Manuscript a proportion of the manuscript illumination recipes, but not those for oil; one of these, now in the Leiden University Library, is more logically ordered and may perhaps be slightly earlier in date.[52] The other, part of a compilation in the Staatliche Provinzialbibliothek Amberg (Cod. 77), may date from the late fifteenth century or later, but, as with the other sources in the group, this does not necessarily mean that the information contained is contemporary. From the names of the painters or illuminators mentioned it has been suggested that the recipes are rather earlier.[53]

In the same circle of sources, the so-called *Liber illuministarum* (Munich, Bayerische Staatsbibliothek, Cgm. 821), from the Monastery of Saint Quirin in Tegernsee, dates from the first few years of the sixteenth century.[54] Only extracts from this manuscript have been published, but from these it is clear that it contains many of the recipes found in the Strasburg Manuscript; those for oil painting are similar, but not identical. In addition it has some material on oil painting and gilding, including the preparation and application of the gilded foil used in relief gilding, not present in the Strasburg Manuscript. The grinding of colours in oil is

mentioned in both (and also, incidentally, in the Netherlandish manuscript in MS Sloane 345, mentioned above);[55] the preparation of the panel with two applications of glue, followed by four of white (chalk) is referred to in the following paragraph, on the preparation of *quadranten*; the treatment of canvas and a list of those pigments which may be ground in oil and stored under water occur in the *Liber illuministarum*, but not in the Strasburg Manuscript.[56] As this list is written in Latin, it is possible that, as is often the case with manuscript compilations, it derives from an earlier source. A slightly earlier manuscript in the Preussische Staatsbibliothek, Berlin, MS germ. fol.244, which was compiled before 1447 in the area of Mainz, has some of the same recipes, but is mostly concerned with the preparation of pigments and varnishes. However, in the single instruction it gives for grinding oil colours it differentiates between lead white and all other colours, in that linseed oil was recommended for lead white, whereas other pigments were to be ground with the darker-coloured heated drying oils.[57]

Of the tiny number of earlier sources that have come to light, undoubtedly the most important is *De diversis artibus* written by Theophilus (generally identified as a monk, Roger of Helmershausen) in the early part of the twelfth century. His description of the preparation of drying oil and of varnish are well known, although he has little to say about painting in oil colours as such.[58] The influence of his work is indicated by the number of 'Theophilus' manuscripts, in various degrees of completeness, that are known, including that copied by Le Begue; these were produced in centres all over Europe. The work was also drawn upon by later writers of manuscript compilations. One such collection, the *Liber diversarum arcium*, perhaps dating from the late fourteenth or fifteenth century, in the library of the Ecole de Médecine de Montpellier (MS 277), is ordered by subject; it covers glass-making and other topics as well as painting.[59] It derives much of its content from Theophilus and some from Eraclius, not always accurately transcribed: it includes Theophilus's varnish recipe, for example, and the list of pigments for use on wood. What is more interesting is that it also includes information (whether original or from some other source is not known) on the behaviour of certain pigments with oil: 'azure' darkens; indigo does not dry; vermilion should be used with red lead. It also describes the layering of paint: red lake over 'azure' to produce a purple, or over vermilion to intensify the colour. The use of two or three layers of paint for images or areas, of which the lower one or two can be in egg white if desired, is described.[60] Although one may suspect that the copyist sometimes misunderstood or mistranscribed the text, and the procedures described may refer to polychroming sculpture rather than to easel painting, it is clear that the behaviour of oil paint and its principal components was perfectly well understood. It could be said that the information contained in the Montpellier manuscript, limited though it is, summarises the 'received wisdom' circulating in the workshops in the fourteenth century, upon which the forefathers of the earlier painters represented in the National Gallery collection, such as Robert Campin or the anonymous Cologne painter, the Master of Saint Veronica, might have drawn.

Supports and preparation for painting

Panel

The vast majority of the Gallery's Early Netherlandish and German School paintings were painted on wood panels. Some have subsequently been transferred to other supports, including several panels from the Liesborn altarpiece (NG 256–61), by the Westphalian painter known as the Master of Liesborn, and two of the four panels ascribed to the workshop of the Master of the Life of the Virgin which originally formed the wings of the Werden altarpiece (NG 250–3). Many have been planed down from their original thickness, cradled, or have received other forms of treatment at some point in their history; these procedures have inevitably obscured much information on the construction of the panels. Of over two hundred paintings, only seven or so (including the two *Tüchlein*) have canvas as their original support.

The German School pictures show a greater variation in the woods used. Rather more than half are on oak supports; the remainder are on beech, lime, spruce and various other softwoods. The division is broadly geographical: paintings

on panels constructed from woods other than oak were produced in Southern Germany or Austria. Interestingly, a parallel may be drawn with the woods used for sculpture during this period, where a broadly similar pattern is seen. This reflects the range of suitable woods produced locally in the extensively forested areas of this region, but also the fact that, in the north, high-quality oak imported from eastern Baltic regions by the northern cities of the Hansa league was readily available. Oak was certainly available in the south, but it is structurally the most robust of the available woods; much would have been used by the building trade.[61] This does not mean to say that painters generally associated with Southern Germany did not use oak – Jakob Seisenegger's *Portrait of a Girl* (NG 4206) of about 1545–50 is on an oak panel. Painters like Seisenegger or Dürer who travelled a great deal and produced paintings in the places they visited are likely to have used the panels locally available: Dürer's purchase of three panels while in Antwerp, mentioned above, is only one example of this.

Of the Southern German paintings in the National Gallery collection, paintings on limewood (*Tilia* sp.) include Albrecht Altdorfer's *Christ taking Leave of his Mother* (NG 6463).[62] Beech (*Fagus* sp.) was used for Lucas Cranach the Elder's *Charity* (NG 2925). *The Trinity and Mystic Pietà* (NG 1427), painted by the Swabian painter Hans Baldung Grien, is on silver fir (*Abies alba*), while spruce (*Picea* sp.) has been identified as the wood used for the support of the *Portrait of Alexander Mornauer*, painted by the Master of the Mornauer Portrait.[63] The Tyrolean School painting of *The Death of the Virgin* (NG 4190) is on a stone-pine (*Pinus cembra*) support.[64] The range of woods used in Central Germany can in fact be demonstrated through an examination of the supports for Cranach's paintings alone. Although the majority are on beech or lime supports, a substantial minority are on oak and a very few examples of supports constructed from spruce, silver fir, pine, elm and maple have also been identified.[65] Of Cranach's paintings in the National Gallery, several are on lime: the *Portrait of a Man* (NG 1925), *Saints Genevieve and Apollonia* (NG 6511.1) and *Saints Christina and Ottilia* (NG 6511.2); the latter two panels formed the outside shutters for the *Saint Catherine* altarpiece (Dresden, Gemäldegalerie). Like the *Charity*, the *Portrait of a Woman* (NG 291) is on a beech support; *The Close of the Silver Age* (NG 3922) is on oak. The wood used for the paired portraits of Johann the Steadfast (NG 6538) and Johann Friedrich the Magnanimous (NG 6539) cannot be examined as the paintings have retained their original frames.

The pictures from the Northern parts of Germany are, with one exception, on oak. These include paintings by Cologne School painters such as Stephan Lochner, the Master of the Saint Bartholomew Altarpiece, the Master of the Life of the Virgin and Bartholomeus Bruyn the Elder. The Liesborn altarpiece also has (or had, in the case of the transferred panels) an oak support. The exception is *Saint Veronica with the Sudarium* (NG 687), painted by the Cologne painter known as the Master of Saint Veronica, which is on a walnut panel. Oak was also used for the paintings Holbein produced in London: *A Lady with a Squirrel and a Starling* (NG 5640), of about 1526–8,[66] *Jean de Dinteville and Georges de Selve ('The Ambassadors')* (NG 1314), of 1533, and *Christina of Denmark, Duchess of Milan* (NG 2475), documented as 1538. In every case where an oak panel has been submitted to dendrochronological analysis (which gives a date for the felling of the tree and, from the pattern of growth rings, an indication of its source), it has been found that the wood came either from the Baltic regions or from a local west German or Netherlandish source.

Almost all the Netherlandish School paintings are on oak; in those cases where the origin of the wood has been ascertained, it appears to have been imported from the Baltic region.[67] The few that are on other woods were painted outside the Netherlands. Two panels ascribed to the workshop of Joos van Wassenhove, *Music* (NG 756) and *Rhetoric* (NG 755), are thought to have formed part of what may have been a series of paintings representing the Liberal Arts painted for Federigo da Montefeltro around 1480. Not surprisingly, they are on the usual support for Italian panel paintings: poplar.

In general, the oak used for the Netherlandish School panels is of high quality, without irregularities, and usually radially, or near-radially, cut; this type of plank has been widely observed

in Netherlandish panels. During construction of the panels, care was taken to match the grain of the wood on either side of the join. The panels have been assembled with the grain of the wood running in the direction of the longest side; that is, vertically for portraits and other pictures in this format, horizontally for those with a 'landscape' format. It has already been pointed out that most of the paintings under discussion are relatively small: for very large panels, the planks would usually be arranged vertically whether the longest side was that running vertically or not. While a number of different methods of reinforcing the joins between planks have been reported, for Netherlandish panels at least, those in the National Gallery collection appear to have simple butt joints, sometimes reinforced with dowels set into the thickness of the panel. The German oak panels generally follow the same method of construction; dowels appear not to have been used in panels made from woods other than oak, however. While it is generally the case that panels tended to be constructed of thinner planks as time progressed, it is difficult to demonstrate this as far as the National Gallery collection is concerned as the sample of unthinned panels is small.[68] The average thickness of those German School pictures that are thought to have retained their original reverse surfaces is about 0.5–1.5 cm, but it must be remembered that the paintings in the collection are relatively small. The Liesborn altarpiece would have been far more substantial and two of its fragments, *The Annunciation* (NG 256) and *The Adoration of the Kings* (NG 258), are about 2.2 cm thick.

From those Early Netherlandish panels that have retained their original thickness, it is noticeable that the reverse surfaces are relatively carefully finished; sixteenth-century panels often have bevelled edges for later insertion into frames.

Frames and decoration of panels

The presence of a barbe at the edge of the painted surface can be an indication that a panel was painted in its frame, as illustrated in the versions of *Saint Luke painting the Virgin* discussed above (Plate 1 and Fig. 2). However, temporary mouldings seem also to have been employed and proof that the frame was present when the picture was painted is only provided when traces of gilding or paint from the frame are present on the picture surface or barbe. Where the ground and paint extend to the edge of the panel, it is likely that the panel was inserted into its frame after painting;[69] an example is Jan Gossaert's *Virgin and Child* (NG 1888).[70]

As the frame would have been an integral part of the structure from the earliest stage of painting for many of the panels in the National Gallery collection, it is logical to discuss it as part of the support. A number of the smaller panels, both Early Netherlandish and German, retain their original frames; in general, these fall into three categories.[71] In the first, frame and painting surface are carved in one piece from the plank of wood: the painting surface is carved into the plane of the plank, like a tray or dish, leaving a plain flat frame around the four sides into which further mouldings can be gouged and the inner edge bevelled. Because oak is hard and manipulating a plane and other tools within a confined space is not easy, frame mouldings tend to be very simple; also the paintings are usually fairly small. Of the Netherlandish School paintings with frames of this type, one, *The Virgin and Child in an Interior* (NG 6514) from the workshop of Robert Campin, measures 22.5 x 15.4 cm including its frame; another, the *Portrait of a Man* (NG 6377) by a follower of Robert Campin, measures 22.7 x 15.2 cm, also including the frame. The frames have identical mouldings, but there is no indication (in the form of hinge marks) that they were united as a diptych. Dendrochronological analysis has shown that the wood for the two panels came from the same tree, however; it is probable that they were made by the same carpenter.

The wings of a small triptych of the Cologne School, *The Virgin and Child in Glory with Saint James the Great and Saint Cecilia* (NG 6497), from the workshop of the Master of the Saint Bartholomew Altarpiece, have integral frames as described above; the central panel of this triptych has a different type of frame, where the moulding is attached to the front surface of the panel by dowels and the back surface remains plain and flat (Plate 4). In the fifteenth-century Tyrolean School *Death of the Virgin* (NG 4190), which has a frame of this type, the dowels are

Plate 4 Workshop of the Master of the Saint Bartholomew Altarpiece, *The Virgin and Child in Glory with Saint James the Great and Saint Cecilia* (NG 6497), *c.*1510–15. Oak, 36 × 59.2 cm (including frame).

exposed as the edges of the picture have been trimmed. It is interesting to note also that there are dowel holes in the unpainted edges of Martin van Heemskerck's *The Virgin and Saint John the Evangelist* (NG 6508.1) and *The Donor and Saint Mary Magdalene* (NG 6508.2),[72] and several other German School paintings: presumably they too had applied frames of this type. Van Eyck's *Man in a Turban* (NG 222) has a frame where the side mouldings are carved in one with the panel, that is, with the grain; the mouldings at the top and bottom of the panel have been carved separately (also with the grain) and attached to the front of the panel, mitring the corners. This permitted sharper mouldings to be carved in the top and bottom mouldings than was possible when they were carved across the grain of the plank.

The third type found on the Northern European pictures in the collection, the 'engaged' frame, consists essentially of four pieces of grooved moulding, which can be fitted round the panel and pegged and/or glued together at the corners at any stage during the painting process. The design of joint and carpentry of the corners may vary according to where the frame was made. With the 'engaged' frame, the back of the panel is framed as well as the front. The edges of the panel are usually thinned so that the groove does not need to be too wide; the strength of both frame and panel is thereby maintained. The frames of *The Virgin and Child with Two Angels* (NG 2608) and *Saint Clement and a Donor* (NG 2669), both of the Netherlandish School, are of this type. The triptych of *The Virgin and Child* (NG 3066), by a follower of Hugo van der Goes, is a particularly interesting example. The engaged frame of the central panel is constructed in a manner generally associated with Brussels.[73] It was made into a triptych by a nineteenth-century dealer, who, having planed down the edges a little, set the whole panel into another frame, also old, into which the wing panels, in their original frames, were also set. There is no indication, though, that the central panel was part of a triptych originally.

Many of the frames have retained something of their original decoration. The frames of Cranach's portraits of Johann the Steadfast (NG 6538) and Johann Friedrich the Magnanimous (NG 6539) were mordant-gilded (this method of gilding is discussed below). The *Man in a Turban* and the *Virgin and Child* (NG 3066), discussed above, also have gilded frames; in addition, the *Virgin and Child* has traces of red decoration over the gold. The small triptych from the workshop of the Master of Saint Bartholomew still retains traces of its original red paint (see Plate 4). In some cases, remnants of frame paint around the edge of the painted surface or barbe give some indication of the colour of a frame now missing. The South German School painting of *Saint John on Patmos* (NG 4901) had red paint on its frame; the Cologne School *Portrait of a Woman* (NG 2670) had blue. Robert Campin's portraits of *A Man* and *A Woman* (NG 653.1 and NG 653.2) show traces of red and green paint; possibly the original frames were marbled.

The backs of panels were often painted, either in a decorative manner or in a uniform dark colour, but where this paint has survived to the present day it is often in poor condition; in a

Plate 5 *(above left)* Attributed to the Workshop of Pieter Coecke van Aalst, *The Virgin and Child Enthroned* (NG 2606), 1527–50. Oak, 32 × 48.5 cm (including frame), and **Plate 6** *(above)* with wings closed, showing grisailles on the reverse.

number of cases it has been found to have been overpainted. Painting the reverse surface of the panel increased its stability, reducing any tendency of the wood to absorb or lose moisture and thus to warp or crack. A preparatory layer or ground was usually applied, exactly as on the front of the panel, before painting was carried out. If the back of the panel was not intended to be seen (as would be the case for many triptychs, for example) it might be left unpainted. The wings of altarpieces would necessarily have some painting on the outside of the wing, to be seen when the structure was closed; quite frequently (and traditionally) they were painted entirely or partly in grisaille, alluding to their relationship with sculpted altarpieces.[74] Figures were depicted in niches, imitating the appearance of statues in an architectural setting. The principle is illustrated by a small triptych, still in its original frame, of *The Virgin and Child Enthroned* (NG 2606) attributed to the workshop of Pieter Coecke van Aalst and painted during the second quarter of the sixteenth century (Plates 5 and 6); here the flesh tones of the figures are painted naturalistically. In other cases, the figures are depicted entirely in monochrome, as seen in the grisailles on the reverse of the wings of Hans Memling's *The Virgin and Child with Saints and Donors (The Donne Triptych)* (NG 6275.2 and NG 6275.3).

In other cases, including portraits, the reverse surface might be painted with the device of the owner or some other form of decoration: the back of the Austrian School *Trinity with Christ Crucified* (NG 3662), for example, has a decorative pattern of green foliage on a white background, a form of decoration that was not uncommon.[75] Marbling was a particularly popular form of decoration in both the fifteenth and the earlier part of the sixteenth centuries, not only for frames, but also on the back of the panel. A number of paintings, both Early Netherlandish and German, retain traces of marbling on their reverse surfaces, sometimes in poor condition; as a result it has often been covered with another layer of paint. The Robert Campin portraits are typical examples, showing the remains of reddish marbling on their reverse surfaces. The marbling present on the back of the South German School *Portrait of a Man* (NG 1232), of about 1530–40, was probably dark green with a very pale greenish-white pattern, but the copper-containing green glaze over the lowest layer of black paint, forming the background colour, has deteriorated to brown in the manner typical for so-called 'copper resinate' glazes.[76] The red marbled pattern (consisting of black and vermilion, red mercuric sulphide, HgS) on the reverses of the wings of the Netherlandish School triptych, *The Virgin and Child with Saints and Angels in a Garden* (NG 1085), is in relatively good condition (Plates 7 and 8).

Preparation of panels for painting

Several of the fifteenth-century German School paintings have canvas applied to the surface of the panel below the ground. These include the two fragments from the Liesborn altarpiece that retain their original support, *The Annunciation* (NG 256) and *The Adoration of the Kings* (NG 258); the Austrian School *Trinity with Christ*

Crucified; the Tyrolean School *Death of the Virgin* (NG 4190); Lochner's *Saints Matthew, Catherine of Alexandria and John the Evangelist* (NG 705); *The Presentation in the Temple* (NG 706), by the Cologne painter, the Master of the Life of the Virgin; and the small panel attributed to Michael Pacher, *The Virgin and Child Enthroned with Angels and Saints* (NG 5786). In those paintings that have retained their original frames, such as the Austrian School and Tyrolean School paintings, the canvas is continuous over panel and frame moulding. Apart from the Pacher, all these panels come from large altarpieces with large areas of water gilding (that is, gilding applied to a bole, discussed below); possibly canvas was applied to ensure a smooth surface for gilding, as was frequently done with the, admittedly very much rougher, Italian poplar panels. In the case of the double-sided Austrian School picture and the Lochner, canvas is present only on the side where most water gilding has been carried out, which may be significant. That not all extensively water-gilded panels were prepared in this way is clear from the two wing panels from the Werden altarpiece, from the workshop of the Master of the Life of the Virgin, that have not been transferred: *Saints Augustine, Ludger(?), Hubert and Gereon(?)* (NG 251, the outside left-hand wing), and *The Conversion of Saint Hubert* (NG 252, the inside left-hand wing). No canvas is present on these.

An interesting feature observed in the X-radiograph of *Charity* (NG 2925), by Lucas Cranach, is the mat of unidentified fibrous material between the panel and the ground, on the right-hand side, under Charity's left side. While this has rarely been observed on panels in the National Gallery collection (the Wilton Diptych, NG 4451, of *c.*1395–9, is another example),[77] it is not that uncommon. Fibrous material has occasionally been found reinforcing the joints in Netherlandish School panels or frames.[78] Possibly it is fulfilling this function here, or perhaps it was intended to correct some imperfection in the panel before the ground was applied.

None of the Early Netherlandish School paintings in the collection has canvas applied to the panel in this way. It is worth noting, however, that very few of the Early Netherlandish panels are from large altarpieces and none has large areas of water gilding.

Plate 7 *(left)* Netherlandish School, Left wing of *The Virgin and Child with Saints and Angels in a Garden* (NG 1085), *c.*1500, showing Saint John the Baptist. Oak, 67.8 × 18.8 cm.
Plate 8 *(right)* Marbling on reverse of the left wing.

Nearly all the Early Netherlandish School panels were prepared with a ground of calcium carbonate, almost certainly natural chalk, applied in several layers in a medium of animal skin glue and then scraped or rubbed down until it was level.[79] The principal exceptions are the few paintings produced in Italy, such as the panels of *Music* and *Rhetoric*, ascribed to the workshop of Joos van Wassenhove, which have gesso (calcium sulphate) grounds. The Netherlandish School triptych, *The Virgin and Child with Saints and Angels in a Garden* (NG 1085) is unusual in having a lead white ground.

Most of the German School panels have been prepared with natural chalk grounds; however there are exceptions among the Southern German pictures, perhaps reflecting the range of suitable white minerals available in particular localities. The grounds on the paintings by Lucas Cranach, for instance, contain calcium carbonate, chemically speaking, but there is no indication

that the source was natural chalk: no coccoliths (the remains of the tiny unicellular marine organisms, from which the chalk deposits were formed) are present, for example.[80] The source may thus have been a local limestone, ground for use. The white mineral used in the Swabian School *Portrait of a Woman of the Hofer Family* (NG 722) and the *Portrait of Alexander Mornauer* has been identified as dolomite, calcium magnesium carbonate ($CaCO_3.MgCO_3$), deposits of which occur in the area of the Dolomite mountains.[81] The small *Virgin and Child Enthroned with Angels and Saints* attributed to Michael Pacher has a gesso (calcium sulphate) ground.

Microscopical examination of paint cross-sections clearly shows that several layers of ground were applied, and sometimes some difference in texture between the upper and lower parts of a chalk ground can be observed: in those panels of the Liesborn altarpiece (*The Annunciation* and *The Adoration of the Kings*) that have not been transferred from their original support, for example. However, there is no indication of anything like the layers of coarse *gesso grosso* followed by fine *gesso sottile* (anhydrous calcium sulphate, $CaSO_4$, and calcium sulphate dihydrate, $CaSO_4.2H_2O$, respectively) seen in some fourteenth- and fifteenth-century Italian paintings. Unlike chalk, which has one crystalline form, these two forms of calcium sulphate differ in their crystal structure; thus the appearance and texture of the layers of gesso is markedly different when observed under the microscope.[82] The ground tends perhaps to be rather thinner than that found on some early Italian panels; however, it must be remembered that the panels themselves are a finer-grained, better quality wood. A thicker ground might be necessary if the panels had a great deal of gilding, particularly where a relief design was carved into the ground itself before gilding (discussed below), a practice seen in Stephan Lochner's *Saints Matthew, Catherine of Alexandria and John the Evangelist* (NG 705), discussed on page 60, and the Pacher *Virgin and Child Enthroned with Angels and Saints* mentioned above.

Fig. 3 Hans Memling, *The Donne Triptych*. Detail of infra-red reflectogram mosaic showing brushstrokes of the priming under the paint of Lady Donne's head.

In the majority of the Early Netherlandish panels and many of the German a thin layer of priming is present on top of the ground; sometimes it is so thin that it is difficult to distinguish from the ground itself or from the paint layer above. In some cases the discontinuities observed in very thin priming layers in cross-section suggest that the application may have been quite streaky, and sometimes the brushstrokes of the priming layer can be seen quite clearly in X-radiographs, infra-red reflectograms, or even in raking light, running across the picture, bearing no relationship to the forms depicted. They can be so observed in, for example, the infra-red reflectogram of Memling's *Donne Triptych* (Fig. 3), and in the X-radiograph of *The Virgin, Saint John, Mary Magdalene and a Holy Woman* (NG 3903), painted by Bartholomeus Bruyn the Elder around 1530–40. The use of a priming layer of this type was probably widespread; in the panel from an altarpiece by the French painter Jean Hey (the Master of Moulins), *Charlemagne, and the Meeting of Saints Joachim and Anne at the Golden Gate* (NG 4092), a thin white priming layer containing lead white is present over the ground.

The principal function of the priming was probably to isolate the ground, preventing it from absorbing medium from the layers of oil paint above and thus causing them to become lean and matt (perhaps unevenly so) in appearance. Where the paint above contains oil, the use of a priming layer is more effective than simply sealing the ground with a layer of size, although this, too, was frequently (perhaps generally) done and has been observed in a number of paintings. In, for example, Bouts's *Portrait of a Man* (NG 943) and the *Virgin and Child* (NG 709) from the workshop of Hans Memling, the size layer could clearly be seen in paint cross-sections stained with a suitable protein stain.[83] In the *Virgin and Child*, where only drying oil could be detected in the paint, the priming was also found to contain a drying oil; this may be the case generally in such circumstances. The presence of linseed oil was in fact confirmed in the pale pink priming of Jan Gossaert's *Man with a Rosary* (NG 656). There is some evidence that some earlier fifteenth-century Netherlandish School painters, such as Robert Campin, Rogier van der Weyden and Dieric Bouts, used protein-containing underpaint, in some of their works at least.[84] In these circumstances, a proteinaceous medium in the priming might be expected. It is difficult to analyse the medium content of what is often a very thin layer, however: the brown isolation layer present in *The Virgin and Child before a Firescreen* (NG 2609), from the workshop of Robert Campin, is only about 2µm thick.[85] Here, staining tests suggested that the medium was proteinaceous. In the Bouts *Portrait of a Man* it is possible that the lead white-containing priming layer is in a medium of egg tempera, but other paintings from the Bouts workshop (which in other respects are reasonably consistent) gave more ambiguous results. The paintings from the workshop of Rogier van der Weyden are discussed on pages 71–2 of this *Bulletin*.

The priming layer is frequently very rich in medium and may have a low pigment content: that in Hans Holbein's *Lady with a Squirrel and a Starling* (NG 6540) appears to consist of unpigmented oil alone.[86] In other cases there is little more than a scattering of pigment particles in the medium spread across the ground: for example, in the *Portrait of a Man* (NG 245), painted in 1514 by Hans Baldung Grien, and in a South German School *Portrait of a Man* (NG 1232) of about 1530 to 1540. It is therefore not surprising to find that, in paint cross-sections, the upper part of the ground often appears translucent where it has absorbed medium from the priming layer.

The evidence of those German School paintings with much gilding suggests that no priming or isolation layer is present in areas where water gilding has been carried out; painted or mordant-gilded areas may have an isolation layer. In the Tyrolean School *Death of the Virgin* (NG 4190) and also in *Saints Ambrose, Exuperius and Jerome* (NG 254) painted by an artist in the circle of the Master of Liesborn, gold leaf has been applied over the ground on top of a thin orange layer of bole (or something similar) mixed with animal-skin glue; in the painted areas an extremely thin whitish priming is present.[87] However, the Werden altarpiece panels produced by the workshop of the Master of the Life of the Virgin, which also have areas of water gilding, appear to have no overall priming of this sort in the painted areas.

In some cases, such as the Bouts *Portrait of a Man* (NG 943), the priming layer contains lead white alone, but often it has been tinted with tiny quantities of other pigment, usually red and black. The actual colour of this layer was often very pale: 'whitish' in many cases, for example in the work of painters like Bouts, Memling and Rogier van der Weyden.[88] Painting on a light surface is regarded as a fundamental characteristic of Early Netherlandish painting technique. In some of the sixteenth-century paintings examined, such as Gossaert's *Virgin and Child* (NG 1888) and Wolf Huber's *Christ taking Leave of his Mother* (NG 6550, discussed on page 101), the colour of the priming is rather more pronounced. The brown isolation layer present in the *Virgin and Child before a Firescreen* (NG 2609) might be expected to have some effect on the colour, but the works associated with the Campin workshop have a markedly complex layer structure, incorporating layers of greyish underpaint; the toning effect of the priming appears to be deliberate.[89] Pale grey primings (lead white mixed with a very little black) are found in another painting by Bouts, *The Virgin and Child with Saints Peter and Paul* (NG 774); in *Saint Jerome in a Landscape* (NG 4826), ascribed to Joachim Patinir; and in

the *Portrait of a Man* (NG 245), by Hans Baldung Grien. Pale pink primings (lead white mixed with a very little red pigment) occur in, for example, *The Virgin, Saint John, Mary Magdalene and a Holy Woman* (NG 3903), painted by Bartholomeus Bruyn the Elder, the portraits of *A Man* (NG 1042) and *A Lady* (NG 4732) by Katharina de Hemessen, and Gossaert's *Man with a Rosary*, mentioned above; in the three latter examples the pigment was identified as red lead (minium, Pb_3O_4), which is, incidentally, a strong drier. Primings of lead white tinted with both red and black to give a pinkish-beige to warm grey tint are commonly found: Gerard David's *Deposition* (NG 1078) and *Adoration of the Kings* (NG 1079), two panels probably from the same altarpiece, the Master of the Saint Bartholomew Altarpiece's *Saints Peter and Dorothy* (NG 707) and the *Portrait of a Girl* (NG 4206) by Jakob Seisenegger are only a few examples.

It is tempting to identify the priming layer with the *primuersel* Karel van Mander describes the painters of an earlier generation as applying over the underdrawing. It is described as thin, translucent (the underdrawing was visible through it), oil-based and flesh-coloured.[90] The priming layer observed in so many of the Gallery's Early Netherlandish School paintings fulfils these conditions on the whole, more closely in the work of painters working from about 1500 onwards. Some of the very pale pinkish or beige priming layers could even be described as flesh-coloured, but this is a less important characteristic: van Mander could draw his general conclusions on earlier practice only on the basis of what he himself had observed, learned or been told, which may not have included descriptions of very pale grey or white primings.

Canvas and other supports

Very few of the Gallery's Early Netherlandish and German School paintings dating from before 1550 are on canvas. The five Netherlandish School paintings concerned include the *Tüchlein* mentioned above, which in their technique are typical of what would have been a very large number of paintings.[91] *The Entombment* (NG 664), painted by Dieric Bouts, and *The Virgin and Child with Saints Barbara and Catherine* (NG 3664), painted by Quinten Massys, are on plain-weave linen canvases, sized with animal-skin glue, but with no further ground or priming layer; both have been lined. Both have been painted using an aqueous, animal-skin glue medium, but the Massys painting differs from that by Bouts in that a definite layer structure is present in several of the areas examined, indicating that one layer had been allowed to dry before the next was applied.[92]

These can be contrasted with *Saint Lawrence showing the Prefect the Treasures of the Church* (NG 3665), which was painted in Cologne in about 1510 by an artist in the circle of the Master of the Legend of Saint Ursula. This painter is named from a series of canvases showing the life of Saint Ursula; NG 3665 is from a similar cycle devoted to the life of Saint Lawrence.[93] It is thought that cycles of painted canvases of this type had a decorative function; they were cheap substitutes for tapestries.[94] This painting is on a plain-weave canvas, constructed from two pieces joined by a horizontal seam. Unlike the two *Tüchlein* paintings, but like other canvases from the cycles, the painting has a chalk ground in an animal-skin glue medium and is a conventional oil painting: the medium of the paint is linseed oil (see Table 1 on pages 53–5). A white chalk ground is present even in the latest Early Netherlandish School painting on canvas examined, *A Little Girl with a Basket of Cherries* (NG 6161) dating perhaps from the 1570s, by an unknown artist. Darker grounds were in general a later phenomenon.[95]

For painting, the canvas appears to have been stretched on a stretcher of some description (or conceivably on a board). Contemporary illustrations, such as the woodcut by Hans Burgkmair of *The Emperor Maximilian in a Painter's Studio* of about 1518 or Jost Amman's rather later depiction of an artist at work in Hans Sachs's *Eygentliche Beschreibung aller Stände auff Erden* (Frankfurt am Main, 1568) show the canvas nailed to a stretcher or board (Fig. 4).[96] Occasionally it may have been glued to the board, but this appears to have been less successful.[97] Some seventeenth-century representations of artists' studios show the canvas laced to a framework and this method may have been favoured for larger canvases. A description of canvases being spread out on the floor is included by Jehan le Begue in his compilation, but this

method was probably intended for decorative painted cloths.[98] Research on Early Netherlandish *Tüchlein* and other canvases has indicated that the painted canvas was detached from this stretcher and laid on a board; when the elements of the frame were nailed to the board, the canvas was attached permanently to this auxiliary support at the same time; it was rarely glued. The painted border present in the Bouts *Entombment* and in many other *Tüchlein* would serve to indicate the dimensions of the picture to the person attaching it to its final support and framing it; this border would usually have been covered by the frame.[99] The traces left by nails in the lower border of *The Entombment* could relate to this stage, rather than to the initial stretching of the canvas.[100]

There are one or two examples in the collection of pictures painted on parchment, including Altdorfer's *Landscape with a Footbridge* (NG 6320) and Gossaert's *Elderly Couple* (NG 1689); the latter painting has a lead white ground. Both are mounted on auxiliary supports, oak panel in the former case, canvas in the latter. Neither support is contemporary, but it may be assumed that the parchment would in any case have been mounted on an auxiliary support before painting. One or two are on paper attached to panel; infra-red reflectography has revealed that one, *The Entombment* (NG 1151), currently catalogued as 'in the style of Ysenbrandt', but copied from an engraving by Schongauer, is actually painted over a damaged copy of the engraving.[101]

Underdrawing and transfer of the design

Before painting, it was customary to draw some indication of the overall design and the placing of individual elements of the composition on the panel. Where it has been possible to examine the layer structure of a painting in the precise area where underdrawing is known to be present, it has been found that the drawing was usually carried out on the ground, before the application of any layer of priming that might be present. In *Canon Bernardinus de Salviatis and Three Saints* (NG 1045), by Gerard David, for example, the cross-section prepared from the lining of Saint Donatian's cloak shows a thin layer of black pigment particles on top of the ground (Plate 9).

Fig. 4 Hans Burgkmair, *The Emperor Maximilian in a Painter's Studio*. Woodcut, from *Der Weisskunig*, *c.*1518.

Occasionally the drawing was applied over the priming layer, an example being Jan Gossaert's *The Adoration of the Kings* (see page 89).

Our knowledge of the underdrawing stage of the construction of the painting is largely based on the evidence supplied by infra-red photography and infra-red reflectography. Drawing under the paint film was not intended to be seen, although sometimes it can be observed through the paint film where the paint is thin and has become more translucent with time: for example in Balthasar's red cloak in Gossaert's *Adoration of the Kings* and in the two altarpiece wings by Martin van Heemskerck, *The Virgin and Saint John the Evangelist* and *The Donor and Saint Mary Magdalene*.[102] The paint film is more or less transparent to infra-red radiation, however; thus if underdrawing has been carried out in an infra-red-absorbing material, such as something black (the most common), it can often be detected using infra-red imaging.[103] The image obtained is affected by factors such as the thickness of the paint or the materials present: if the paint itself contains much infra-red-absorbing pigment it may be impossible to reveal the underdrawing. The material used for the underdrawing is also of relevance; black pigment absorbs infra-red radiation across the wavelength range so is usually detected without difficulty, but iron gall ink becomes more transparent to infra-red radiation of longer wavelengths so can-

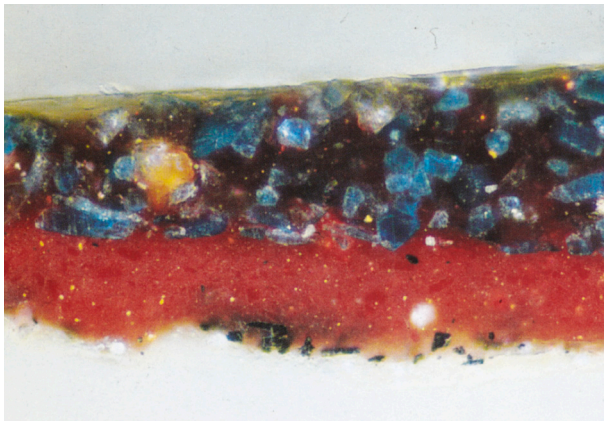

Plate 9 Gerard David, *Canon Bernardinus de Salviatis and Three Saints* (NG 1045). Cross-section through the purplish-red lining of Saint Donatian's cloak. Scattered splinter-like particles of charcoal black from an area of dry underdrawing are visible at the bottom of the sample. The reddish-purple paint of the cloak lining consists of a mixture of red lake and azurite. Photographed at a magnification of 500×; actual magnification 460×.

Fig. 5 Master of the Saint Bartholomew Altarpiece, *The Virgin and Child with Musical Angels* (NG 6499). Detail of infra-red photograph showing underdrawing of the Virgin's skirt.

not be observed by infra-red reflectography. Red chalk was used for drawing on paper, but how widely it was used for the underdrawing stage of a painting is impossible to assess as it cannot be rendered visible by infra-red recording methods.

The underdrawing revealed may indicate how the composition evolved, perhaps from differences between the underdrawing and the final painting, perhaps from changes in the actual underdrawing itself. Even the extent of the underdrawing and its style may contribute something in this respect. The composition was based on drawings and workshop patterns, both for the design as a whole and for figures and other details within it; for a commissioned piece (apart from a portrait) it would usually be necessary to produce a drawing (or to show the patron some other model) of the proposed composition. Depending on the complexity of the design, the drawing on the panel therefore need not necessarily be very detailed. The master of the workshop need not have carried out the transfer of the design to the panel himself; he may have left it to assistants. However, a part of the composition for which there was no pre-existing model might need to be worked out more thoroughly, and here the master might be expected to intervene. The re-use of figures, poses, textiles and other details provides evidence for the use of patterns in the workshop. A study of the paintings produced by Hans Memling and his workshop has shown that the same designs for figures, including those of the Virgin and Child and Saint John the Baptist, recur frequently. Measurements made on the designs used for the cloths of honour in a number of Memling paintings have shown that not only does the same pattern appear in *The Donne Triptych* and three other paintings, but also that the motifs are the same size, suggesting that some method of mechanical transfer (discussed below) was used to reproduce the design.[104] The brocade pattern decorating the gold background behind Lochner's *Saints Matthew, Catherine of Alexandria and John the Evangelist* is also found on other Cologne paintings in the Lochner circle.

Some underdrawings give the impression of having been carefully copied from the agreed design and pre-existing patterns, with few mistakes or alterations (all features which could suggest a routine transfer by an assistant, although

this is not necessarily the case). An example is the underdrawing for the Master of the Saint Bartholomew Altarpiece's *Virgin and Child with Musical Angels* (NG 6499, Fig. 5). Whether or not the underdrawing was a careful copy, the rendition of shadow and modelling may be sufficiently complex to indicate the curvature or volume of the forms, as well as the depth of shadow. The drawing style may be very much more summary, however; many of the underdrawings revealed are straightforward, with bold outlines and little or no indication of shadow; the features are often delineated in a 'shorthand' form. An example is the underdrawing for the Austrian School *Trinity with Christ Crucified* (NG 3662, Fig. 6). In some cases the style of the underdrawing is that of a master draughtsman – fluent, confident and free, as seen in the underdrawings for the two altarpiece wings by Martin van Heemskerck and in that of Altdorfer's *Christ taking Leave of his Mother* (NG 6463).[105] In these cases the artist himself was certainly at work.

The drawing revealed is not always freehand; in some cases, mechanical transfer of all or part of the composition was plainly carried out, by tracing from a drawing or perhaps by pouncing from pricked cartoons. In only one painting is there any evidence for squaring up: on the inner surfaces of the two altarpiece wings by Martin van Heemskerck traces of the grid drawn in charcoal, used to enlarge the preparatory drawing during the transfer of the image to the panel, are apparent.[106] Evidence for pouncing is present on the reverse (grisaille) surfaces of two fragments by Simon Marmion from the shutters of an altarpiece, *The Soul of Saint Bertin carried up to God* (NG 1302) and *A Choir of Angels* (NG 1303), finished by 1459.[107] It was also used to transfer the design on the gilded background of the Lochner *Saints Matthew, Catherine of Alexandria and John the Evangelist.*

Tracing from a drawing might be expected to be used for portraits, where at least one, and perhaps several, detailed preliminary drawings on paper was often produced. In the *Portrait of a Man* (NG 245), by Hans Baldung Grien, faint dry blurred lines of tracing are visible under the precise pen drawing of the face.[108] In the portraits of Hans Holbein the Younger there is some evidence from examples where a preliminary study the same size as the finished portrait also exists that tracing of some form was probably used to transfer the image. In *A Lady with a Squirrel and a Starling,* the brush underdrawing shows little more than the outline of the main form (looking very like the enhancement of a traced image).[109] It has been found, in fact, that the underdrawing for portraits is often extremely scanty: it was largely unnecessary because of the preliminary studies made of the subject. Sometimes these were extremely detailed: Holbein made detailed notes of the colours of the sitter and his clothes, and the metalpoint drawing (Dresden, Kupferstichkabinett) produced by Jan van Eyck for the *Portrait of Cardinal Niccolò Albergati* (Vienna, Kunsthistorisches Museum) in about 1438 has notes on the colours, with traces of colour present on the drawing.[110] Memling's *Young Man at Prayer* (NG 2594) has a fairly extensive, hastily scribbled underdrawing, revealing many changes in the positions of the features and the hands (Fig. 7). This appears to be an example of the painter reworking his ideas for the composition directly on the panel; a busy workshop would have been accustomed to producing portraits in a range of poses and types, but in this case it appears that something slightly more unusual (by comparison with other commissions) was required.[111]

The materials used for underdrawing can be

Fig. 6 Austrian School, *The Trinity with Christ Crucified* (NG 3662), *c.*1410. Silver fir, painted surface 118.1 × 114.9 cm. Infra-red photograph.

Fig. 7 Hans Memling, *A Young Man at Prayer* (NG 2594). Detail of infra-red reflectogram mosaic showing changes in the position of the sitter's hands.

divided into those, like black pigment suspended in some fluid medium or, indeed, iron gall ink, which are applied wet using a brush or pen, and those, like so-called black chalk or charcoal, which can be used dry. Metalpoint (a thin pointed stylus of silver or lead, usually, in a suitable holder) was used as a drawing material on paper to which a thin coating of suitable pigment was applied; it could be used for drawing on panel, but does not seem to have been employed in any of the Northern European paintings in the collection. The handling characteristics of the drawing revealed under infra-red radiation usually enable a distinction to be made between the even fluidity of a brush-drawn line and the more 'broken' quality of one drawn with dry charcoal or chalk. Even so it is hard to distinguish between drawing carried out in a soft chalk and one where a liquid was used, but with a dry brush. However, black pigment in a liquid, applied with a brush, seems to have been widely used in both Early Netherlandish and German School paintings (see Fig. 6). In some cases the brush was so loaded that, in the infra-red image, the liquid drawing material can be seen to have formed a small pool at the end of the brushstroke. This is a feature of the underdrawing of Gerard David's *The Adoration of the Kings* (Fig 8). The quality of line given by a dry drawing material such as black chalk (a soft, slightly greasy, form of naturally occurring graphite, found in Piedmont in northern Italy, Cumbria in northern England and other regions) may be seen particularly clearly in the underdrawing for Pieter Bruegel the Elder's *Adoration of the Kings* (Fig. 9).

Occasionally liquid and dry drawing materials are found together. In these cases usually the image or a sketch of the design as a whole was first drawn in the dry material and then clarified or strengthened where necessary using a liquid drawing material and a brush. This can clearly be seen in the extremely free and graphic underdrawing for Altdorfer's *Christ taking Leave of his Mother*. An earlier stage in the composition of the design, sketched in a dry material which could be brushed away if the artist so desired, is still visible in certain areas, such as the distant mountains and the legs of the figure standing on the right). The drawing was then strengthened using a thin black paint.[112]

It is not usually possible to characterise the black pigment used in underdrawing, be it wet or dry, very exactly. Charcoal occurs rather infrequently, in dry or liquid form, but has a very characteristic appearance under the microscope. It has been observed in, for example, Gerard David's *Canon Bernardinus de Salviatis and Three Saints* under the paint of the purplish-red lining of Saint Donatian's cloak (Plate 9). It was also used for the underdrawing in the *Tüchlein* of *The Entombment*, by Dieric Bouts, and the squaring up on the Heemskerck panels referred to above.[113]

So-called iron gall ink was prepared from ground oak galls, a gum and copperas (iron(II) sulphate, $FeSO_4.7H_2O$), with water, vinegar or wine. (Occasionally the equivalent copper salt appears to have been used, giving a 'copper gall ink'.) It was necessary to leave the ink to stand to allow the colour to develop fully (that is, to allow the formation of the blue-black complexes of iron and the gallic acid produced by the gradual hydrolysis of the oak gall tannins to take place).[114] Black pigment was sometimes added to intensify the colour. Iron gall ink is thought to have been used for the underdrawing in a small triptych from the workshop of the Master of the Saint Bartholomew Altarpiece, *The Virgin and Child in Glory with Saint James the Great and*

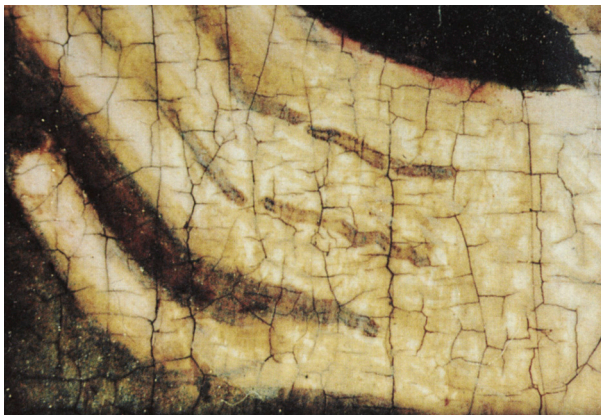

Plate 10 Workshop of the Master of the Saint Bartholomew Altarpiece, *The Virgin and Child in Glory with Saint James the Great and Saint Cecilia*. Photomicrograph of Saint Cecilia's hand, showing iron gall ink drawing material.

Plate 11 Lucas Cranach the Elder, *Cupid complaining to Venus* (NG 6344). Photomicrograph of fur trimming of Venus's hat, showing red underdrawing material.

Saint Cecilia (NG 6497), which is visible through the paint but could not be detected by infra-red reflectography; the lines of drawing, which are in a translucent brownish material, with a little black pigment added, are denser at the edge of the stroke and have markedly square ends, suggesting the use of a pen rather than a brush (Plate 10).

The dark underdrawing visible through the white of the nun's habit in a Netherlandish School painting in the style of Joachim Patinir, *The Virgin and Child with a Nun* (NG 945), similarly could not be detected by infra-red reflectography. In this case, however, a sample of paint taken from the area of drawing revealed that it consisted of an extremely thin layer of pigment particles, most of which were brown in colour; it was not iron gall ink. Analysis has revealed the presence of an iron oxide, but the pigment may be something like Cassel earth, where much organic material is present.[115] In many of his later paintings, including the National Gallery's *The Close of the Silver Age (?)* (NG 3922), *Cupid complaining to Venus* (NG 6344), and *Charity* (NG 2925), Lucas Cranach the Elder used a red drawing material which shows through the paint in thinner, lighter areas (Plate 11). It has been noted during examination of the surfaces of the paintings with the stereomicroscope, but it has not been possible to identify the pigment present.

Incised lines were commonly used for those features of the composition, such as architectural elements, brickwork or paved floors, where straight lines could be ruled. In the German

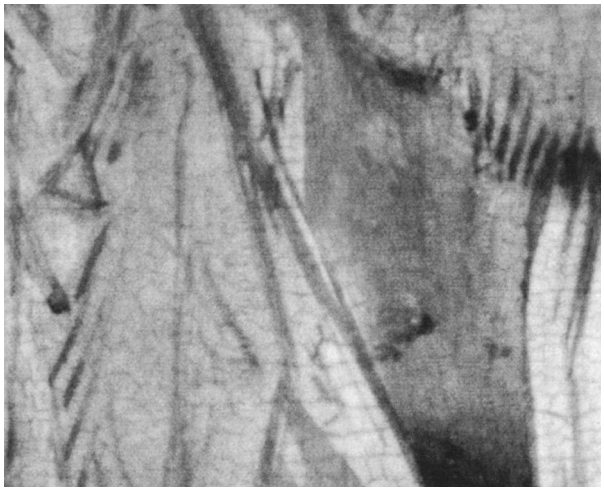

Fig. 8 Gerard David, *The Adoration of the Kings* (NG 1079). Detail of infra-red reflectogram mosaic, showing liquid underdrawing material used in the folds of the Virgin's drapery.

School paintings with gilded backgrounds or areas of decoration, it is clear that the parts of the composition that were to be gilded were also marked out by lines incised into the ground. Circular features such as haloes or arches were usually outlined with compasses.

Fig. 9 Pieter Bruegel the Elder, *The Adoration of the Kings* (NG 3556). Detail of infra-red photograph showing King on extreme left, drawn in a dry material.

Gilding

From the many references in guild statutes, contracts and technical sources, it is clear that gilding, when it was to be used, commanded a great deal of attention. Many of the German School panels that come from dismembered altarpieces, or that are small altarpieces in their own right, are gilded, although, sadly, the gilding is sometimes in very poor condition, particularly in panels transferred from their original supports. However, examples of the main types of gilded decoration referred to in the guild statutes and other documents – water gilding, mordant gilding and applied relief gilding – may be found among the Gallery's German School pictures. Very few of the Early Netherlandish paintings in the collection have extensive areas of gilding: the *Mater Dolorosa* (NG 711) and *Christ Crowned with Thorns* (NG 712), the separated panels of a diptych from the workshop of Dieric Bouts, have gilded backgrounds, and the throne in Quinten Massys's *The Virgin and Child Enthroned, with Four Angels* (NG 6282), of about 1490–5, is gilded, with the architectural details elaborately and meticulously drawn in black over the gold. However, the evidence of guild regulations and contracts suggests that gilding was an important element in the decoration of some Early Netherlandish altarpieces. The examination of works in other collections, particularly those dating from the earlier part of the fifteenth century or before, has shown that the same methods of gilding were used on these panels as on the German School panels. Water gilding, over an orange bole, is present on, for example, the wings painted by Melchior Broederlam for the altarpiece of the Crucifixion sculpted by Jacques de Baerze for the Chartreuse de Champmol (Dijon, Musée des Beaux-Arts), completed in 1399.[116] It is also used on a small four-panelled altarpiece, also of the 1390s, showing scenes from the life of Christ: two panels, *The Nativity* and *The Resurrection*, are in Antwerp (Museum Mayer van den Bergh); *The Annunciation* and *The Crucifixion* are in Baltimore (Walters Art Gallery).[117] Extensive gilding over an oil mordant is present on the triptych of *The Entombment ('The Seilern Triptych')*, attributed to Robert Campin (London, Courtauld Institute Galleries).[118] Gilded applied relief brocade was used in the decoration of *The Bad Thief*, by Robert Campin (Frankfurt am Main, Städelsches Kunstinstitut).[119] It is, however, an often-quoted characteristic of Early Netherlandish painting of the earlier part of the fifteenth century onwards that, in the painting itself as opposed to the frame, gold is usually represented by paint, rather than by gold leaf.

Where gold leaf was to be burnished and, perhaps, decorated with a punched or incised pattern, it was applied by the technique of water gilding.[120] This method of gilding is described in detail in a recipe in the so-called *Liber illuministarum*, of the early sixteenth century (see page 15): the panel to be gilded was given six coats of chalk mixed with a glue medium, adding ever-increasing amounts of chalk to the mixture, which thus became thicker for each application; the ground was rubbed down and a layer of the iron oxide pigment, brown-red, was applied. This was polished, moistened with weak size and the gold laid. It was burnished with a tooth.[121] Burnished gilding is present on many of the fifteenth- and early sixteenth-century German School panels in the collection. A typical exam-

ple is the Cologne School painting from the circle of the Master of Saint Veronica, *Saint Veronica with the Sudarium* (NG 687), where the background and haloes are extensively decorated with punched stippling. Its use is also seen in the Tyrolean School *Death of the Virgin* (NG 4190), in the delicately punch-decorated background of *The Presentation in the Temple* (NG 706), one of eight panels from an altarpiece by the Master of the Life of the Virgin (the other seven are in Munich, Alte Pinakothek), and in the halo of the Virgin in *The Annunciation* (NG 256), one of the panels from the altarpiece painted by the Master of Liesborn.

In Italian painting, the reddish material used as a substrate for the gilding was the slightly greasy red-brown clay (deriving its colour from an iron(III) oxide) known as bole; this provided a smooth, slightly slippery and soft surface, suitable for later burnishing and tooling. It also gave a warm tone to the gilding. In the German School paintings examined, the reddish layer usually appears to consist of an iron oxide-containing material of this type, although the evidence of the *Liber illuministarum* indicates that bole itself need not necessarily have been used. The red material may be mixed with other pigments; in the Master of Saint Veronica panel it is mixed with a little black. It is difficult to estimate its thickness, but the layer often appears rather thinner and less substantial than in Italian panels; also its application is sometimes very streaky and uneven. In such cases it is likely that the warming effect of its colour was as important as any cushioning or 'slip' it might have been expected to provide. Chalk grounds are harder than those of gesso; tooling is less easy to carry out. That on the German School panels is carried out with a pin punch, unlike the array of different punches used on Italian panels.

Gilding over a pigmented and usually oil-based mordant produced a different type of finish: yellower, matt-surfaced, perhaps slightly raised and without the sonorous quality of burnished gold. In those German School paintings where both types of gilding are present, such as Lochner's *Saints Matthew, Catherine of Alexandria and John the Evangelist* (see pages 59–60) and the *Mass of Saint Hubert* (NG 253), one of the Werden altarpiece panels from the workshop of the Master of the Life of the Virgin, some idea of the original decorative effect obtained by the use of the two types of gilding together may be obtained (Plate 3). Mordant gilding was very widely used, not only in painting, but also for fabric printing and other decorative techniques; it is thus not surprising that a number of recipes for oil mordants exist in German and Netherlandish documentary sources. The usual ingredients listed included yellow ochre, red lead and linseed oil, perhaps with the addition of varnish; for silver leaf the red lead might be replaced by lead white.[122] It was painted over the area to be gilded and, when it had dried to the right degree of 'tackiness', the metal leaf was applied. The finished gilding was not burnished and had a matt surface.

In the German School paintings examined, mordant gilding is found applied over the primed ground, over other paint layers, and to decorate areas of applied relief (discussed below). It is particularly convenient for gilding small details in the painting, such as the details on the costumes of the saints in Cranach's *Saints Genevieve and Apollonia* (NG 6511.1) and the candlestick on the altar in the Master of the Life of the Virgin's *Presentation in the Temple* (NG 706). Here, the brownish-yellow medium-rich mordant contains a yellow earth, lead white, some lead-tin yellow and a little red earth, in linseed oil. In the mordant-gilded areas of the four Werden altarpiece panels from the workshop of the Master of the Life of the Virgin, such as the retable depicted on the altar in *The Mass of Saint Hubert* (Plate 3) or the relief brocade on Saint Hubert's robe in *The Conversion of Saint Hubert* (NG 252), the composition of the mordant is rather similar: yellow earth, with small quantities of lead white, lead-tin yellow and a little black and azurite, in linseed oil. The mordant in panels painted by the Master of Liesborn and from his circle contains much the same mixture with a little red lake in addition. In one of these, *Saints Ambrose, Exuperius and Jerome* (NG 254), a similar mordant has been used for gold and silver leaf. The essential qualities of the mordants seem to be that they are yellowish in colour and that they dry quickly; apart from yellow pigments, a rather heterogeneous mixture of pigments is present in small quantity – they could even be scraps of left-over paint reused – but they always include several, like the lead pig-

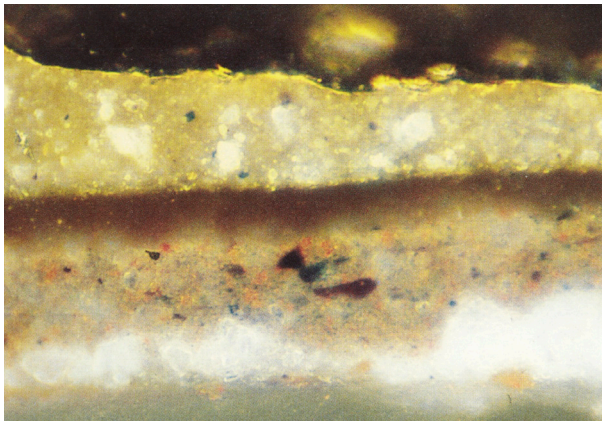

Plate 12 Workshop of the Master of the Life of the Virgin, *The Conversion of Saint Hubert* (NG 252). Cross-section through the mordant-gilded trappings on Saint Hubert's horse. The oil mordant for the gold leaf is yellowish in colour, consisting of yellow earth, lead-tin yellow, lead white and a little black. As often seen in cross-sections through mordant gilding, there is a yellowish-brown unpigmented layer beneath the oil mordant. The brown paint of the horse contains lead white, black, red earth and red lake. Photographed at a magnification of 540×; actual magnification 495×.

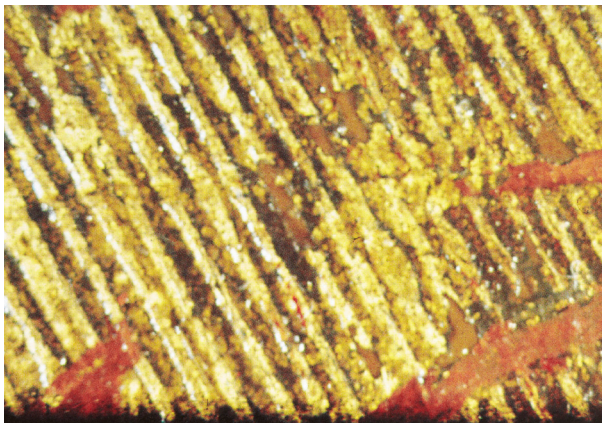

Plate 13 Master of Liesborn, *Adoration of the Kings* (NG 258). Photomicrograph of the tunic of the king at the left of the painting showing the ridges of the applied relief brocade. The mustard-brown adhesive is visible through small losses.

ments and azurite, that are good driers (Plate 12). The oil present in the mordant used for gilding the relief brocade on Saint Hubert's robe was found to have been heat-bodied; it, too, would dry more rapidly (see Table, page 54). In some cities, the colour of the mordant is mentioned in guild regulations: in the 1470 Antwerp regulations discussed above (page 9) it had to be gold-coloured. The evidence of the mordants examined suggests that, unsurprisingly, this is generally the case; they then match the colour of the leaf above them and flaws in gilding are not obvious. The mordants used by the Cologne painter, the Master of the Saint Bartholomew Altarpiece, are markedly yellow. In *Saints Peter and Dorothy* (NG 707) and *The Deposition* (NG 6470) they are pale yellow, consisting of lead white and yellow earth, and quite opaque; interestingly, this is rather similar to that used in the few Early Netherlandish paintings in the collection where gilding is present, such as *Christ Crowned with Thorns* from the Bouts workshop.

Mordant gilding is also sometimes used for gilded backgrounds. One example is the *Saints Peter and Dorothy*, mentioned above; another is the Stephan Lochner panel, where the background is decorated with a pattern incised into the ground and gilded using a thin yellow mordant (described on page 60). For panels decorated by carving or incising the design into the ground, such as the Lochner or the small panel attributed to Michael Pacher, *The Virgin and Child Enthroned with Angels and Saints*, mordant gilding is the most convenient method, given the sharpness and fine detail of the decoration (although it must be said that no analysis of the paint structure has yet been carried out on the Pacher panel). Raised decoration obtained by painting the desired pattern onto the ground, using a creamy mixture of chalk in, perhaps, animal-skin glue, or moulding a chalk-containing paste as desired and gluing it in place, gives a decoration with a flatter or gently curved profile for which water gilding could be used if desired.[123] Raised decoration was widely used – it occurs on the *Seilern Triptych* mentioned above – but is not found on any of the German or Early Netherlandish School paintings examined.[124]

Relief decoration, applied relief brocade, particularly effective when used for fabrics with a repeating pattern, could be obtained by the use of pre-formed relief patterns which were attached to the ground, gilded using an oil-based mordant and painted (Plate 13). This method of decoration is found frequently on polychromed sculpture, where its use is particularly effective, as well as on paintings; the play of light and shade over the lightly embossed surface creates added interest, depth and realism to the work. The description of it in the Antwerp guild statutes of 1470, for example, demonstrates the importance attached to it. Applied relief is absent

from the Early Netherlandish School panels in the collection, although it has been found on Early Netherlandish panels elsewhere.[125] A shallow mould was first made of the design to be replicated, carving and gouging out the fine detail of the design so that, for example, the threads of a textile would appear as a series of thin parallel grooves and ridges. The *Liber illuministarum* describes the method of preparation and the gilding of the sheets of relief that would then follow. A sheet of tin foil, which is resilient enough to be handled, but thin and malleable enough to take up the features of the pattern, was pressed into the mould, covered with wadding and hammered gently into place. A suitable filling (the *semente* mentioned in the Antwerp statutes) was spread into the tin-lined mould, scraping away the excess. A knife was inserted between the mould and the tin to ease out the foil after it had hardened or dried sufficiently; the process was then repeated as often as necessary.[126] The sheets of relief brocade thus obtained were then applied to the painting or sculpture using a suitable adhesive; they could be cut to fit the space available if necessary and gilded and painted as desired either before or after application. It was a rapid way of decorating a panel, but not the most refined: in the Master of the Life of the Virgin's *Presentation in the Temple* (NG 706), it has been used for the cloth-of-gold robes of two of the figures attending the scene, but that of Simeon, who receives the Infant Jesus from the Virgin, has been meticulously painted.

Although applied relief brocade is present on several of the German School paintings, it is frequently in poor condition, often regilded and repainted; however, in several cases it was possible to ascertain how it had been made. In the *Presentation in the Temple*, Fourier transform infra-red analysis indicated that the filling supporting the tin foil consisted of beeswax with a small amount of glue; the same filling was used for the sheets of relief brocade in the panels from the altarpiece by the Master of Liesborn (NG 256–61). Wax appears to have been used for the sheets of relief decorating Saint Hubert's robe in *The Conversion of Saint Hubert*, which, of the four Werden altarpiece panels, is the one in the best condition (Plate 14).[127] Chalk and pitch with glue were suggested in the *Liber illuministarum*

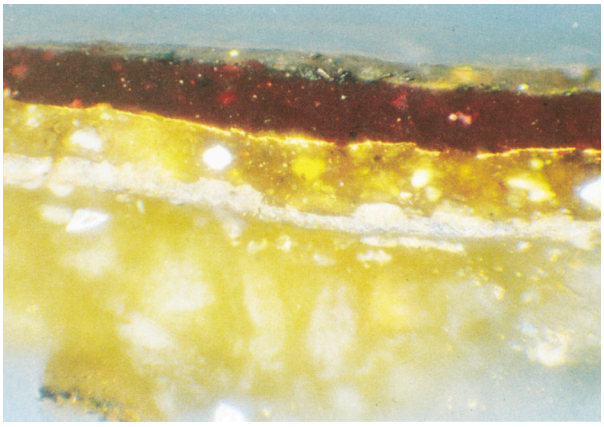

Plate 14 Workshop of the Master of the Life of the Virgin, *The Conversion of Saint Hubert* (NG 252). Cross-section through the red pattern on the applied relief brocade of Saint Hubert's tunic. The ground is missing from this sample. Beneath the silvery-grey layer of tin leaf is a thick whitish translucent layer of the wax-containing filling material. A fragment of the brown adhesive is visible beneath the filling at the left of the sample. Gold leaf has been applied to the relief brocade with a yellow-brown oil mordant. The red lake-containing paint of the pattern can be seen at the top of the sample. Photographed at a magnification of 220×; actual magnification 200×.

recipe, but the fillings found here have the advantage of giving the sheets of foil a degree of flexibility, necessary if they were to be used on sculpture. In the *Presentation in the Temple* the sheets were attached to the ground using a pink adhesive consisting of chalk with some red lead bound in oil; a brownish adhesive (containing bone black and red earth) was used in the *Conversion of Saint Hubert*; orange-brown in the Liesborn panels. In these works the relief was gilded after it had been applied (using the brownish-yellow oil mordant described above) and the painted decoration added. In the *Presentation in the Temple*, the patterns, originally painted in black in one instance and blue (azurite) in the other, have been repainted in red; in the *Conversion of Saint Hubert* traces of the original red lake decoration are present under the orange-red repaint.

The metal leaf used for gilding was found to be pure gold or silver in every case except one. In the Austrian School *Trinity with Christ Crucified*, the leaf used on the frame was found to contain both gold and silver; presumably this is an example of *Zwischgold* or the *gedeilden gulde* of the Cologne 1449 statutes discussed earlier. Analysis suggests that the composite,

two-layered leaf was made by beating gold and silver together.[128]

Shell gold, illustrated sometimes in the depictions of Saint Luke painting the Virgin, consists of gold ground to a powder; a little honey or some similar substance might be added to assist in the grinding process. It could be applied mixed with a little medium or over a mordant to give a delicate glittering embellishment. Its use became extremely popular during the fifteenth and early sixteenth centuries, particularly for manuscript illumination.[129] In the Northern European paintings examined it has been rarely identified; its use by Jan Gossaert on the *Adoration of the Kings* (NG 2790) is discussed on page 95 of this *Bulletin*.

The paint film

Pigments and layer structure

The regulation in the Tournai guild statutes of 1480, or the 1528 inventory of Mathis Neithardt-Gothardt's estate, or the verse in Jean Lemaire de Belges's poem of 1504–5, could almost serve as a record of the pigments found to have been used in the Early Netherlandish and German School pictures in the collection. Orpiment (yellow arsenic sulphide) and mosaic gold (tin sulphide) were not identified on any painting, but every other pigment suitable for use in easel painting occurs to a greater or lesser extent. It is clear that, according to these sources and the sixteenth-century Flemish treatise *Traktaat om kleuren te bereiden*, there were already two varieties of lead white, one of which was named ceruse. According to the *Traktaat*, the difference in quality lay in the degree of refinement, ceruse being the finest grained product that emerged after leaving raw lead white in water for several days, with occasional stirring, and separating the fine material from the coarse by filtration. It was then ground.[130] Whether this was always the only difference, or whether extender (in the form of chalk, for example) was ever added, as was the case in later centuries, is a question that has yet to be answered.

Investigation of the paintings showed that azurite was the most commonly used blue pigment; the use of ultramarine was less widespread, with a very limited use of indigo and smalt. The green pigment verdigris occurred almost universally, but malachite was less common and the ways in which green-coloured mixtures were composed changed over time. Vermilion and the red lake pigments occur in almost every painting, as do lead white, lead-tin yellow, the ochres and other iron oxide pigments and different forms of black, but the ways in which they were employed varied slightly. Similarly, both linseed and walnut oils are found, with only a very limited occurrence of egg tempera, principally in layers of underpaint. It is in the methods of using these materials – the pigment mixtures and the layer structures – that differences may be observed: between different workshops; between one period and another; and between Early Netherlandish and German practice.

Apart from the different forms of metal leaf, blue pigments were those to which guild regulations and contracts devoted most attention; because of the cost of the principal blue pigments used, ultramarine and azurite, there was always the possibility of falsification. Both were extracted from natural mineral sources. The essential component of ultramarine is the blue mineral lazurite (a complex sulphur-containing sodium aluminium silicate, $(Na,Ca)_8(AlSiO_4)_6(SO_4,S,Cl)_2$); its source is the blue mineral lapis lazuli, in which it occurs with a number of other associated aluminosilicates and other impurities, including calcite and pyrites. In the fifteenth and sixteenth centuries the main source of the mineral was Badakshan in modern Afghanistan; most was probably imported into Europe by way of Venice and a proportion was then re-exported. The extraction of the blue pigment was lengthy and laborious, adding to the cost. It resulted in several different grades of ultramarine: the first extraction provided the largest, deepest blue, particles, with fewest impurities; the last had a high proportion of mineral impurities and smaller blue particles.[131] During his visit to Antwerp in 1521, Albrecht Dürer wrote that he had given twelve ducats for an ounce of good ultramarine; some two months earlier he had paid only four *stuivers* for Cassel earth and other goods: perhaps one per cent of the price he paid for the ultramarine.[132] It is not surprising that the pigment was used economically, perhaps glazed over a layer containing azurite, for example, but it was used quite widely in Early Netherlandish

painting: by Jan van Eyck, Rogier van der Weyden, Hans Memling, Gerard David and Quinten Massys and their workshops, for example, to name only a few. Van Eyck used a grade of reasonable quality, but finely ground; he used it in the deepest shadows of red drapery (mixed with a red lake pigment) as well as blue. From the examination of the German School paintings in the collection, its use appears to have been much less common in German painting.[133]

The principal source of the important naturally occurring mineral azurite (basic copper carbonate, $2CuCO_3.Cu(OH)_2$), appears to have been Hungary, but it could be found in other regions of Europe, including Germany. The pigment was prepared by simple washing and grinding.[134] The intensity of the colour is dependent on the degree of hydration and the particle size; although large particles may have a strong, slightly greenish-blue colour, finer particles are paler and greener, with little tinting strength. Azurite tends to occur in association with other copper-containing minerals: the considerably more abundant green mineral, malachite ($CuCO_3.Cu(OH)_2$), also used as a pigment, and the reddish-coloured cuprite (Cu_2O); if present in the ground pigment they have a marked effect on the colour, causing it to appear even greener. Although azurite usually has a greenish cast, that used in quite a high proportion of the German School paintings appears to be of extremely high quality and an almost pure blue colour, particularly marked in the coarsest particles. It may be seen in the paintings by the Master of Saint Bartholomew: examples are the dark blue robe of Saint Peter in *Saints Peter and Dorothy* (Plate 15) and the Virgin's cloak in *The Deposition*, where azurite of unusually large particle size is used. Azurite of this quality would have been the most expensive; like the ultramarine, the highest quality azurite might be glazed over a paler, greener grade, of smaller particle size; this is the case in Saint Peter's robe. However, the greener grade was chosen deliberately for its colour to paint Saint Peter's cuffs and, in *The Deposition*, Saint Joseph of Arimathea's robe, which is a greener blue than that of the Virgin (Plate 16). A similar colour contrast may be made using ultramarine and azurite, as in the Virgin's purplish-blue robe with its greener blue lining in *The Virgin and Child before a Firescreen* (NG 2609),

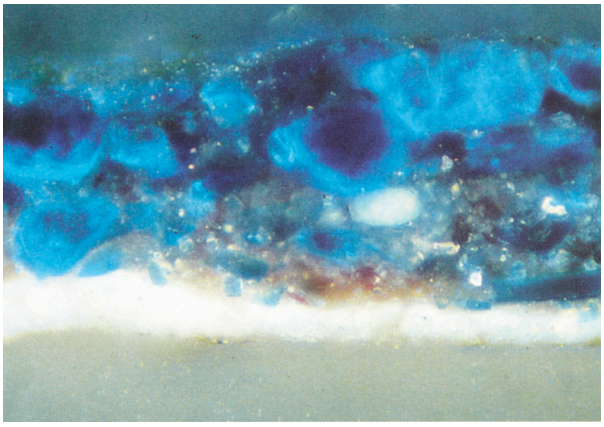

Plate 15 Master of the Saint Bartholomew Altarpiece, *Saints Peter and Dorothy* (NG 707). Cross-section through the dark blue shadow of Saint Peter's robe. The upper layer contains azurite of an intense colour and unusually large particle size. Photographed at a magnification of 480×; actual magnification 440×.

by a follower of Robert Campin.[135] It seems probable that azurite of different grades or shades of colour, based on differences in particle size or impurity content, were available for purchase; it is unlikely that it was all ground for use in the workshop.

The coarsest grades of both azurite and ultramarine in an oil medium have rather poor handling properties; they also require a rather high proportion of oil in their preparation. Azurite films in particular tend to darken and wrinkle. Ultramarine films become very dark as the refractive index of the pigment is very close to that of the oil. Its colour is much improved by the incorporation of a little white, even in the deepest shadows, and some painters, including Rogier van der Weyden, were inclined to do this. Finer grades of both pigments gave a more easily worked paint and it is a noticeable feature of much Northern European painting with fastidiously painted detail that many of the pigments are finely and evenly ground. With azurite, where the depth of colour depended on the degree of grinding, some measure of compromise was necessary (this is discussed in the context of Rogier van der Weyden and Jan van Eyck on pages 78–9).

Paler shades of azurite blue paint could be obtained by the admixture of white, or by the use of a pigment of smaller particle size, or both.[136] Admixture of white alone was used for the gradation of colour in the sky of Lucas Cranach's *Close of the Silver Age* (NG 3922); the

Plate 16 Master of the Saint Bartholomew Altarpiece, *Saints Peter and Dorothy* (NG 707). Detail of Saint Peter's blue robe showing the use of two different grades of azurite.

azurite is extremely finely ground and the paint is applied in a single layer. In the *Flight into Egypt* (NG 1084), from the workshop of the Master of 1518, the deeper blue of the sky consists of a layer of coarser azurite mixed with lead white; where the sky is lighter azurite of less intense colour and smaller particle size is used.

Smalt, the blue ground-glass pigment, which obtains its colour from the small amount of cobalt oxide it contains, occurs in *The Entombment* (NG 664) by Dieric Bouts mixed with ultramarine and azurite.[137] As the painting is thought to date from some time in the 1450s, this is an early occurrence for a pigment that came to be very much more important in the following century and beyond, particularly as supplies of azurite and ultramarine became increasingly unreliable. The pigment was found to occur rather infrequently on Early Netherlandish and German School paintings in the collection. It is found in the painting on canvas, *Saint Lawrence showing the Prefect the Treasures of the Church* (NG 3665), of around 1510, where it was used over azurite in the bodice of the dress of one of the figures, but is now much deteriorated. Its colour is a slightly purplish-blue and it may have been used here as a cheap substitute for ultramarine. Much later, smalt of quite good colour was used for the paint of the Virgin's robe (an area which traditionally would have been painted in a more costly pigment) in Pieter Bruegel's *Adoration of the Kings* (NG 3556), painted in 1564. He also used it, mixed with white and a red lake, for the mauve paint of the hat of the man in spectacles.

Indigo, a natural plant dyestuff, was the most important blue pigment used for dyeing, the pigment being a by-product obtained from the dyeing vats. Indigo derived from species of *Indigofera*, growing in parts of the Far East, had always been imported, although in the fifteenth century much of the indigo used for dyeing was still obtained from woad (*Isatis tinctoria* L.), the woad industry in Erfurt being of particular importance.[138] As a pigment it has an extremely high tinting strength and rather poor light-fastness, particularly when mixed with white. It was used on the reverse surface of Lochner's *Saints Matthew, Catherine of Alexandria and John the Evangelist* specifically for its dark blue colour (see page 65), but it may be found in the underpaint to more expensive blue pigments or, mixed with a yellow pigment, in green paint. Its use in easel painting was not particularly frequent, but it became more common in the sixteenth century; it is seen for example in the work of Holbein and his followers and in one or two of the Netherlandish panels examined. Its use may be more common in decorative commissions or in aqueous media; it is present, mixed with lead-tin yellow, in the green paint of the landscape in Bouts's *Entombment*.[139]

Azurite could be used for a range of colours from green, through a range of blues, to purple by the addition of other pigments or by careful choice of the pigments used in the underlayers. By varying the proportions of the pigments in both layers, a wide range of blues could be obtained. Two paintings by Gerard David provide a good example; *The Adoration of the Kings* (NG 1079) and *Canon Bernardinus de Salviatis and Three Saints* (NG 1045) contain passages of blue paint ranging from purplish blue through greyish blue to bright greenish blue, all based essentially on mixtures of azurite, red lake and lead white in varying proportions. The undermodelling of the draperies is based on mixtures

of azurite and lead white, adding red lake in areas of deep shadow. In a number of early sixteenth-century paintings black is added to the pigment mixture used in the underlayer; in the *Visitation* (NG 1082) and the *Flight into Egypt* (NG 1084), both from the workshop of the Master of 1518, blue draperies are undermodelled with a layer of lead white, azurite, red lake and black, then painted with azurite, perhaps mixed with a little white.

Different shades of reddish to bluish purple were usually similarly obtained by the addition of red lake to the blue pigment, generally azurite, in the uppermost paint layer, sometimes modifying the colour by the addition of lead white. Although ultramarine is sometimes used for such mixtures, as in Lady Donne's purple robe in Memling's *Donne Triptych* (Plate 2), azurite is rather more frequently found, giving a characteristic 'aubergine' tone. Examples of the use of purples based on azurite and red lake mixtures were found in a high proportion of Early Netherlandish and German paintings, including those associated with the workshops of Robert Campin, Rogier van der Weyden, Dieric Bouts, Stephan Lochner, Gerard David, the Master of Liesborn, the Master of Saint Bartholomew, the Master of the Bruges Passion Scenes and Bartholomeus Bruyn the Elder. The paintings by Gerard David provide good examples of the colours obtained: in the robes of the Kings in *The Adoration of the Kings* and in Saint Donatian's cope in *Canon Bernardinus de Salviatis and Three Saints*. It is also common to find purple colours constructed of a red lake pigment glazed over a mauve or blue underpaint, perhaps particularly from the years around the turn of the sixteenth century onwards. Examples may be seen in the works of the Master of Saint Giles,[140] Hans Baldung Grien and Marinus van Reymerswaele. In Marinus's *Two Tax Gatherers* (NG 944), of about 1540, the purple garment of the left-hand figure is modelled with underpaint layers consisting essentially of azurite and lead white in various proportions, azurite (with some red lake) in the shadows. The whole garment was then glazed with a thin layer of red lake-containing paint, which has faded to some extent. Simplification of the layer structure is seen in the work of some other painters; the bluish-purple robe of Saint Luke in *Saint Luke painting the Virgin and Child* (Plate 1), by a follower of Quinten Massys, is painted in a single layer of paint containing azurite, red lake and white, areas of shadow being laid beside mid tones and blended together. Occasionally black, rather than blue, was used to give a purple colour, as in the Gossaert *Virgin and Child*, where black was mixed with red lake and lead white to give the purple of the Virgin's dress.[141]

Plate 17 Master of Liesborn, *The Presentation in the Temple* (NG 257). Detail showing the different reds obtained by the use of a red lake pigment for Simeon's pinkish robe and vermilion in the orange-red cloak of the figure behind him.

The red component of the purple colour, as well as the translucency of the glaze, is contributed by a red lake pigment. These were prepared from naturally occurring organic dyestuffs, extracted from plant or animal sources and precipitated onto a suitable inorganic substrate, usually hydrated alumina; sometimes a calcium salt (derived from the addition of chalk or ground eggshells, for example, during manufacture) might also be present. The presence of the calcium salt may affect the colour of the pigment and the appearance of the paint, giving a slight cloudiness to the glaze. The permanence of the

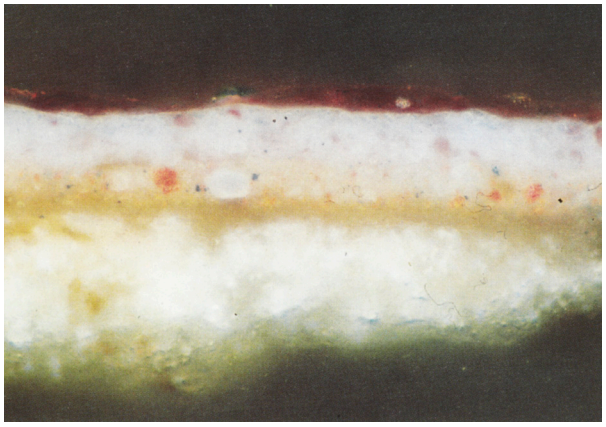

Plate 18 Workshop of the Master of 1518, *The Visitation of the Virgin to Saint Elizabeth* (NG 1082). Cross-section through Saint Elizabeth's red drapery. The opaque red underlayer contains lead white and black, in addition to the red pigments vermilion and red lake. Photographed at a magnification of 500×; actual magnification 375×.

lake pigment is also affected; a calcium salt has been identified in the substrate of the lake pigment used for Saint Dorothy's pink dress in the Master of the Saint Bartholomew altarpiece's *Saints Peter and Dorothy*, which has faded badly.[142] A red lake pigment was present in almost every painting examined; yet, because their analysis presents a number of problems, the identity of the dyestuffs used is usually uncertain. Taking account of the considerable importance of the madder industry in the Low Countries, particularly around Zeeland, at this time, it would be extraordinary if madder dyestuff (extracted from the roots of the herbaceous perennial plant, *Rubia tinctorum* L.) were not used; the analyses that have been performed suggest that madder was indeed the most important dyestuff for lake pigments as well as textiles. During the early years of the sixteenth century, kermes dyestuff (extracted from a species of scale insect, *Kermes vermilio* Planchon) also came to be used for lake pigment preparation and has been identified in a number of paintings. Because the pigments were usually prepared from textile shearings, a mixture of dyestuffs (kermes and madder, for example) could be present; this, too, has been found.[143] The madder lakes on fifteenth- and sixteenth-century paintings are a transparent, often slightly orange-tinged red; kermes lakes are a slightly more blue-red. The orange tone of madder lakes, if pronounced, would contribute to the slightly brownish or greyish tone often observed in Northern European purple hues. Brasilwood lakes (for which a great many recipes from the time exist) were probably not thought suitable for easel painting generally as the dyestuff is impermanent. The crimson or bluish-crimson lac lakes appear also to be uncommon, although why this should be so is unclear.

For passages of red paint the use of the lake pigments was combined principally with the opaque red pigment vermilion (red mercuric sulphide, HgS). Mineral cinnabar occurs naturally, but the pigment was also synthesised from its constituent elements (mercury and sulphur) by dry sublimation of the initially formed black mercuric sulphide.[144] In the simplest cases vermilion is used alone, but usually the layer structure is more complex. In a number of fifteenth-century Early Netherlandish workshops, including those of Jan van Eyck, Petrus Christus, Dieric Bouts and Hans Memling, some passages of red had an underpaint of opaque red vermilion, followed by a layer of red lake pigment mixed with lead white, the proportions of which were varied to model the form or drapery depicted. The whole was then glazed with red lake which might vary in thickness according to the depth of shadow. Deeper red passages were painted in vermilion mixed with a little red lake, glazed with several layers of red lake (see pages 74–8). A little ultramarine might be incorporated in the shadows and appears to be more common in the circle of van Eyck and Petrus Christus; this was observed in van Eyck's *Portrait of Giovanni (?) Arnolfini and his Wife* (NG 186) and the *Man in a Turban* (NG 222) (and also, interestingly, the *Portrait of Marco Barbarigo* (NG 686), by a follower of van Eyck). Only in the very deepest shadows might a trace of black be incorporated.[145] The modelling system thus created is thus very flexible and capable of great subtlety.

The painting of red areas in the earlier Netherlandish paintings examined was generally based on one or other of these two methods of modelling, perhaps in slightly modified form. Passages of red in *Saint Veronica with the Sudarium* (NG 687), painted by the Master of Saint Veronica, in about 1420, were constructed in a very similar manner to some of the Early Netherlandish School paintings, with modelling in a lead white and red lake layer, above vermilion and glazed with a layer of red lake. The

German School paintings often appear to show less complexity in the painting of red areas. The passages of red in the Master of Liesborn's *Presentation in the Temple* (NG 257) are very typical; a lake pigment was used for the pinkish red of Simon's robe while the more solid-looking orange-red draperies contain vermilion (Plate 17).

In the work of Gerard David lead white was added to vermilion and red lake in the underlayers (of which there were usually more than one) in various proportions, depending on the depth of shadow required, a slightly different modelling system to that seen in the earlier fifteenth century. In the early part of the sixteenth century also, there was a tendency in the work of some painters for modelling to become simplified and more directly achieved by the addition of black or white pigment to the mixture in the underlayers, rather similar to that seen in the modelling of blue passages. In two paintings from the workshop of the Master of 1518, *The Visitation* (NG 1082) and *The Flight into Egypt* (NG 1084), the lowest, brownish, underpaint layer consists of varying proportions of vermilion, lead white and black, followed by a pink layer of red lake and lead white, also varying in proportion: these give the modelling of the drapery, which is then glazed with red lake (Plate 18). The bright red robe of the man on the right in Marinus van Reymerswaele's *Two Tax Gatherers* is modelled in the vermilion-containing underpaint by the addition of black and also by variation in the thickness of the glaze layer. Red ochre pigments were added to the mixture by some painters. The work of some painters showed a simplification of the layer structure, reflecting their different approach to painting: this is observable in the work of Martin van Heemskerck for example.

The principal green pigment used, both for translucent glazes and mixed with other pigments, was verdigris (basic or neutral copper acetate). Malachite was also occasionally found; other copper pigments, such as the basic copper chloride pigments, atacamite, paratacamite and calumetite, and posnjakite (basic copper sulphate, $Cu_4(SO_4)(OH)_6.H_2O$) have very occasionally been found in German and Early Netherlandish painting, but were not identified in the National Gallery collection.[146] Verdigris, in addition to having a low refractive index, tends to react with the fatty acid components of the oil medium over time, producing green transparent copper salts (this may also happen with other copper-containing pigments).[147] Under the microscope it is often found that the edges of the particles are indistinct as a result; some may dissolve completely. For this reason it is a particularly successful glazing pigment. A little pine resin was sometimes incorporated into the paint film to increase transparency and saturation (this is discussed below). Fourier transform infra-red analysis of a number of green glazes in paint cross-sections has shown that the pine resin was usually an addition to the medium, made before the pigment was ground with it; indeed, in one of the examples given in the Table (pages 53–5), a North German School painting of *Christ Carrying the Cross* (NG 2160), the mixture is rather inhomogeneous as if insufficiently stirred. Occasionally the reaction between the resin and the pigment was made before admixture with the oil; in other words a 'copper resinate' was formed.[148] True 'copper resinate' glazes were found to be uncommon: some examples, including the green background in Joos van Cleves's *Holy Family* (NG 2603), of about 1515–20, and *Saint Dorothy* (NG 2152, late fifteenth century), from the circle of the Master of Liesborn, are given in the Table. Usually, the glaze was found to contain either oil medium alone (perhaps heat-bodied), or a trace of resin incorporated into the medium. Often the glazes in Northern European paintings are in good condition; 'copper resinate'

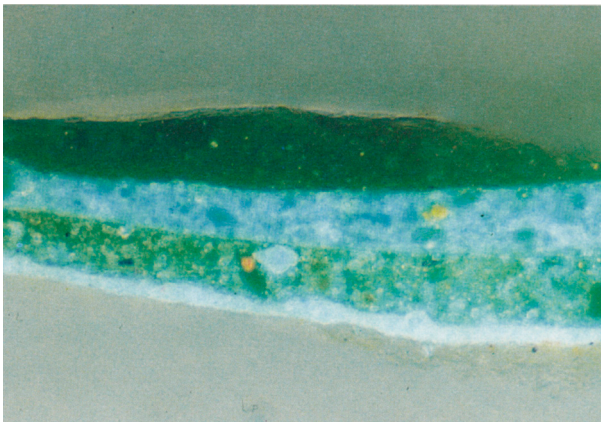

Plate 19 Master of the Life of the Virgin, *The Presentation in the Temple* (NG 706). Cross-section through the green drapery of the woman at the left of the painting. The paint layers consist of mixtures of verdigris, lead-tin yellow and lead white. Photographed at a magnification of 500×; actual magnification 350×.

glazes are known to be liable to discolour, although this does not always occur. Brown discoloration of green glazes was, however, observed in some paintings (including Joos van Cleve's *Holy Family*) and in a few it was possible to confirm the presence of 'copper resinate'.

Very commonly the paint consisted of verdigris mixed with lead-tin yellow or lead white, often both, in various proportions depending on the depth of shadow (Plate 19). This was found in Early Netherlandish and German School paintings throughout the fifteenth and early sixteenth centuries. Occasionally a little yellow ochre was included, depending on the colour required. In the work of some painters, including Gerard David, the Master of Saint Giles and the workshop of Quinten Massys, mixtures of azurite and lead-tin yellow (that is, without a green pigment) were used in areas of distant landscape, the bluer toned green giving the notion of distance. Azurite was also occasionally incorporated into the verdigris mixture, and sometimes, in the work of David for example, occurs with malachite, a pigment this painter used regularly.

The paintings from the workshop of the Master of 1518 show a complex pigment mixture for foliage and landscape: verdigris, azurite and malachite were found, mixed with a translucent yellow pigment, possibly an iron oxide or a yellow lake, or even a mixture of the two. Lead-tin yellow was used in the more opaque greens. The use of translucent yellow pigments in the greens is not uncommon in sixteenth-century Early Netherlandish paintings. Translucent yellow iron oxide or a yellow lake on a calcium-containing substrate are used for the darker greens in the landscapes in several paintings from the workshop of the Master of the Female Half-Lengths; azurite and lead-tin yellow give the lighter, opaque greens.

Some sixteenth-century painters did not use green pigment in the underpaint layers. The green background of the *Portrait of a Lady* (NG 4732) by Katharina de Hemessen of 1551 has a yellowish-grey underpaint, containing lead-tin yellow, lead white and black, but no green pigment. It is covered by a green glaze of partially dissolved verdigris, apparently containing drying oil only. Two paintings of the first half of the sixteenth century, Lucas van Leyden's *Portrait of a Man aged 38* (NG 3604) and Jakob Seisenegger's *Portrait of a Girl* (NG 4206), have red undermodelling extending under the green backgrounds:[149] in the latter portrait the undermodelling layer consists of red earth, lead white and black, while the green paint contains verdigris, lead-tin yellow and lead white, in two layers.

The paint medium

Documentary sources show that there was a long tradition of oil painting in Northern Europe; this is supported by a growing body of experimental results. Recent examinations of thirteenth- and fourteenth-century Norwegian altar frontals and the thirteenth-century Westminster Retable, for example, have revealed a very thorough understanding of the properties of drying oils and associated materials, as well as the pigments.[150] Since Theophilus was compiling his treatise (presumably based on practice, at least in part) at least a century earlier, this should not come as any surprise. It is borne out by the observations made during the investigations of other fourteenth-century panels from various parts of Northern Europe, including the Netherlands, exemplified perhaps by the highly refined practice revealed in the polyptych panels divided between Antwerp and Baltimore, referred to above. The highly sophisticated handling of paint and the exploitation of its rheological properties revealed in the work of fifteenth-century painters like Robert Campin, Jan van Eyck and Rogier van der Weyden are only logical developments of this in the hands of practitioners who were, in their different ways, particularly gifted.

A selection of the results obtained from examination of the paint medium used by Early Netherlandish and German School painters is given in the Table (pages 53–5).[151] This has shown that linseed oil was that most commonly used. In the fifteenth century walnut oil was sometimes used by painters of the Early Netherlandish School, usually for whites, blues or other pale, cool colours.[152] It occurs, for example, in the pale blue paint of the sky in *Saint Clement and a Donor* (NG 2669), a painting in the style of Simon Marmion. In the panel of *Music* (NG 756) from the workshop of Joos van Wassenhove (Justus of Ghent), walnut oil was identified in an area of white paint, whereas linseed oil was used for the green paint of the carpet. This pattern is

observed in other Netherlandish School paintings of the period so it may be that there was a tendency towards using the initially less yellowing walnut oil for pale cool colours, although the practice was certainly not observed consistently or universally: the Table shows several examples where walnut oil was used in red or green paint. The fact that *Music* and its companion, *Rhetoric(?)* (NG 755) were painted in Italy is interesting, but further study of the practice of Joos van Wassenhove and his workshop, to say nothing of both Netherlandish and Italian practice of the period, is necessary before its significance can be appreciated. In the sixteenth-century Netherlandish School paintings examined, walnut oil was occasionally found, particularly for areas of white paint. Walnut oil was rarely found in the German School paintings, although the particular bias of the collection must be borne in mind. It appears to have been used on occasion by the Master of the Life of the Virgin (see Table) and his workshop and the Master of the Saint Bartholomew Altarpiece: walnut oil was identified in Saint Dorothy's white overdress in *Saints Peter and Dorothy* (NG 707).

The limited use of egg tempera, generally confined to layers of underpaint or priming (discussed above), is seen in the products of several fifteenth-century Early Netherlandish workshops, including those of Campin, van der Weyden and Bouts.[153] It is also found occasionally in the work of later Netherlandish School painters, again usually in areas of underpaint, but too infrequently for any particular pattern to become apparent. While one must presume that a reason behind the use of egg may be the sound practice of applying an oil-rich paint over a leaner and rapidly drying underpaint, very little is known about the development of painting practice, and the use of egg tempera in particular, in the Low Countries during the period before 1400, or when Campin and his contemporaries would have been training.[154] Egg tempera seems to have been used in certain areas of pale-coloured flesh paint and white paint in Gerard David's *The Virgin and Child with Saints and Donor* (NG 1432), probably because egg tempera gives a cooler tone to white than oil and was preferred for this reason.[155] If so, it demonstrates a sophisticated understanding of the optical as well as the working properties of the different media. Egg tempera appears not to have been used in the Gallery's paintings of the German School, but it is not possible to say whether or not this finding applies to fifteenth- and sixteenth-century German School painting as a whole.

Examination of the paint medium has revealed numerous examples of the use of heat-prepolymerised or other forms of modified oils, used for pigments that dried poorly, or where particular body or richness and gloss was required, or simply, perhaps, where more rapid drying was necessary. Several examples are included in the Table (pages 53–5). The use of oil thickened by standing (possibly, but not necessarily, in the sun) can almost certainly be assumed; the polymerisation that begins to occur naturally results in no chemical alteration that can be detected by mass-spectrometry. At the other extreme, paint could be thinned by the addition of more ordinary, unpolymerised, drying oil, but an indication of the use of volatile diluents (like oil of turpentine, for instance) is difficult to find: there is no longer any detectable evidence for their presence in the paint film. There is circumstantial evidence that suitable diluents could be prepared, however. The distillation of alcohol had been known in Europe (initially in the south) from the twelfth century; the process had been much improved during the thirteenth, resulting in a reasonably strong solution known then as *aqua vitae*. With this it was possible to extract the water-insoluble essential oils from flowers, herbs and other substances and by the fourteenth century the process was of considerable pharmaceutical importance. During the fourteenth century, lavender and other flowers and herbs were cultivated on a large scale in Burgundy and other areas; it appears that there were eleven stills in Dijon devoted to such distillation.[156] Much of the product would have been for perfumery or medical purposes, but one should remember that, by the seventeenth century, spike oil (obtained from lavender) was regularly referred to as a diluent for certain purposes in painting and in theory there is no reason why it should not have been used before, assuming the solution was strong enough. It is interesting to note that the writer of a mid-fourteenth-century Netherlandish manuscript on the distillation of alcohol and the preparation of various 'waters' from flowers and other materials also copied down brief sum-

maries of the preparations of several 'oils'; these accounts, which are in Latin, are from an earlier alchemical source. They include the preparation of oil of turpentine – *terebintina* – by sublimation (of the resinous raw material presumably) to give an oil 'as clear as fountain water and it burns like fire'.[157] There is therefore no reason to suppose that volatile diluents were not available by the fifteenth century, although no documentary evidence has yet been found to associate their use with the application of paint.

The use of heat-bodied oil is particularly appropriate for pigments that dry poorly, such as black and red lake pigments: it was used in the black background of Lucas Cranach's *Portrait of a Man* (NG 1925), for instance. Concern for the drying properties of pigments was shown in other ways as well; for example, Cranach's black backgrounds are very thinly painted and have dried well, showing only a thin fine network of drying cracks. In order that the paint should dry properly a little verdigris was added to the lamp black pigment in the *Portrait of a Man* to act as a drier. In paintings by other artists azurite has been used similarly. A heat-bodied linseed oil was used by Stephan Lochner with the red lake pigment used to glaze red garments in *Saints Matthew, Catherine of Alexandria and John the Evangelist* (NG 705), but in addition a zinc salt (possibly white vitriol, zinc sulphate $ZnSO_4.7H_2O$) seems to have been incorporated, as suggested in sources like the Strasburg Manuscript, perhaps because it was thought to act as a drier, although one of the references to the material in the Strasburg Manuscript suggests that it was thought to help clarify or bleach the oil.

It can be seen from the Table that, in areas of red and green glazes, the medium present was very frequently a heat-bodied oil (usually linseed). Apart from its improved drying properties, heat pre-polymerised oil dries to form a smooth level film, free from brushmarks, and contributes a greater richness to the paint. This, together with the translucency of the verdigris used in many cases, would be sufficient to give a glaze-like finish to green paint without the use of a 'copper resinate' type of glaze; it is used for the upper, more glaze-like, green layer of the green carpet in Joos van Wassenhove's *Music*, while ordinary linseed oil was used for the green underpaint, which was also leaner in medium. Occasionally a trace of pine resin was found to be present in the paint, for example in Arnolfini's wife's dress in the Arnolfini Portrait; sometimes the medium was both heat-prepolymerised and had pine resin incorporated. It is not impossible that the addition of resin was thought (erroneously) to improve drying, but its principal effect would be to raise the refractive index of the paint medium a little so that it would approach even more closely that of the red lake pigment or verdigris particles, thus imparting greater colour saturation, transparency and richness to the glaze. It would also increase the gloss. The Strasburg Manuscript recommends that, for each colour, three drops of varnish should be added to the pigment, ground with oil; in practice traces of resin have only been found in red and green glazes, more frequently in the red.[158] Red and green glazes with a similar composition have also been observed on the thirteenth- and fourteenth-century Norwegian altar frontals mentioned above and it occurs in both Early Netherlandish and German School paintings, as the Table shows.

Lake pigments require a fairly high proportion of oil medium to acquire satisfactory working properties. In addition, paint containing pre-polymerised oil has a rather viscous or jelly-like consistency. If too much glaze is applied it may be necessary to blot it off, possibly with a cloth or even the fingers.[159] In several of the paintings, both Early Netherlandish and German, the red or green glazes had an uneven or 'spotty' appearance when the surface was examined under high magnification, as if blotting had been carried out. This was apparent in several of the red-glazed garments in *The Mass of Saint Hubert* (NG 253) from the workshop of the Master of the Life of the Virgin and in the red glaze on the purple cloak in *The Virgin and Child Enthroned with four Angels* (NG 6282) by Quinten Massys. Jan van Eyck blotted the green glaze on the woman's dress in the *Portrait of Giovanni (?) Arnolfini and his Wife*, possibly with his fingers; he certainly used a finger or thumb to smudge the edge of the shadow of the dog's hind leg, as a print remains as evidence.

The reduction in the complexity of the paint structure which took place after the first decade or two of the sixteenth century, concomitant

with developments in painting techniques, had several consequences. One was the possibility of a far speedier production of the painting. The technique observed in the works associated with the workshop of the Master of the Female Half-Lengths, for example, or the later works of Lucas Cranach, lends itself very well to workshop production. In a number of paintings by Cranach it was observed that, while they were soundly painted, the paint was very thin and economical in its construction. In several, areas of flesh were often simply red earth pigment very thinly scumbled over a lead white underpaint, barely tinting it. Only in darker toned flesh, such as that of the Bronze Age men in *The Close of the Silver Age* (NG 3922), was a slightly more solid paint (red earth with lead white and black) used. In the *Portrait of a Woman* (NG 291, Plate 20), an idealised 'portrait', opaque highlights on the woman's dark red dress consist of vermilion painted over the black paint of the background. A layer of red lake paint glazed directly over the black background gives the modelling; the black paint is allowed to show through to produce areas of shadow in the folds. Workshop production based on economical painting methods is rather different from that implied by the re-use of compositions, drawings or figure types. It differs also from that resulting from division of labour. Perhaps, too, the more direct method of modelling connected with the more frequent use of black and white in underpaint or undermodelling layers, or added to areas of shadow, is less laborious in the long run, and also more easily and speedily reproduced in the workshop. The economic aspects of workshop production and painting techniques of the early seventeenth century have been the subject of some discussion;[160] perhaps the seeds were already present a hundred years or so before.

The features and consequences of simplification of the paint layer structure, observed in the work of Pieter Bruegel or Martin van Heemskerck, for example, were noted by Karel van Mander. He described the method in the phrase '*ten eersten opdoen*'; that is, applying the desired colour (pre-mixed on the palette) in a single layer over the drawing. He also remarked on the cheapness of such rapidly painted works from the workshop of Pieter Aertsen and others.[161] As the paint film becomes more transparent with time, however, the underdrawing and any pentimenti become very obvious; it appears that some of the consequences of using such thin paint were apparent even at the time. Attention has been drawn to the 's Hertogenbosch guild regulations of 1546 which demanded that, on panel, every colour should be 'first dead-coloured and thus on a double ground'.[162] The regulation may have been intended to prevent this method of painting.

Plate 20 Lucas Cranach the Elder, *Portrait of a Woman* (NG 291), probably 1520s. Beech, 35.9 × 25.1 cm.

After the first quarter of the sixteenth century, there were many more outside influences on German and Early Netherlandish methods of painting. In this discussion the similarities in approach between Early Netherlandish and German painting as a whole are rather more marked than the differences, but differences between the techniques of individual painters are already apparent. As the century advanced painters become very much more individualistic and this is mirrored in their methods of painting.

Notes and References

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3. It is possible to make some comparison based on documentary sources; for example, the accounts for the Banqueting House and theatre constructed at Greenwich in 1527 record payments for materials obtained in London for 'Master Hans'. See *Letters and Papers, foreign and domestic, of the reign of Henry VIII 1509–47*, ed. J.S. Brewer, J. Gairdner and R.H. Brodie, 21 vols, London 1862–1932, Vol. IV, part II, 1872, no. 3097 pp. 1390–1.
4. See, for example, *Antwerpse retabels, 15de–16de eeuw* 1993, cited in note 2; M. Baxandall, *The Limewood Sculptors of Renaissance Germany*, New Haven and London 1980.
5. See, for example, L. Campbell, 'The Art Market in the Southern Netherlands in the Fifteenth Century', *Burlington Magazine*, CXVIII, 1976, pp. 188–98; L.F. Jacobs, 'The Marketing and Standardization of South Netherlandish Carved Altarpieces: Limits on the Role of the Patron', *Art Bulletin*, LXXI, 2, 1989, pp. 208–29. For the reproduction of devotional images in the workshop of Dieric Bouts see M. Wolff, 'An Image of Compassion: Dieric Bouts's "Sorrowing Madonna"', *Art Institute of Chicago Museum Studies*, XV, 2, 1989, pp. 113–25.

A useful summary on the reproduction of images is given in J. Dunkerton, S. Foister, D. Gordon and N. Penny, *Giotto to Dürer: Early Renaissance Painting in the National Gallery*, London 1991, pp. 68–73.

6. A. Goovaerts, 'Les ordonnances données en 1480, à Tournai, aux métiers des peintres et des verriers', *Compte rendu des séances de la Commission royale d'histoire, ou Recueil de ses Bulletins*, 5e série, VI, 1896, pp. 97–182; clause 13, pp. 156–8.
7. For a brief discussion of the status of painters, the guild system, workshop structure and contracts see Dunkerton et al. 1991, cited in note 5, pp. 122–39. For Early Netherlandish guilds and workshop structure see L. Campbell, 'The Early Netherlandish Painters and their Workshops', *Le Dessin sous-jacent dans la peinture: Colloque III, 6–8 septembre 1979: Le problème Maître de Flémalle-Van der Weyden*, edited by D. Hollanders-Favart and R. Van Schoute, Louvain-la-Neuve 1979, pp. 43–61; references to statutes for the guilds in Antwerp, Bruges, Louvain, Mons, Tournai, Brussels and Dijon are given in note 1, p. 54. Brief extracts of guild regulations for Antwerp (1470, 1472, 1493), Tournai, Mons, Ghent, Mechelen and Rouen, as far as they relate to polychromed sculpture, are included in E. Vandamme, *De polychromie van gotische houtsculptuur in de zuidlijke Nederlanden: Materialen en technieken*, Brussels 1982, (*Verhandelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Klasse der Schone Kunsten*, Jaargang 44, no. 35), pp. 186–97. For German guilds and workshops see Baxandall 1980, cited in note 4, pp. 106–16; for published guild regulations see note 44, p. 229. See also H. Huth, *Künstler und Werkstatt der Spätgotik*, Augsburg 1923 (4th edn Darmstadt 1981), pp. 5–22; references to the regulations of a number of guilds, principally German, are given in note 7, pp. 87–8.
8. H. von Lösch, *Die kölner Zunfturkunden, nebst anderen kölner Gewerbeurkunden bis ... 1500*, 2 vols, Bonn 1907 (reprinted Düsseldorf 1984); Vol. 1, statutes of the Painters' guild, 1371–96, pp. 135–6; clause 1, p. 135; clause 3, p. 136. Painters', Glassworkers' and Sculptors' guild, 23 April 1449, pp. 137–41; clause 23, p. 140; clause 8, pp. 138–9: 'Vort sower einich werk geloifde so machen van olievarven, der en sall dat niet machen van wasservarven. Ind an weme man des gewair wurde, der sall gelden zo boissen vunf m. ind darzo besseronge des werks doin. Ouch wer geloifde so machen einich dink van vijnem gulde, der en sall des niet machen van gedeildem gulde under der boissen vurs.'
9. J.B. van der Straelen, *Jaarboek der vermaerde en konstryke gilde van Sint Lucas binnen de stad Antwerpen*, Antwerp 1855; statutes of 9 November 1470, clauses iv–vi, pp. 13–14. See also Vandamme 1982, cited in note 7, clauses iv–vi, p. 186. The Antwerp foot was, like that of many Netherlandish towns, divided into 11 inches; its metric equivalent is *c.*28.68 cm; see A. Martini, *Manuale di metrologia ossia misure, pesi e monete in uso attualmente e anticamente presso tutti i popoli*, Turin 1883, p. 38; see also H. Verougstraete-Marcq and R. Van Schoute, *Cadres et supports dans la peinture flamande aux 15e et 16e siècles*, Heure-le-Romain, 1989, pp. 76–81. It seems likely that 'wainscot' was oak timber of a particular grade and form, perhaps a plank or beam; see A. von Ulmann, 'Über die Qualitätsbestimmung im Holzhandel. Ein Beitrag zur Materialgeschichte des ausgehenden Mittelalters', *Sculptures médiévales allemandes: conservation et restauration* 1993, cited in note 2, pp. 223–32, especially pp. 226–8.
10. Van der Straelen 1855, cited in note 9, statutes of 30 July 1472, clause viii, p.19; Vandamme 1982, cited in note 7, clause viii, p. 188.
11. Van der Straelen 1855, ibid. statutes of 20 March 1493, clauses xiv–xv, pp. 33–4. See also Verougstraete-Marcq and Van Schoute 1989, cited in note 9, pp. 11–12.
12. Van der Straelen 1855, ibid. (1470), clause ix, p. 14; Vandamme 1982, cited in note 7, clause ix, p. 187.
13. Van der Straelen 1855, ibid. (1470), clauses x–xiv, pp. 14–15; Vandamme 1982, ibid., clauses x–xiv, p. 187. The clause apparently referring to applied relief gilding, no. xii, p. 15, reads: 'Item gheen folie oft tentvelle en sal men verwercken by fyn gout, ten sal geprint, gevult achter met semente, ende opgestelt met gout veruwe oft pourmuersel.'
14. Goovaerts 1896, cited in note 6, pp. 97–182. Clauses referring to gilding include no. 24, pp. 163–4; no. 31, p. 170; no. 44, pp. 178–80. By the fifteenth and sixteenth centuries the area around Liège, Dinant and Aachen had become an important centre for the brass-making industry. Brass is an alloy of copper and zinc; small percentages of lead and tin are usually also present in Flemish brass of this period; see R.F. Tylecote, *A History of Metallurgy*, 2nd edn London, 1992, pp. 84–5, 111.
15. Goovaerts 1896, ibid.; for example, for illuminators see clause 32, p. 171; playing cards, no. 34, pp. 172–3; images on paper, no. 35, pp. 173–4; modelled images, no. 36, pp. 174–5; wooden horses, carts, parrot perches, no. 37, p. 175.
16. Goovaerts 1896, ibid. clause 44, pp. 178–80. The list of pigments reads: 'blancq de plonc, chéruse, blanc et noir commun, et azur de Liége, vermeillon, mynne, roze, sinopre, lac, graynne, florée de warance, brésil, azur, chendre d'azur, florée, inde, lecquemous, foel, vert de gris, vert de montaigne, vert de vesie, vert de glay, machicot, orpieument, okere, brun d'ansoire, rouge commun, bolarménicq'. The identity of 'azur de Liége' is uncertain. 'Lac' may indeed indicate lac lake, but at this date it is conceivable that the name could simply signify a pigment of a particular colour and transparency. In the 'Table of Synonyms' Jehan le Begue compiled and included in his collection of manuscripts made in Paris in 1431, '*lacca*' is described as being prepared from a gum extracted from ivy, but early medieval writers perhaps reported a garbled and misunderstood description of sticklac, the source of lac dyestuff, the use of which appears to have been brought to the parts of the Near East

formerly under Roman domination by the Arabs in the mid-seventh century or thereabouts; these recipes were then transcribed uncritically by later scribes. It is probable that 'sinopre' is also a lake pigment, perhaps of a particular hue; its use as a glazing pigment is occasionally mentioned in contracts (see below, note 24) and it is thus unlikely to be identifiable with the red iron oxide pigment known in Italian and Latin as '*sinopia*'. Le Begue defines '*sinopis*' as 'redder than vermilion' and prepared from madder or '*lacha*', but its composition may have been quite variable. See M.P. Merrifield, *Original Treatises dating from the XIIth to XVIIIth Centuries on the Arts of Painting*, 2 vols., London 1849 (Dover reprint, New York, London 1967), Vol. 1, pp. 30, 35; 190–3; D.V. Thompson, *The Materials and Techniques of Medieval Painting*, London 1936 (Dover reprint, New York, London 1956), pp. 98, 109–11, 121–4, 127. 'Graynne' may be a lake prepared from shearings of cloth dyed with the scale insect kermes. By analogy with the pigment derived from the scum skimmed off the indigo-dyeing vat, 'flowers – *florée* – of indigo', 'florée de warance' may be a similar by-product of the madder vat, or may refer to a madder lake derived from shearings. 'Foel' is folium; probably, like litmus, it is derived from a species of lichen; see D. Cardon, *Guide des teintures naturelles: Plantes, lichens, champignons, mollusques et insectes*, Paris 1990, pp. 323–7. 'Vert de glay' has been identified as green earth, but it is more likely to have been a vegetable green of some sort.

17. Goovaerts 1896, ibid.; see for example clause 26, pp. 165–6; clause 30, pp. 169–70.
18. D. van de Casteele, 'Documents divers de la société S. Luc à Bruges. Première partie, Keuren', *Annales de la Société d'Emulation de Bruges*, 3rd series, I, 1866, pp. 5–54. For the law suit of 1458, see pp. 28–30; the law suit of 1463, pp. 30–3; the prohibition of oil, p. 33. See also D. Wolfthal, *The Beginnings of Netherlandish Canvas Painting: 1400–1530*, Cambridge 1989, pp. 6–12.
19. Van de Casteele 1866, ibid., pp. 30–3; Wolfthal 1989, ibid., pp. 7, 23–4.
20. P. Pino, *Dialogo di pittura*, Venice 1548, p. 20 recto: 'Il modo di colorire à guazzo è imperfetto, et più fragile, et à me non diletta, onde lasciamolo all' oltramontani, i quali sono privi della vera via.' 'Dipingere a guazzo' implied tempering the colours with an aqueous medium, such as gum or animal skin glue. For the various uses to which canvas was put see Wolfthal 1989, ibid., pp. 20–2, 31, 34. For a discussion of the relative quality and cheapness of *Tüchlein* in the Netherlands and Germany, see E.D. Bosshard, 'Tüchleinmalerei – eine billige Ersatztechnik?', *Zeitschrift für Kunstgeschichte*, XLV, 1982, pp. 31–42.
21. W. Schöne, *Dieric Bouts und seine Schule*, Berlin and Leipzig 1938, document 55, p. 240; see also documents 56–9, pp. 240–1.
22. Huth 1981, cited in note 7, pp. 36–54 and Plates 18–35; L. Campbell, 'Approaches to Petrus Christus', in *Petrus Christus in Renaissance Bruges: An Interdisciplinary Approach* 1995, cited in note 2, pp. 1–10, especially p. 6 (referring to A.-M. Bonenfant-Feytmans, 'Aert van den Bossche peintre du polyptyque des saints Crépin et Crépinien', *Université Libre de Bruxelles, Annales d'histoire de l'art et d'archéologie*, 13, 1991, pp. 43–58).
23. Schöne 1938, cited in note 21, documents 64–7, 69, 71, pp. 242–4. Other documents refer to the setting for the panels, the theological accuracy of the work and the fixing of a protective linen-covered framework in front of the one finished panel.
24. Vandamme 1982, cited in note 7, pp. 199–200, originally published by E. de Busscher, *Recherches sur les peintres gantois du XIV^e^ et XV^e^ siècles*, Ghent 1859, pp. 28–30. 'Sinopere' is discussed in note 16 above.
25. Vandamme 1982, cited in note 7, pp. 198–9; Huth 1981, cited in note 7, p. 110.
26. Huth 1981, cited in note 7, pp. 116–17.
27. Vandamme 1982, cited in note 7, pp. 206–7, originally published by A. de la Grange and L. Cloquet, *Etudes sur l'art à Tournai et sur les anciens artistes de cette ville*, Vol. 2, Tournai 1889, pp. 233–5.
28. *Dürer, Schriftlicher Nachlass*, ed. H. Rupprich, 3 vols, Berlin 1956–69 (cited hereafter as Rupprich); letter dated 28 August 1507, Vol. 1, 1956, pp. 64–5.
29. Rupprich 1956, ibid., Vol. 1, p. 152, lines 83–8: 'Mehr hab ich 14 stüber für 3 täfelein geben. Mehr 4 stüber zu waisen, darvon zu bereiten' (5 August 1520).
30. W.K. Zülch, *Der historische Grünewald: Mathis Gothardt Neithardt*, Munich 1938, pp. 373–5; see also B. Saran, *Matthias Grünewald: Mensch und Weltbild*, Munich 1972, pp. 210–13
31. Valentin Boltz wrote that 'Schiefergrün' was extracted from ores, one being better than the other: V. Boltz, *Illuminierbuch: wie man allerlei Farben bereiten, mischen und auftragen soll*, Basel 1549 (annotated edn Munich 1913; reprinted Schaan 1982), p. 76. It could be green earth or another iron or copper-containing green; see E.-L. Richter, 'Seltene Pigmente im Mittelalter', *Zeitschrift für Kunsttechnologie und Konservierung*, 2, 1, 1988, pp. 171–7. Pigments were frequently sold or described by the name of the place from which a particularly desirable quality could be obtained. 'Paris red' is thus a colour name, or a name for a class of lake pigment. The sources of dyestuff included brasilwood, lac and shearings of dyed cloth; see, for example, Boltz 1982, p. 61 (brasilwood); *The Strasburg Manuscript: a Medieval Painter's Handbook*, trans. V. and R. Borradaile, London 1966, pp. 34–5 (lac); the Nuremberg *Kunstbuch* [Nürnberger Stadtbibliothek, MS cent. VI, 89, mid-fifteenth century] in E.E. Ploss, *Ein Buch von alten Farben: Technologie der Textilfarben im Mittelalter mit einem Ausblick auf die festen Farben*, Heidelberg and Berlin 1962, no. li, pp. 113–14 (shearings).
32. B. Saran, 'Der Technologe und Farbchemiker "Matthias Grünewald"', *Maltechnik Restauro*, 78, 4, 1972, pp. 228–37. See also Saran 1972, cited in note 30. Saran identifies '*fellig bla*' as azurite.

33. M.J. Friedländer, *Early Netherlandish Painting*, 14 vols, trs. H. Norden, Leyden and Brussels 1967–76, Vol. IV, Plate 92; C. Périer-D'Ieteren, *Colyn de Coter et la technique picturale des peintres flamands du XV^e siècle*, Brussels 1985, fig. 127 and pp. 55–9, 141. This painting is thought to be a copy after a lost original by Robert Campin.
34. For a brief account of workshop practice see Dunkerton et al. 1991, cited in note 5, pp. 138–51; Campbell 1979, cited in note 7. Pieces of pigs' bladder might be used to cover prepared paint; see note 123 below.
35. *Oeuvres de Jean Lemaire de Belges*, ed. J. Stecher, 4 vols, Louvain 1882–91; Vol. IV, 1891.
36. E. Duverger and D. Duverger-Van de Velde, 'Jean Lemaire de Belges en de Schilderkunst. Een Bijdrage', *Jaarboek van het Koninklijk Museum voor Schone Kunsten Antwerpen*, 1967, pp. 37–78.
37. *Oeuvres de Jean Lemaire de Belges*, cited in note 35, Vol. III, 1885, p. 162; IV, p. 158; Duverger and Duverger-Van de Velde 1967, cited in note 36, p. 53.
38. *Oeuvres de Jean Lemaire de Belges*, cited in note 35, IV, p. 158; Duverger and Duverger-Van de Velde 1967, cited in note 36, p. 54. The list reads:
    'Inde, Azur vert, et Azur de Poulaine,
    d'Acre Azur fin, qui du feu n'ha peril,
    Et Vermillon, dont mainte boite est pleine.
    D'autres couleurs y ha abondamment:
    Lacque, Synope, et Poupre de haut prys:
    Fin Or molu, Or music, Orpieument,
    Carnation faite bien proprement:
    Ocre de Ruth, Machicot, Vert de gris,
    Vert de montaigne, et Rose de Paris,
    Bon blanc de plomb, Flourée de garance,
    Vernis de glace, en deux ou trois barilz,
    Et Noir de lampe, estant noir à oultrance.'
39. *Oeuvres de Jean Lemaire de Belges*, cited in note 35, III, pp. 162–3; Duverger and Duverger-Van de Velde 1967, cited in note 36, p. 54. Colyn de Coter's *Saint Luke painting the Virgin* shows a mussel shell, apparently containing blue pigment, on the shelf of the easel: see Périer-D'Ieteren 1985, cited in note 33, fig. 127.
40. E. Darmstaedter, *Berg-, Probir- und Kunstbüchlein*, Munich 1926.
41. See, for example, A. Wallert, 'Aquae conficiendae ad temperandos omnes colores: Manuscript in the Leiden University Library, Voss. Chym. Oct 6', *Technologia Artis*, 3, 1993, pp.134–46.
42. H. Lehmann-Haupt, *The Göttingen Modelbook*, Columbia 1972 (2nd edn 1978); see also R. Fuchs and D. Oltrogge, 'Utilisation d'un livre de modèles pour la reconstitution de la peinture de manuscrits: aspects historiques et physico-chimiques', *Pigments et colorants de l'Antiquité et du Moyen Age* (proceedings of an international colloquium of the Centre National de la Recherche Scientifique, Orléans, 5–8 December 1988), Paris 1990, pp. 309–23. See also H. and M. Roosen-Runge, *Das spätgotische Musterbuch des Stephan Schriber in des Bayerischen Staatsbibliothek München, Cod. Icon. 420*, Wiesbaden 1981; H.J. Leloux, 'Noordoostmiddelnederlands in Keulen: een Keuls manuskript met laatmiddeleeuwse recepten voor verf en inkt voor het schrijven en verluchten van boeken', *Driemaandelijkse Bladen*, 29, 1977, pp. 11–31, and A. Wallert, 'Instructions for Manuscript Illumination in a 15th Century Netherlandish Technical Treatise', *ACTA of the Congress on Medieval Manuscript Illumination in the Northern Netherlands, University of Utrecht, 10–13 December 1989*, Utrecht 1991, pp. 447–56 (both on Cologne, Historiches Archiv MS W 8° 293).
43. Boltz 1982, cited in note 31.
44. The Nuremberg *Kunstbuch* is one of three manuscripts published in Ploss 1962, cited in note 31, pp. 101–25. See also [London, British Library (British Museum) MS Sloane 345, first decade sixteenth century]: M.M. Van Dantzig, 'Een vijftiende eeuwsch receptenboek', *Oud Holland*, LIII, 1936, pp. 207–18, 269, and W.L. Braekman, *Medische en technische middelnederlandse recepten*, Ghent 1975, in which the manuscript is one of three published: for recipes concerned with materials used in painting, as well as dyeing and printing (including fabric printing) see pp. 165–87. For other collections see *Middelnederlandse verfrecepten voor miniaturen en "alderhande substancien"*, ed. W.L. Braekman, Brussels 1986 (Scripta – Mediaeval and Renaissance Texts and Studies – 18).
45. *Traktaat om kleuren te bereiden* [Antwerp, Plantin-Moretus Museum MS 253, sixteenth century]: E. Vandamme, 'Een 16e-eeuws Zuidnederlands receptenboek' *Jaarboek van het Koninklijk Museum voor Schone Kunsten Antwerpen*, 1974, pp. 101–37; this also includes a list of some other Netherlandish recipe books printed during the century. For lead-tin yellow see p. 116.
46. R. Borghini, *Il riposo*, Florence 1584, Book II, p. 209: 'Di Fiandra viene un giallo, detto giallorino fine, che ha in sè materia di piombo [lead]; e si adopra a colorire a olio.'
47. The varieties of lead-tin yellow, their links with glassmaking and pottery glazes and occurrences of the pigment are discussed in H. Kühn, 'Lead-Tin Yellow', *Artists' Pigments: A Handbook of their History and Characteristics*, Vol. 2, ed. A. Roy, Oxford 1993, pp. 83–112.
48. K. van Mander, *Het Schilder-Boeck waer in Voor eerst de leerlustighe lueght den grondt der Edel Vry Schilderconst in verscheyden deelen Wort Voorghedraghen ...*, Haarlem 1604; see also K. van Mander, *Den grondt der edel vry schilderconst*, ed. H. Miedema, 2 vols, Utrecht 1973. The most recent edition of the Lives is the English translation, with notes, by H. Miedema, *The Lives of the illustrious Netherlandish and German Painters*, 2 vols published, Doornspijk 1994–5. For a commentary on the theory and practice of painting in van Mander see H. Miedema, *Kunst, kunstenaar en kunstwerk bij Karel van Mander: een analyse van zijn levensbeschrijvingen*, Alphen aan den Rijn 1981.
49. This point was made by Catherine Reynolds in 'Panel and Parchment: Fifteenth-century Painters and Illuminators in the Netherlands', the second of the 1995 National Gallery Linbury Lectures held

on 4 October 1995.

50. Merrifield 1849, cited in note 16; apart from an introductory essay Vol. 1 is entirely devoted to the Le Begue manuscripts.
51. The Strasburg Manuscript: E. Berger, *Quellen und Technik der Fresko-, Oel und Tempera-Malerei des Mittelalters*, Munich 1897, pp. 143–76; *The Strasburg Manuscript*, Borradaile 1966, cited in note 31.
52. Wallert 1993, cited in note 41.
53. E.E. Ploss, 'Das Amberger Malerbüchlein. Zur Verfandtschaft der spätmhd. Farbrezepte', *Festschrift Herman Heimpel (Veröffentlichen des Max-Planck-Instituts für Geschichte*, 36) Göttingen 1972, pp. 693–703.
54. *Liber illuministarum* [Munich, Bayerisches Staatsbibliothek, Cgm. 821, first decade sixteenth century]: Berger 1897, cited in note 51, pp. 178–86. Extracts have been published by L. Rockinger, 'Zum baierische Schriftwesen im Mittelalter', *Abhandlungen der königlich bayerischen Akademie der Wissenschaften, historischen Classe*, XII, Munich 1872/3, Part 1, pp. 1–72, part 2, pp. 167–230.
55. Strasburg Manuscript: Berger 1897, cited in note 51, nos. 69–77, pp. 169–72; Borradaile 1966, cited in note 31, pp. 54–61. *Liber illuministarum* (Cgm. 821): Berger 1897, ibid., pp. 182, 184. MS Sloane 345: Dantzig 1936, cited in note 44, p. 217; Braekman 1975, cited in note 44, no. 507, pp. 167–8. Pigments should be first ground in water and allowed to dry (p. 168).
56. *Liber illuministarum* (Cgm. 821): Berger 1897, cited in note 54; preparation of panels and canvas p. 182; the pigments that can be ground in oil and kept under water, p. 184; these are: yellow ochre, malachite [*perkgrün*], Paris red, lead white, lead-tin yellow [*pleigel*], vermilion, minium, blue, Cassel earth, brown-red (an earth pigment), black, violet.
57. E. Ploss, *Studien zu den deutschen Maler- und Färberbüchern des Mittelalters*, Doctoral dissertation, Ludwig-Maximilians-Universität, Munich 1952, pp. 165–76, especially p. 169. This recipe is apparently older than that in the Strasburg Manuscript. The term 'slechtem oley' implies oils darkened by heating, according to Ploss.
58. Theophilus, [*De diversis artibus*] *De diversis artibus: the various arts*, ed. C.R. Dodwell, London 1961 (reprinted Oxford 1986), pp. 18–20 ; *On divers arts: the foremost medieval treatise on painting, glassmaking and metalwork*, trans. J.G. Hawthorne and C.S. Smith, Chicago 1963 (Dover reprint, New York and London 1979), pp. 27–9.
59. '*Liber diversarum arcium*' [Montpellier, Ecole de Médecine, MS 277, fourteenth–fifteenth century, text no. 17, ff. 81^{v}–100^{v}]: *Catalogue général des manuscrits des bibliothèques publiques des départements*, Vol. I, Paris 1849, pp. 394–9, 739–811; see pp. 788–92. Thanks are due to Dr Dominique Cardon for bringing this manuscript to the authors' attention.
60. '*Liber diversarum arcium*' 1849, ibid., pp. 790–1.
61. Of the woods used for German sculpture at this time, oak and, to some extent, walnut were used in the North and in the Netherlands (and also France and Burgundy, where the use of walnut was perhaps rather higher); lime was used in Swabia, Franconia, Bavaria and other areas, softwoods in the Tyrol and alpine regions. These divisions are not clearcut and there are variations within regions, particularly those in the east. See Baxandall 1980, cited in note 4, pp. 27–31; Colinart and Éveno 1993, cited in note 2, pp. 167–9.
62. A. Smith and M. Wyld, 'Altdorfer's "Christ taking Leave of His Mother"', *National Gallery Technical Bulletin*, 7, 1983, pp. 50–64, especially p. 53.
63. S. Foister, 'The Portrait of Alexander Mornauer', *Burlington Magazine*, CXXXIII, 1991, pp. 613–18; in this article the wood was identified as being a softwood, perhaps pine or fir: see note 5, p. 614.
64. Thanks are due to Dr Peter Klein, University of Hamburg, who identified the woods used for these panels by dendrochronological analysis.
65. P. Klein, 'Lucas Cranach und seine Werkstatt. Holzarten und dendrochronologische Analyse', *Lucas Cranach: Ein Maler-Unternehmer aus Franken*; ed. C. Grimm, J. Erichsen and E. Brockhoff, exhibition catalogue, Haus der Bayerischen Geschichte, Augsburg 1994 (published Regensburg 1994), pp. 194–200.
66. S. Foister, M. Wyld and A. Roy, 'Hans Holbein's *A Lady with a Squirrel and a Starling*', *National Gallery Technical Bulletin*, 15, 1994, pp. 6–19.
67. This appears to be commonly the case: see P. Klein, 'Dendrochronological Findings of the van Eyck-Christus-Bouts Group', *Petrus Christus in Renaissance Bruges: An Interdisciplinary Approach* 1995, cited in note 2, pp. 149–65; P. Klein, D. Echstein, T. Wazny and J. Bach, 'New Findings for the Dendrochronological Dating of Panel Paintings for the 15th to 17th century', *ICOM Committee for Conservation, 8th Triennial Meeting, Sydney, Australia, 6–11 September 1987; Preprints*, Los Angeles 1987, pp. 51–4.
68. Verougstraete-Marcq and Van Schoute 1989, cited in note 9, pp. 33–9, 49.
69. Verougstraete-Marcq and Van Schoute, ibid., pp. 52–3. There are two depictions of *Saint Luke painting the Virgin* by Martin van Heemskerck (in Haarlem, Frans Hals Museum, and Rennes, Musée de Beaux-Arts) where the panels being painted are shown unframed and painted up to their edges. That in Rennes shows the saint painting his picture on a panel that has a grooved cross-piece into which the top edge of the panel has been attached (the bottom edge is unclear).
70. L. Campbell and J. Dunkerton, 'A famous Gossaert rediscovered', *Burlington Magazine*, CXXXVIII, 1996, pp. 164–73. Traces of a bevelled edge are still apparent at the top of the panel.
71. Verougstraete-Marcq and Van Schoute, cited in note 9, pp. 39–53. Mouldings and decoration are discussed on pp. 60–7.
72. J. Dunkerton, A. Burnstock and A. Smith, 'Two Wings of an Altarpiece by Martin van Heemskerck', *National Gallery Technical Bulletin*, 12, 1988, pp. 16–35, especially p. 20.

73. 'Assemblage à queue d'aronde': Verougstraete-Marcq and Van Schoute, cited in note 9, pp. 41, 46, 67, 85–6.
74. This is discussed very briefly in Dunkerton et al. 1991, cited in note 5, pp. 30–5; further references are given in the notes. See also E. Vandamme, 'Verwantschappen tussen Schilderkunst en Polychromie tijdens de Late Middeleeuwen', *Jaarboek van het Koninklijk Museum voor Schone Kunsten Antwerpen*, 1984, pp. 27–37.
75. A very similar decoration on the back of the case of a sculpted Tyrolean altarpiece is illustrated in M. Serck-Dewaide, 'Examen et restauration du retable tyrolien de l'Adoration des Mages de 1496', *Sculptures médiévales allemandes: conservation et restauration*, 1993, cited in note 2, pp. 305–21; see p. 320.
76. The dark colour of the marbling in NG 1232 consisted of a layer of fine black pigment covered with a translucent brown layer in which EDX analysis revealed the presence of copper; this is therefore likely to be a deteriorated, copper-containing green glaze.
77. D. Gordon, A. Roy and M. Wyld, 'The Technique of the Wilton Diptych', and M. Wyld, 'The Recent Treatment of the Wilton Diptych', in D. Gordon, *Making and Meaning: The Wilton Diptych*, London 1993, pp. 74–87, especially pp. 74, 86–7. In this case the fibres were identified as parchment.
78. Verougstraete-Marcq and Van Schoute 1989, cited in note 9, pp. 53–4.
79. The presence of calcium carbonate was indicated by EDX analysis; the presence of animal-skin glue was confirmed on a number of occasions by FTIR, and occasionally by staining with Amido Black 10B reagents: see E. Martin, 'Some Improvements in Techniques of Analysis of Paint Media', *Studies in Conservation*, 22, 1977, pp. 63–7.
80. R.J. Gettens, E.W. Fitzhugh and R.L. Feller, 'Calcium Carbonate Whites', *Artists' Pigments: A Handbook of their History and Characteristics*, Vol. 2, 1993, cited in note 47, pp. 203–26, especially pp. 211–12.
81. Foister 1991, cited in note 63, note 29, p. 618. Identification carried out by X-ray diffraction, JCPDS file no. 11-78. A dolomite ground has also been reported on an altarpiece at Bopfingen, painted by Friedrich Herlin in 1474: see F. Rieber and R.E. Straub, 'The Herlin altarpiece at Bopfingen (1474): technique and condition of the painted wings', *Studies in Conservation*, 22, 1977, pp. 129–45, especially p. 135. Three polychromed sculptures from the southern Tyrol have also been found to have dolomite grounds; see Colinart and Éveno 1993, cited in note 2, p.160. Interestingly, the Tyrolean School *Death of the Virgin* (NG 4190), in which a ground of this type might also have been possible, has a calcium carbonate ground.
82. Dunkerton et al., 1991, cited in note 5, pp. 162–4.
83. Martin 1977, cited in note 79.
84. R. White, 'Medium Analysis of Campin Paintings in the National Gallery', paper given at the Robert Campin Symposium held at the National Gallery in March 1993, in course of publication. The use of egg tempera-containing underpaint appears to be confined to certain areas only in some of the paintings examined, but this may reflect the fact that the opportunities for examining the medium present in underpaint and priming layers were extremely limited, rather than the actual pattern of usage.
85. L. Campbell, D. Bomford, A. Roy and R. White, '*The Virgin and Child before a Firescreen*: History, Examination and Treatment', *National Gallery Technical Bulletin*, 15, 1994, pp. 20–35, especially p. 31. A similar layer has been reported in the *Entombment Triptych* (London, Courtauld Institute Galleries); see C. Villers and R. Bruce-Gardner, 'The Painting Technique of the Entombment Triptych attributed to Robert Campin/Master of Flémalle in the Courtauld Institute Galleries', paper given at the Robert Campin Symposium, in course of publication.
86. Foister, Wyld and Roy 1994, cited in note 66, pp. 8–9. In Holbein's portrait, *Christina of Denmark, Duchess of Milan* (NG 2475), of 1538, a mid-grey priming is present; in '*The Ambassadors*' the priming is a slightly darker grey.
87. EDX analysis suggested that the orange layer in the Tyrolean School *Death of the Virgin* (NG 4190) was an iron(III) oxide-containing clay mineral, i.e. bole. In this painting, the priming contained lead white alone; in the Master of Liesborn painting (NG 254), it consisted largely of lead white with a trace of lead-tin yellow.
88. M. Spring, 'The Technique and Materials of the Paintings attributed to Memling in the National Gallery, London', paper given at the Memling Symposium held in Bruges, 1995, in course of publication; see also the article on Rogier van der Weyden in this *Bulletin*, pp.68–86.
89. See Campbell et al. 1994, cited in note 85, pp. 30–2; Villers and Bruce-Gardner (in press), cited in note 85. A layer which may be similar is reported to be present in van Eyck's *Adoration of the Lamb* altarpiece; it is described as drying oil containing a little chalk and traces of red and black pigment: see Brinkman et al. 1984/85, cited in note 1, pp. 147–57; 162–66. It is worth noting that thin layers of white or pale flesh-coloured paint applied over a relatively dark underpaint appear cooler in colour.
90. Van Mander 1604, cited in note 48, ff. 47^{v}–48^{r}; 1973 edn, Vol. 1, pp. 257–8. For a commentary on van Mander's descriptions of the ground and priming (*primuersel*) layers see Miedema 1981, cited in note 48, pp. 182–3. The description van Mander gives of Hieronymus Bosch using a flesh-coloured priming is particularly well known (*Leven*, f. 216^{v}; 1994 edn. Vol. 1, pp. 124-5); however, in his *Christ Mocked (The Crowning with Thorns)* (NG 4744), painted in about 1500, Bosch used an extremely thin very pale grey priming.
91. Wolfthal 1989, cited in note 18, p. 50; D. Martens, 'A propos d'un "Tüchlein" flamand du XVI^{e} siècle conservé au Louvre', *La Revue du Louvre et des*

Musées de France, XXXVI, 6, 1986, pp. 394–402, especially p. 398. In his discussion of a group of *Tüchlein* paintings, Martens assumes that 97–98% of paintings of this type may have been lost, although he gives no evidence to support this figure.

92. D. Bomford, A. Roy and A. Smith, 'The Techniques of Dieric Bouts: Two Paintings Contrasted', *National Gallery Technical Bulletin*, 10, 1986, pp. 39–57; A. Roy, 'The Technique of a "Tüchlein" by Quinten Massys', *National Gallery Technical Bulletin*, 12, 1988, pp. 36–43.
93. Several canvases from the two cycles are in the Wallraf-Richartz Museum, Cologne; see Zehnder 1990, cited in note 2, pp. 382–95; for analytical results from one of the Legend of Saint Ursula canvases see p. 639.
94. Wolfthal 1989, cited in note 18, pp. 20–2, 31.
95. Van Asperen de Boer, Faries and Filedt Kok 1986, cited in note 2, pp. 107–8.
96. H. Sachs, *Eygentliche Beschreibung aller Stände auff Erden*, with woodcuts by (and after) Jost Amman, Frankfurt am Main 1568: 'Der Handmaler', f. G ii (Dover facsimile reprint New York/London 1973, p. 30).
97. Verougstraete-Marcq and Van Schoute 1989, cited in note 9, p. 56.
98. Merrifield 1849, cited in note 16, pp. 88–91; Verougstraete-Marcq and Van Schoute 1989, cited in note 9, p. 56; Wolfthal 1989, cited in note 19, p. 24.
99. Verougstraete-Marcq and Van Schoute 1989, cited in note 9, p. 56–8.
100. This assumes that the nail holes are original, which need not be so: see Bomford et al. 1986, cited in note 92, p. 46. An irregular line of nail holes, following the distortion of the canvas which resulted from its having been stretched, is present along the top edge of the Massys *Tüchlein* (NG 3664); whether these relate to the painting stage or to the framing stage is not clear as the other edges show no signs of any stretching process: see Roy 1988, cited in note 92, pp. 36, 38.
101. M. Davies, *Early Netherlandish School, National Gallery Catalogues,* 3rd edn, London 1968, pp. 178–9.
102. Dunkerton et al. 1988, cited in note 72, pp. 26–8.
103. J.R.J. van Asperen de Boer, *Infra-red Reflectography. A Contribution to the Examination of earlier European Paintings*, doctoral thesis, University of Amsterdam 1970. For a description of the infra-red reflectography equipment used at the National Gallery, see R. Billinge, J. Cupitt, N. Dessipris and D. Saunders, 'A note on an improved procedure for the rapid assembly of infra-red reflectogram mosaics', *Studies in Conservation*, 38, 1993, pp. 92–8. The literature on underdrawings and interpretations of details of their different styles is very large and the reader is referred to the proceedings of the biennial series of conferences entitled *Le dessin sous-jacent dans la peinture*, cited in note 2.
104. L. Campbell, 'Memling's Creative Processes as seen in his Paintings in the National Gallery, London', *Le dessin sous-jacent dans la peinture. Colloque X: Le dessin sous-jacent dans le processus de création; Université Catholique de Louvain, 5–7 septembre 1993*, ed. H. Verougstraete and R. Van Schoute, Louvain-la-Neuve 1995, pp. 149–52.
105. R. Billinge and S. Foister, 'The Underdrawing of Altdorfer's "Christ taking Leave of his Mother"', *Burlington Magazine*, CXXXV, 1993, pp. 687–91.
106. Dunkerton et al. 1988, cited in note 72, p. 26.
107. R. Grosshans, 'Simon Marmion and the Saint Bertin Altarpiece: Notes on the Genesis of the Painting', *Margaret of York, Simon Marmion and "The Visions of Tondal"* (papers delivered at a symposium held at the J. Paul Getty Museum, 21–24 June, 1990), ed. T. Kren, Malibu 1992, pp. 233–42, especially p. 236.
108. R. Billinge, 'The National Gallery-Leverhulme Infra-red Reflectography Project: an Overview', *Le dessin sous-jacent dans la peinture. Colloque XI: Dessin sous-jacent et technologie dans la peinture – Perspectives; Université Catholique de Louvain, 14–16 septembre 1995*, in press.
109. Foister et al. 1994, cited in note 66, pp. 7, 16; M. Ainsworth, 'Paternes for Phiosioneamyes', *Burlington Magazine*, CXXXII, 1990, pp. 173–86, especially note 25, p. 176.
110. *Dynasties: Painting in Tudor and Jacobean England, 1530–1630*, ed. K. Hearn, exhibition catalogue, Tate Gallery, London 1995/6, pp. 146–50; Dunkerton et al. 1991, cited in note 5, p. 145.
111. Campbell 1995, cited in note 104, p. 151 and Plate 74.
112. Billinge and Foister 1993, cited in note 105, pp. 687–91.
113. Bomford et al. 1986, cited in note 92, p. 46; Dunkerton et al. 1988, cited in note 72, p. 26 and Plate 3a, p. 33.
114. M. Zerdoun Bat-Yehouda, *Les encres noires au Moyen Age*, Paris 1983, pp. 186–211.
115. Iron identified by EDX analysis.
116. L. Kockaert, 'Note on the Painting Technique of Melchior Broederlam', *ICOM Committee for Conservation, 7th Triennial Meeting, Copenhagen, 10–14 September 1984*, Paris 1984, pp. 84.19.7–10.
117. H.M.J. Nieuwdorp, R. Guislain-Wittermann and L. Kockaert, 'Het pre-eyckiaanse vierluik Antwerpen-Baltimore. Historisch en technologisch onderzoek', *Bulletin de l'Institut Royal du Patrimoine Artistique*, XX, 1984/85, pp. 70–98; E.M. Gifford, 'A Pre-Eyckian Altarpiece in the Context of European Painting Materials and Technique c.1400', *Flanders in a European Perspective: Manuscript Illumination c.1400 in Flanders and Abroad. Proceedings of an International Colloquium, Leuven, September 1993*; ed. M. Smeyers and B. Cardon, Louvain 1995, pp. 357–70.
118. Villers and Bruce-Gardner (in press), cited in note 85.
119. J.R.J. van Asperen de Boer, 'On the Painting Technique of the Master of Flémalle panels', paper given at the Robert Campin Symposium held at the National Gallery in March 1993, in course of publication.
120. The clearest explanation of water gilding, albeit in an Italian context, is in D. Bomford, J. Dunkerton, D. Gordon, A. Roy and J. Kirby, *Art in the*

Making: Italian Painting before 1400, exhibition catalogue, National Gallery, London 1989, pp. 21–6; mordant gilding and shell gold are discussed on pp. 43–8.

121. *Liber illuministarum* (Cgm. 821): Berger 1897, cited in note 54, pp. 179–80. Interestingly, a little drying oil was incorporated into the iron oxide pigment mixture, perhaps to provide something of the unctuous greasy quality of Armenian bole itself.
122. See, for example, *Liber illuministarum* (Cgm. 821): Berger 1897, cited in note 54, p. 181; MS Sloane 345: Dantzig 1936, cited in note 44, pp. 209–13; Braekman 1975, cited in note 44, nos. 501–5, pp. 166–7; Strasburg Manuscript: Berger 1897, cited in note 51, p. 171–4; Borradaile 1966, cited in note 31, pp. 60–7. For the use of pieces of bladder to prevent skin-formation on oil mordants, varnishes and colours see the Strasburg Manuscript: Berger 1897, no. 77, p. 172; and Borradaile 1966, cited in note 31, pp. 60–1.
123. The method of applying the decoration is described, very briefly, in MS Sloane 345: Dantzig 1936, cited in note 44, pp. 208–9; Braekman 1975, cited in note 44, no. 499, p. 166.
124. Villers and Bruce-Gardner (in press), cited in note 85; it appears that mordant gilding was used in this case.
125. For occurrences on Early Netherlandish panels see van Asperen de Boer (in press), cited in note 119; E. Vandamme, 'Technieken voor Reliëfapplikaties in de 14e-eeuwse Schilderkunst der Nederlanden', *Jaarboek van het Koninklijk Museum voor Schone Kunsten Antwerpen*, 1971, pp. 7–12.
126. *Liber illuministarum* (Cgm. 821): Berger 1897, cited in note 54, pp. 180–1. For a detailed description of the use of applied relief brocade on a polychromed sculpted altarpiece, see K.-W. Bachmann, E. Oellermann and J. Taubert, 'The Conservation and Technique of the Herlin Altarpiece (1466)', *Studies in Conservation*, 15, 1970, pp. 327–69; M. Broekman-Bokstijn, J.R.J. van Asperen de Boer, E.H. van 't Hul-Ehrnreich and C.M. Verduyn-Groen, 'The Scientific Examination of the Polychromed Sculpture in the Herlin Altarpiece', *Studies in Conservation*, 15, 1970, pp. 370–400.
127. Beeswax has been identified in the filling used for the relief brocade on a Strasburg School limewood relief of *The Virgin with Two Angels* of about 1480 (Saverne, Musée d'Art et d'Histoire de la Ville); other fillings identified have been chalk-based (where there was no subsequent gilding) or have contained a pigment-rich, orange-brown oil-based mixture. See Colinart and Éveno 1993, cited in note 2, pp. 162–4. As far as the National Gallery paintings are concerned, it is worth noting that, particularly where the paintings had been transferred to other supports, the applied relief brocade was sometimes in such poor condition that it was hard to recognise: the tin leaf was found to have degraded completely and was only identifiable by the presence of tin revealed by EDX examination of paint cross-sections.
128. Analysis by EDX. See also Colinart and Éveno 1993, ibid., pp. 164–5; M. Éveno and E. Martin, 'Les feuilles mixtes or-argent en peinture de chevalet', *ICOM Committee for Conservation, 11th Triennial Meeting, Edinburgh, Scotland, 1–6 September 1996; Preprints*, ed. J. Bridgeland, London 1996, pp. 355–9.
129. Dunkerton et al. 1991, cited in note 5, p. 182.
130. *Traktaat om kleuren te bereiden*: Vandamme 1974, cited in note 45, p. 116.
131. J. Plesters, 'Ultramarine Blue, Natural and Artificial', *Artists' Pigments*, Vol. 2, 1993, cited in note 47, pp. 37–65.
132. Rupprich 1956, cited in note 28, Vol. 1, p. 165, lines 156–8: 'Ich hab dem für 12 ducaten kunst für ein uncz gut vltermarin geben' (11 February 1521); for the purchase of Cassel earth (24 November 1520) see p. 162, line 49. Ultramarine, although dear, was not always so costly: Lucas Cranach is said to have paid only one florin (about one-sixteenth the price) for a pound in 1505, although the quality of the material purchased is unknown. See *Lucas Cranach: Ein Maler-Unternehmer aus Franken*, cited in note 65, cat. no. 16, p. 230. Dürer recommended that good ultramarine should be underpainted by a cheaper grade: see Rupprich 1956, p. 216.
133. Of the German School paintings, ultramarine was identified in the Lochner (see p. 63) and the Tyrolean School painting, NG 4190. This may not reflect its use in German painting as a whole; certainly its use is more common in Cologne School painting than this survey would suggest: see Kühn 1990, cited in note 2, pp. 92–5.
134. R.J. Gettens and E. West Fitzhugh, 'Azurite and Blue Verditer', *Artists' Pigments*, Vol. 2, 1993, cited in note 47, pp. 23–35.
135. Campbell et al. 1994, cited in note 85, pp. 30–3.
136. J.R.J. van Asperen de Boer, 'An Examination of Particle Size Distributions of Azurite and Natural Ultramarine in Some Early Netherlandish Paintings', *Studies in Conservation*, 19, 1974, pp. 233–43.
137. B. Mühlethaler and J. Thissen, 'Smalt', *Artists' Pigments*, Vol. 2, 1993, cited in note 47, pp. 113–30; Bomford et al. 1986, cited in note 92, p. 50.
138. Cardon 1990, cited in note 16, pp. 133–51; L. Diegmann, 'Eine deutsche Farbenindustrie im Mittelalter', *Technischen Mitteilungen für Malerei*, 53, 1937, 123–5; Bomford et al. 1986, cited in note 92, pp. 50–1.
139. Bomford et al. 1986, ibid., pp. 50–1.
140. D. Bomford and J. Kirby, 'Two Panels by the Master of Saint Giles', *National Gallery Technical Bulletin*, 1, 1977, pp. 46–56 and Plate 1, pp. 14–15.
141. Campbell and Dunkerton 1996, cited in note 70, p. 170. A little azurite is also present.
142. Calcium, aluminium and silicon were identified in the substrate of the lake by EDX. See D. Saunders and J. Kirby, 'Light-induced Colour Changes in Red and Yellow Lake Pigments', *National Gallery Technical Bulletin*, 15, 1994, pp. 79–97, especially pp. 83–4, 88–9.
143. J. Kirby and R. White, 'The Identification of Red

Lake Pigment Dyestuffs and a Discussion of their Use', *National Gallery Technical Bulletin*, 17, 1996, pp. 56–80, especially pp. 64–73.

144. R.J. Gettens, R.L. Feller and W.T. Chase, 'Vermilion and Cinnabar', *Artists' Pigments*, Vol. 2, 1993, cited in note 47, pp. 159–82.
145. P.W.F. Brinkman et al. 1988/89, cited in note 1, pp. 36–8, 48.
146. E. Martin and M. Eveno, 'Contribution to the study of old green copper pigments in easel paintings', *3rd International Conference on Non-Destructive Testing, Microanalytical Methods and Environment Evaluation for Study and Conservation of Works of Art, Viterbo 4–8 October 1992: Preprints*, Viterbo 1992, pp. 781–91; Richter 1988, cited in note 31, pp. 171–7.
147. H. Kühn, 'Verdigris and Copper Resinate', *Artists' Pigments*, Vol. 2, 1993, cited in note 47, pp. 131–58.
148. J. Pilc and R. White, 'The Application of FTIR-Microscopy to the Analysis of Paint Binders in Easel Paintings', *National Gallery Technical Bulletin*, 16, 1995, pp. 73–84, especially p. 82.
149. Filedt Kok 1978, cited in note 2, pp. 58–60, 144–8.
150. R. White, 'Analyses of Norwegian medieval paint media. A preliminary report', *Norwegian Medieval Altar Frontals and Related Material: Papers from the Conference in Oslo, 16–19 December 1989*, published as *Institutum Romanum Norwegiae Acta ad Archaeologiam et Artiam Historiam Pertinentia*, XI, 1995, pp. 127–35; and U. Plahter, 'Colours and pigments used in Norwegian altar frontals', ibid., pp. 111–26.
151. While every painting was examined as thoroughly as possible, the areas sampled were dictated by the condition of the picture; often sampling was restricted to one or two areas only, from a damage or from the edge of the painting, and the survey is inevitably limited as a result. It gives a broad picture of how the materials commonly employed as paint media were used, but it is not possible to say precisely how the use of egg tempera, in particular, varied or developed. In addition to instrumental analysis, the presence of protein was confirmed by a ninhydrin and/or modified Ehrlich test in those cases where ambiguous results had been obtained.
152. It has been suggested that proteinaceous media, like animal-skin glue or egg white, were used for areas of pure blue, particularly where ultramarine was used: see, for example, in the case of van Eyck, E.M. Gifford, 'Jan van Eyck's *Annunciation*: Development and Alterations', *Le dessin sous-jacent dans la peinture. Colloque X: Le dessin sous-jacent dans le processus de création* 1995, cited in note 104, pp. 85–93, particularly p. 86. This is even obliquely referred to, in garbled fashion, in the '*Liber diversarum arcium*' discussed above ('*Liber diversarum arcium*' 1849, cited in note 59, p. 790). The possibilities for examining suitable areas of blue paint were limited but even allowing for the possibility of contamination by conservation treatment, there was very little evidence for the use of any medium other than oil for blue paint. In the case of the *Mater Dolorosa* (NG 711) from the workshop of Dieric Bouts, the Virgin's blue robe was painted with azurite in linseed oil, but examination by FTIR microscopy revealed the presence of traces of animal-skin glue, closely associated with the surface of the azurite particles, as if the pigment had been ground with an aqueous soloution of glue (and had then been allowed to dry) before it was ground with the oil. A similar phenomenon has been reported in two other paintings, Roger van der Weyden's *The Magdalen Reading* (NG 654) and *The Virgin and Child with Two Angels* (NG 2608) by a follower of Robert Campin: see White (in press), cited in note 84. No cases of a blue paint in an essentially aqueous proteinaceous medium alone have yet been identified.
153. White, cited in note 84; Campbell et al. 1994, cited in note 85, pp. 31–2.
154. See for example the discussions in Kockaert 1984, cited in note 116; Nieuwdorp, Guislain-Wittermann and Kockaert 1984/85, cited in note 117; Gifford 1995, cited in note 117.
155. M. Wyld, A. Roy and A. Smith, 'Gerard David's "The Virgin and Child with Saints and a Donor"', *National Gallery Technical Bulletin*, 3, 1979, pp. 51–65, especially pp. 62–3.
156. R.J. Forbes, *A Short History of the Art of Distillation*, Leiden 1948, pp. 91–2, referring to A. Baudot, *La pharmacie en Bourgogne* (dissertation, University of Paris), Dijon 1905.
157. L.J. Vandewiele, 'De eerste publikatie in het Nederlands over alkohol', *Pharmaceutisch Tijdschrift voor België*, 41, 4, 1964, pp. 65–80, especially p. 79, lines 453–5. (On one of 17 treatises in MS 15624–15641, mid-fourteenth century, in the Bibliothèque Royale de Bruxelles.) The fact that the distillate was inflammable would probably have been its most interesting feature in the thirteenth and fourteenth centuries.
158. Strasburg Manuscript: Berger 1897, cited in note 51, no. 71, p. 170; Borradaile 1966, cited in note 31, pp. 54–5.
159. J. Murrell, 'John Guillim's Book: A Heraldic Painter's *Vade Mecum*', *The Walpole Society*, LVII, 1993/94, pp. 1–51, especially p. 25: 'To Make a Red Rose'.
160. J.M. Montias, 'Cost and value in seventeenth-century Dutch art', *Art History*, 10, 1987, pp. 455–66.
161. Miedema 1981, cited in note 48, pp. 30–1, 186–7; Van Mander 1604, cited in note 48, ff.48^{r} (1973 edn, Vol. 1, pp. 258–9); ff.210^{v}, 210^{v}, 216^{v}, 243^{v}–4^{v} (1994 edn, Vol. 1, pp. 100–1, 124–5, 232–6).
162. H. Miedema, 'Over kwaliteitsvoorschriften in het St. Lucasgilde; over "doodverf"', *Oud Holland*, 101, 1987, pp. 141–7.

Table 1: The binding medium in Early Netherlandish and German paintings

ARTIST	TITLE OF PAINTING	DATE	SAMPLE	MEDIUM
EARLY NETHERLANDISH SCHOOL				
GREEN				
Jan van Eyck	*Giovanni (?) Arnolfini and his Wife ('The Arnolfini Portrait')* NG 186	1434	green drapery of wife's dress	heat-bodied linseed oil + pine resin medium (not 'copper resinate')
Attributed to Joos van Wassenhove	*Music* NG 756	*c.* 1480	opaque green of carpet	linseed oil
Workshop of Joos van Wassenhove	*Rhetoric (?)* NG 755	*c.* 1480	opaque green, second step from bottom, right-hand side	linseed oil
Gerard David	*Christ Nailed to the Cross* NG 3067	probably 1480s	green sleeve of man nailing Christ's feet to the cross	walnut oil
	Canon Bernardinus de Salviatis and Three Saints NG 1045	after 1501	green foliage, left-hand side	linseed oil
	An Ecclesiastic Praying NG 710	*c.* 1515	brownish-green grass	linseed oil + a little pine resin (probably not 'copper resinate')
Joos van Cleve	*The Holy Family* NG 2603	*c.* 1515–20	green background: opaque, yellowish-green underpaint	linseed oil
			green background: translucent dark green upper paint layer	heat-bodied linseed oil + pine resin ('copper resinate')
RED				
Jan van Eyck	*Giovanni (?) Arnolfini and his Wife* NG 186	1434	red lake paint of bed canopy	linseed oil
Hieronymus Bosch	*Christ Mocked (The Crowning with Thorns)* NG 4744	*c.* 1500	red lake paint of right-hand man's robe	oil + some resin (FTIR only)
			red glaze paint of headdress of figure in bottom left corner	linseed oil + pine resin
			orange red opaque underpaint of headdress	probably linseed oil
Jan Gossaert	*The Adoration of the Kings* NG 2790	*c.* 1510	red glaze paint on wing of angel	linseed oil + pine resin
	A Little Girl NG 2211	*c.* 1530	red lake glaze on girl's bodice	linseed oil + a little pine resin
Joos van Cleve	*The Holy Family* NG 2603	*c.* 1515–20	deep red lake-containing paint of Virgin's cloak, right-hand edge	heat-bodied linseed oil + pine resin
Quinten Massys	*The Virgin and Child with Saints* NG 3664	probably *c.* 1515–25	red of Saint Barbara's robe	glue distemper [*Tüchlein*]
Ambrosius Benson	*The Magdalen Reading* NG 655	*c.* 1525	red glaze paint of drapery	walnut oil
Marinus van Reymerswaele	*Two Tax Gatherers* NG 944	probably *c.* 1540	red lake glaze of purplish robe of left-hand man	heat-bodied linseed oil
WHITE				
Attributed to Joos van Wassenhove	*Music* NG 756	*c.* 1480	white highlight on sleeve tassel	walnut oil
Gerard David	*Christ Nailed to the Cross* NG 3067	probably 1480s	flesh paint of Christ's thigh	walnut oil
Follower of Hugo van der Goes	*The Virgin and Child* NG 3066	*c.* 1485	white cloth	heat-bodied linseed oil
Jan Gossaert	*An Elderly Couple* NG 1689	*c.* 1520	woman's greyish-white headdress	walnut oil
	Man with a Rosary NG 656	*c.* 1525–30	greyish white of architecture, left-hand side	walnut oil

ARTIST	TITLE OF PAINTING	DATE	SAMPLE	MEDIUM
Attributed to Quinten Massys	*A Grotesque Old Woman* NG 5769	*c.* 1525–30	white paint of headdress	walnut oil
Marinus van Reymerswaele	*Two Tax Gatherers* NG 944	probably *c.* 1540	warm white of documents	linseed oil

BLUE

Simon Marmion	*The Soul of Saint Bertin carried up to God* NG 1302	finished by 1459	greenish-blue background	linseed oil
Style of Marmion	*Saint Clement and a Donor* NG 2669	probably 1480–90	pale blue sky, to left of Saint Clement's head	walnut oil
Gerard David	*Christ Nailed to the Cross* NG 3067	probably 1480s	blue sky	walnut oil
	Canon Bernardinus de Salviatis and Three Saints NG 1045	after 1501	blue sky, right-hand side	linseed oil
Quinten Massys	*The Virgin and Child with Saints* NG 3664	probably *c.* 1515–25	blue of Saint Catherine's dress	glue distemper [*Tüchlein*]
After Quinten Massys	*The Virgin* NG 295.2	probably *c.* 1530	blue of the Virgin's robe, right upper arm	walnut oil
Marinus van Reymerswaele	*Two Tax Gatherers* NG 944	probably *c.* 1540	rather lean blue underpaint of purplish robe of left-hand man	linseed oil

Early German School

GREEN

Stephan Lochner	*Saints Matthew, Catherine of Alexandria and John the Evangelist* NG 705	*c.* 1445	green of Saint Matthew's robe (obverse)	strongly heat-bodied linseed oil + pine resin medium (not 'copper resinate')
			dark green, translucent paint of foliage (reverse)	heat-bodied linseed oil + pine resin medium (not 'copper resinate')
Master of the Life of the Virgin	*The Presentation in the Temple* NG 706	probably *c.* 1460–75	green drapery of dress of woman on far left	linseed oil
Attributed to Michael Pacher	*The Virgin and Child Enthroned with Angels and Saints* NG 5786	*c.* 1475	green tile	linseed oil
Workshop of the Master of the Life of the Virgin	*The Conversion of Saint Hubert* NG 252	probably *c.* 1480–5	green foliage	walnut oil
North German School	*Christ carrying the Cross* NG 2160	*c.* 1490–1510	green foliage of bush, adjacent to sword	linseed oil + pine resin medium, FTIR suggests an inhomogeneous mixture (not 'copper resinate')
Circle of the Master of Liesborn	*Saint Dorothy* NG 2152	late 15th century	discoloured green vegetation	linseed oil + pine resin ('copper resinate')

RED

Stephan Lochner	*Saints Matthew, Catherine of Alexandria and John the Evangelist* NG 705	*c.* 1445	rich red cloak of Saint Catherine (obverse)	heat-bodied linseed oil + a little pine resin
			bright red lake paint of lining of Saint Cordula's (?) cloak (reverse)	heat-bodied linseed oil + some pine resin
Cologne School	*Portrait of a Woman* NG 2670	*c.* 1495	red lake-containing paint of hanging behind the woman, top edge	heat-bodied linseed oil + some pine resin
North German School	*Christ carrying the Cross* NG 2160	*c.* 1490–1510	red glaze paint of right-hand figure's tunic	heat-bodied linseed oil

ARTIST	TITLE OF PAINTING	DATE	SAMPLE	MEDIUM
Master of Cappenberg (Jan Baegert?)	*Christ before Pilate* NG 2154	*c.* 1520	red paint of border	linseed oil
WHITE				
Stephan Lochner	*Saints Matthew, Catherine of Alexandria and John the Evangelist* NG 705	*c.* 1445	white highlight of drapery of angel, left-hand corner (obverse)	linseed oil
			white background to right of Saint Gregory's shoulder (reverse)	linseed oil
Master of the Life of the Virgin	*The Presentation in the Temple* NG 706	probably *c.* 1460–75	white of floor tile	heat-bodied walnut oil
Workshop of the Master of the Life of the Virgin	*The Conversion of Saint Hubert* NG 252	probably *c.* 1480–5	warm white paint of fur	linseed oil
	The Mass of Saint Hubert NG 253	probably 1480–5	thick white paint of feather of angel's wing	heat-bodied walnut oil
	Saints Jerome, Bernard (?), Giles and Benedict (?) NG 250	probably 1485–90	white cloth, hanging from crozier	heat-bodied linseed oil
Master of the Saint Bartholomew Altarpiece	*The Deposition* NG 6470	*c.* 1500–5	white highlight of drapery	linseed oil
Circle of the Master of the Legend of Saint Ursula	*Saint Lawrence showing the Prefect the Treasures of the Church* NG 3665	*c.* 1510	yellow turban of Prefect	linseed oil
BLUE				
Stephan Lochner	*Saints Matthew, Catherine of Alexandria and John the Evangelist* NG 705	*c.* 1445	pale blue-grey drapery of Saint Gregory's robe (reverse)	linseed oil
Workshop of the Master of the Saint Bartholomew Altarpiece	*The Virgin and Child in Glory with Saint James the Great and Saint Cecilia* NG 6497	*c.* 1480	blue sky	linseed oil
Workshop of the Master of the Life of the Virgin	*Saints Augustine, Hubert, Ludger (?) and Gereon (?)* NG 251	probably 1485–90	blue shield, right-hand edge	linseed oil
Master of the Saint Bartholomew Altarpiece	*Saints Peter and Dorothy* NG 707	probably 1505–10	blue sky (obverse)	linseed oil
Circle of the Master of the Legend of Saint Ursula	*Saint Lawrence showing the Prefect the Treasures of the Church* NG 3665	*c.* 1510	blue bodice	linseed oil
MORDANTS				
Master of the Life of the Virgin	*The Presentation in the Temple* NG 706	probably *c.* 1460–75	mordant of gilded applied relief brocade on sleeve of fourth figure from the right	linseed oil
Circle of the Master of Liesborn	*Saints Gregory, Maurice and Augustine* NG 255	*c.* 1465–90	mordant of silver gilding of sword	oil
	Saint Dorothy NG 2152	late 15th century	mordant of silver leaf, area above Saint Catherine's wheel	linseed oil
Workshop of the Master of the Life of the Virgin	*The Conversion of Saint Hubert* NG 252	probably *c.* 1480–5	mordant of gilded applied relief brocade	heat-bodied linseed oil