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FRONT COVER
Vincenzo Foppa, *The Adoration of the Kings*
(NG 729) (detail of Plate 1, p. 19)

TITLE PAGE
Attributed to Pedro Campaña, *The Conversion of the Magdalen*
(NG 1241) (detail of Plate 1, p. 55)

A Survey of Nineteenth- and Early Twentieth-Century Varnish Compositions found on a Selection of Paintings in the National Gallery Collection

RAYMOND WHITE AND JO KIRBY

If, in the years around 1850, anyone had solicited the opinions of restorers and those in charge of major collections of pictures on the most suitable picture varnish, the majority would have given one answer: mastic varnish. In fact, such opinions were canvassed as part of the evidence given to the 1853 Select Committee on the National Gallery and presented to the House of Commons, and the answer is summarised in one sentence in the resulting Report. 'The species of varnish which has long been generally preferred in this country, and throughout Europe, as best calculated both to protect the surface of a picture, and to preserve its colour and cleanliness, is that called mastic varnish, consisting of the gum or resin of the mastic tree, combined with spirits of turpentine.'[1] A study of printed sources, from handbooks for restorers or amateur painters to books on the technology of varnish manufacture, suggests that mastic retained its position as the principal resin from which picture varnishes were made, through the nineteenth century and into the twentieth. However, alternative varnishes, based on other resins, were available and preferred by some.

In a short handbook for painters published by the colourman George Rowney in 1859, Charles Martel summarised the essential qualities of a good picture varnish: transparency; durability and hardness; freedom from colour; speed of drying.[2] As these properties depend on the resin and solvent used, the popularity of the basic mastic varnish is easy to understand. It was described as brightening or giving lustre to the colours and preserving the paint surface from dirt, pollution and what nineteenth-century authors describe as 'atmospheric changes'. Other varnishes, such as that prepared from copal resin, melted, or 'run', and heated with drying oil, would do this, but the varnish of mastic in turpentine had the advantage that it was easy to prepare, it dried quickly and, above all, it was relatively easy to remove, either by friction or solvent action.[3] It was also thought to darken less. The painter William Dyce, giving evidence to the Select Committee, agreed that mastic varnish would yellow, but not to the same extent as a varnish containing oil.[4]

Those giving evidence to the 1853 Select Committee, and most writers on picture conservation, were united in their criticism of copal/oil varnish. The restorer John Seguier, employed by the National Gallery from 1843, told the Committee that it should not be used as it was almost impossible to remove.[5] In his evidence, the 'picture cleaner' Retra Bolton commented that an oil varnish discoloured more quickly and had a greater tendency to disfigure a picture than mastic varnish, as it became browner and attracted more dust. Unlike mastic, it required the use of alkali to remove it.[6] Charles Dalbon, writing rather later, in 1898, thought copal and drying linseed oil varnish should never be used: it was always yellowish-to-brown, a colour accentuated by time. As the varnish lacked fluidity it was hard to spread and formed a rather thick coat (a comment also made by Bolton). It also provoked cracking and to attempt removal was dangerous to the picture.[7] On the other hand, a few nineteenth-century writers thought the very hardness, toughness and permanence of copal/oil varnishes to be an advantage; the relatively thick varnish film was also thought to be helpful if the painting had an irregular surface.[8]

It seems that dammar varnish was not widely known in England in the early 1850s. The dried residues of varnish in a bottle found in the studio of J.M.W. Turner after his death in 1851 were identified as containing dammar, but Turner was interested in trying different materials and it is impossible to know how typical his use of the varnish was.[9] The restorer Henry Farrer, who made his own dammar varnish, told the Select Committee that he knew nobody in England who used it, apart from himself. He had first heard of dammar on the Continent and found it preferable to mastic, not least because he thought it less liable to 'chill' (bloom), a common problem with mastic varnish.[10] According to the Baron de Klenze, Chamberlain to the King of Bavaria, who presented comparative evidence on the Munich galleries, only the use of mastic in

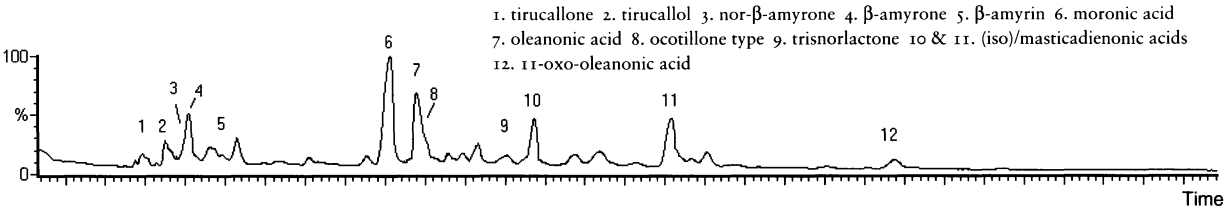

FIG. 1a Total ion chromatogram of mastic varnish from *A Family Group* (NG 1699), attributed to Michiel Nouts; the varnish was applied in 1915. Small amounts of residual tirucallol and some of the corresponding ketone are present as well as traces of β-amyrone. Moronic acid appears as the major component, with oleanonic acid; traces of masticadienonic acids still persist.

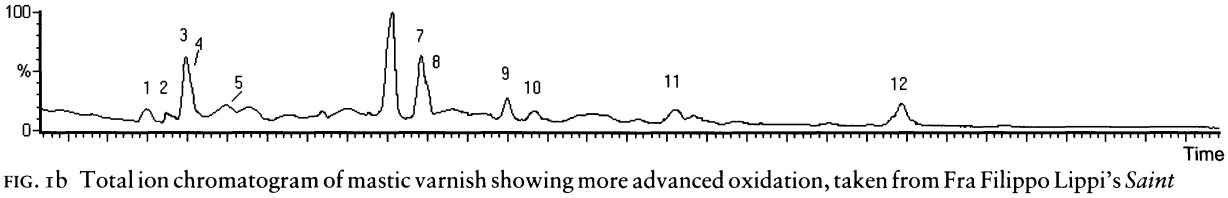

FIG. 1b Total ion chromatogram of mastic varnish showing more advanced oxidation, taken from Fra Filippo Lippi's *Saint Bernard's Vision of the Virgin* (NG 248); the varnish was applied in 1856. The principal components are as in FIG. 1a. Traces of β-amyrone remain and the corresponding nor-compound is now seen clearly; no masticadienonic acids can be detected. Some ocotillone-type components and a trace of 11-oxo-oleanonic acid can be seen.

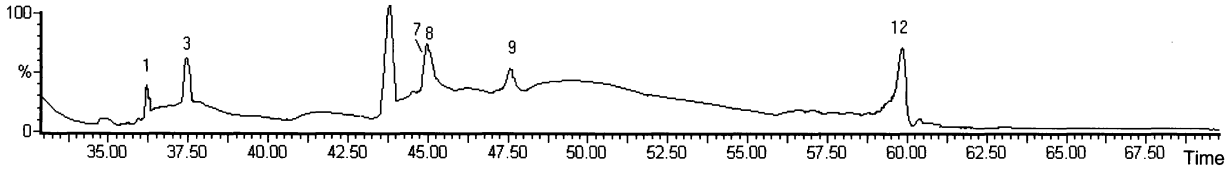

FIG. 1c Chromatogram given by a highly degraded mastic varnish, obtained from Leandro Bassano's *Tower of Babel* (NG 60); the varnish was applied after 1853 and in or before 1855. Moronic acid dominates the chromatogram and 11-oxo-oleanonic acid has become quite susbtantial.

turpentine spirits had formerly been permitted. However, for the last ten years or so a varnish of dammar in turpentine spirits, with a little alcohol, had been used in preference to mastic: it was less likely to cause cracks in the paint and he thought less liable to darken. Dammar was also about nine times cheaper, which must have been a significant factor. The varnish was also used elsewhere in Germany and had recently been introduced into Florence.[11] This was confirmed by another Select Committee witness, W.B. Spence, who had observed restorers in the Uffizi, Florence, filtering the dammar varnish which they obtained from France; they had used it for about a year.[12] This would suggest that dammar varnish, the use of which was apparently first reported by Lucanus in 1829, was in use in Germany in the early 1840s, while its introduction to other parts of Europe may have been more gradual.[13] It is interesting, therefore, that dammar was identified (with mastic and fir balsam) in the discoloured varnish on *The Adoration of the Shepherds* (NG 1858), by an unknown follower of Jacopo Bassano, bequeathed to the National Gallery by Sir John May in 1847, but not exhibited until many years later (see Table, p. 82).[14] If, as seems probable, the varnish was applied before the painting entered the National Gallery, this would be a relatively early use for the resin. From the 1850s, the sources and properties of dammar are discussed with markedly greater authority: Ulisse Forni, for example, writing in 1866, was able to write with some conviction that dammar was preferable to mastic as a varnish (or as a retouching varnish) for tempera paintings as it yellowed less.[15] One may even speculate that Forni, who had worked as a restorer in Florence for twenty years by the time his book was published, was one of those questioned by Spence.

Many restorers commented in their writings on materials other than varnishes that might have been applied to a painting to improve its appearance, some of which were difficult to remove once aged. These included drying oil, animal fat and egg white and it seems they were still in use.[16] 'Refreshing' the paint surface (or even a decaying varnish) was a common practice during restoration. Forni discussed the use of oil of spike lavender to refresh tempera paintings and it is interesting that the use of a similar

FIG. 2 Attributed to Michiel Nouts, *A Family Group* (NG 1699), *c.*1655. Canvas, 178 × 235 cm.

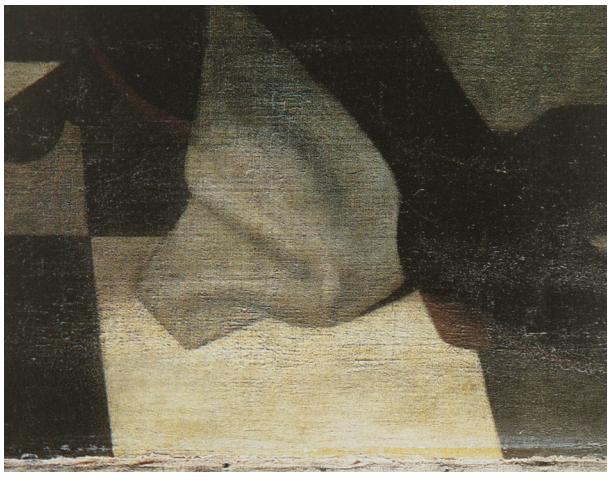

PLATE 1 Attributed to Michiel Nouts, *A Family Group* (NG 1699). Detail of right foot of man. The varnish layer is discoloured, but not otherwise deteriorated.

material has occasionally been observed on paintings in the National Gallery.[17] One example is Fra Filippo Lippi's *Saint Bernard's Vision of the Virgin* (NG 248), which was in the collection of E. Joly de Bammeville, Paris, by 1850 and bought from its sale in 1854.[18] Beneath layers of mastic varnish applied in 1856 and 1882, traces of a polyterpene material (now oxidised) were present immediately above the paint. These probably derived from a layer of spike oil, or something very similar, applied to the rather lean paint at some point before it entered the National Gallery.

The prevalence of mastic varnish suggested by the literature is confirmed by a survey of results obtained from the examination of varnishes applied to pictures in the National Gallery during the nineteenth and early twentieth centuries, the analytical methods used being gas chromatography–mass spectroscopy (GC–MS) and Fourier transform infrared spectroscopy (see Table, pp. 81–4). In some cases results were obtained from residues of one or more earlier varnishes beneath the existing surface coating. Many of these varnishes were applied before the painting concerned entered the collection and it can be deduced from what is known of the history of individual paintings that some varnishes were European in origin. Both analytical results and written sources indicate that the basic recipe of mastic dissolved in spirits of turpentine was often modified by the addition of other resins or oil with the aim of altering the characteristics of the final varnish.

Mastic varnish

By far the most common varnish composition found in this survey was that based on mastic resin, that is, resin derived from a *Pistacia* sp. source. As with any organic natural product, exposure to light, air and other atmospheric conditions inevitably causes changes to the chemical constituents originally present.[19] However, the range of variation in the composition of the mastic terpenoids observed is surprising given that all the varnishes examined are similar in age: 100–150 years old. Three examples of the chromatograms obtained are shown in FIG. 1. In each, moronic acid, the principal identifying indicator of mastic, is abundantly evident; in some cases traces of the more vulnerable masticadienonic and iso-masticadienonic acids remain, while in others they are entirely absent.

FIG. 1a exhibits the typical characteristics of a moderately aged fairly thick mastic varnish film, from *A Family Group* (NG 1699), attributed to Michiel Nouts (FIG. 2, PLATE 1); the varnish was applied in 1915. Small amounts of residual tirucallol and some of the corresponding ketone are present. Moronic and oleanonic acids predominate, with only minor amounts of masticadienonic acid and its isomer, as well as the corresponding O-acetyl analogues. A minor amount of 11-oxo-oleanonic acid is apparent at higher retention times. Small amounts of components usually referred to as ocotillones, because of their predominant base peak at $m/z = 143$ and very weak higher mass spectral region, are also evident.[20] In this article the term 'ocotillone-like' components is preferred, and it is proposed that they will be the subject of another paper. FIG. 1b shows the total ion chromatogram (TIC) of a mastic varnish layer from Lippi's *Saint Bernard's Vision of the Virgin*, which was applied in 1856 by John Bentley. This layer exhibits a somewhat more advanced state

FIG. 3 Attributed to Girolamo da Treviso, *The Adoration of the Kings* (NG 218), probably 1525–30. Wood, 144.2 × 125.7 cm.

of oxidation. Here, moronic acid is quite evident, but oleanonic acid content has been reduced and a significant increase in the proportion of the 'ocotillone types' has occurred. Tirucallol has entirely disappeared and a minor trace of tirucallone, the principal oxidation product of tirucallol, and β-amyrone can be detected. 11-oxo-oleanonic acid content is quite pronounced. The chromatogram in FIG. 1c shows the results from a highly degraded residue of mastic varnish, where the structure of the upper surface of the varnish film has partially disintegrated. The sample was obtained from Leandro Bassano's *Tower of Babel* (NG 60), painted after 1600; the varnish was applied at some time after 1853 (and possibly in or before 1855) over an even earlier varnish, composed of mastic and heat-bodied linseed oil, applied between the acquisition of the painting in 1837 and 1853.[21] These variations between the three varnish films may perhaps have been caused in part by factors such as their different thicknesses, differences in their immediate environments – in other words, the constitution of the paint or varnish layers immediately below and above them – or even the different ambient conditions to which the paintings were exposed before they came into the collection.

Probably the only source of mastic available for conservation purposes during the nineteenth and early twentieth centuries was that derived from *Pistacia lentiscus* var. *chia*. It was usually obtained in a characteristic form resembling tears, produced as the resin trickled down the tree from cuts in the bark and solidified. Resin that fell to the ground was also collected and was known as common mastic.[22] As a triterpenoid-based material, mastic resin is for the most part composed of non-polymerising molecular species and must thus be classed as a 'soft' resin.[23] Whatever the source of the mastic resin, some relatively low molecular weight isoprene-related polymer is present.

The importance of allowing mastic, and, indeed, all varnish preparations, to mature for at least six months to a year was often emphasised. In his evidence to the Select Committee, W.B. Spence, for example, said that he never trusted people who sold varnish ready prepared as it was often sold before it was seasoned: 'All varnish, especially mastic, if not kept, has a very deleterious effect upon pictures.'[24] Probably the maturation period would bring about two important changes in the composition of the resin varnish formulation. First, it would allow unstable oleanonic aldehyde to oxidise to the corresponding acid; secondly, it would afford time for the production of more polymeric material. The effect, as far as the restorer was concerned, would be to allow any cloudiness to clear or to settle out and to improve brushability: the increased polymer content would improve the rheological properties of the varnish.

Mastic/oil varnishes

In the varnishes examined, the mastic was sometimes used without any additives, but often it had been plasticised with a little drying oil. Several examples are given in the Table (pp. 81–4), a typical instance being that from *The Adoration of the Kings* (NG 218), attributed to Girolamo da Treviso (FIG. 3), which was composed of mastic resin mixed with heat-bodied linseed oil. This varnish was probably applied in 1849 and certainly before 1853. In most cases, the palmitic/stearic ester ratios in the picture varnishes examined were indicative of the use of linseed oil, sometimes heat-bodied or partially so, sometimes not. In only one varnish examined was a plasticising drying oil other than linseed or walnut oil employed, and that appeared to be poppy-seed oil.

The addition of a small quantity of pre-polymerised, or bodied, oil to the varnish would have been expected to make it more resistant and also to improve its ability to level out minor uneven areas in the paint surface. As long as this addition was indeed

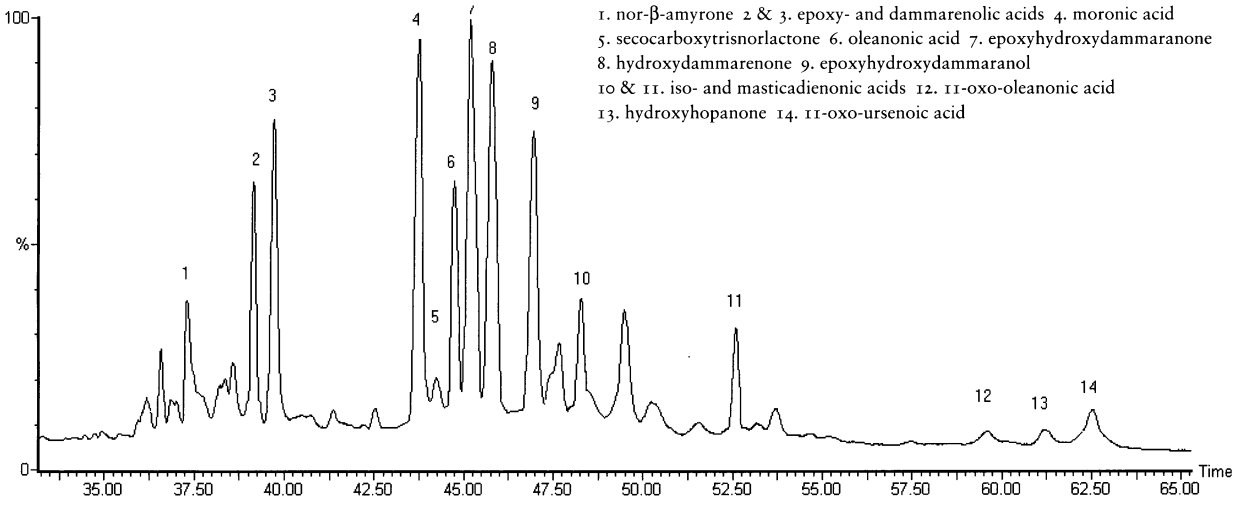

FIG. 4 Total ion chromatogram (TIC) obtained from a sample of the upper varnish layer on *The Adoration of the Kings* (NG 218), attributed to Girolamo da Treviso, applied in 1887. Hydroxy- and epoxy-hydroxy-dammarene-related ketone and acid components dominate this TIC, suggesting the presence of dammar resin. The significant content of moronic acid points to admixture of the dammar with mastic resin.

small it would not have rendered the varnish markedly difficult to remove, as the solubility properties of the mastic would have overwhelmed those of the oil. The use of heat-bodied oils to strengthen and toughen the varnish film seems logical in view of their reduced propensity for yellowing, if properly made, and reduced shrinkage on drying. In the laboratory, at least, it has been observed that non-bodied oils mixed with triterpenoid resin have less satisfactory rheological properties and the films have a greater tendency to wrinkle, although this has never assumed severe proportions. Certainly, non-bodied oil/soft resin formulations appear to have inferior levelling effects when applied to a more textured surface and appear to be more prone to sinking in absorbent passages than varnishes with additions of bodied oil, and, surprisingly, even more so than mastic alone.

Another reason put forward for the addition of oil was to reduce the tiresome tendency of mastic varnish to bloom, that is, to develop a cloudy appearance. This was the reason given by John Seguier, the restorer employed by the National Gallery from 1843, to the Select Committee for his use of a mastic varnish mixed with linseed oil, originally at the suggestion of his brother William, Keeper of the National Gallery until 1843. However, in the words of the 1853 Report, 'The effect of this mixture is stated to be, that it renders the mastic more liable to discoloration, and that it imparts to it a greater tendency to attract dirt and noxious effluvia.'[25] It was also said to become hard and difficult to remove. The explanation for this lay in the amount of oil present. John Bentley, who was subsequently employed by the Gallery on the care of the pictures, said that he had been informed that the so-called 'Gallery varnish' consisted of approximately half mastic varnish and half 'light drying oil' stirred together and left to

FIG. 5 Moretto da Brescia, *The Madonna and Child with Saints Hippolytus and Catherine of Alexandria* (NG 1165), *c.*1538–40. Canvas, painted surface 229.2 × 135.8 cm.

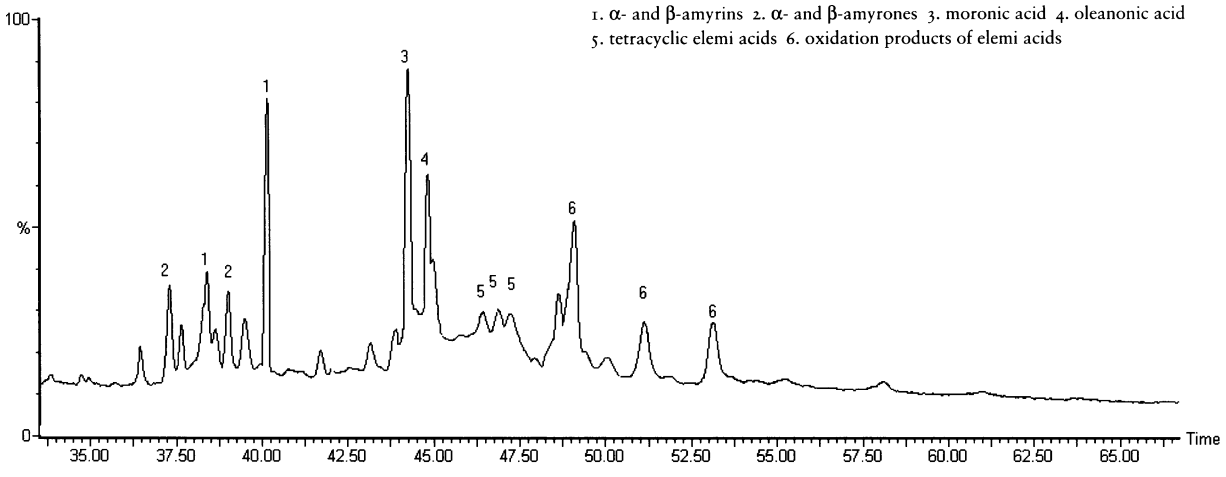

FIG. 6 Total ion chromatogram of the upper varnish layer on *The Madonna and Child with Saints Hippolytus and Catherine of Alexandria* (NG 1165), by Moretto da Brescia; the varnish was applied in 1891. The presence of significant amounts of moronic acid shows the presence of mastic resin in this varnish; however, it is clear from the amyrin/amyrone content and acids derived from the euphane group that a Burseraceous resin is also present. Elemi resin is the most likely candidate.

stand; spirits of turpentine were then added and it was stirred again, at repeated intervals. It was, in other words, a variety of the painting medium megilp ('maguylp'), which Seguier, who had no idea of its formulation, bought ready-made.[26] Indeed, its formulation may well have varied from batch to batch, but the traces of darkened, oil-containing mastic varnish found on, for example, Leandro Bassano's *Tower of Babel* and other paintings that came into the collection before 1853 (see Table) are probably remnants of 'Gallery varnish'.

Mastic with triterpenoid resins: dammar and elemi

Several mastic-based formulations were identified in which at least one other resin had been incorporated. Broadly these may be divided into those containing a triterpenoid resinous addition, such as dammar, and those where a diterpenoid resin, such as pine resin, fir balsam, Venice turpentine (larch resin), sandarac or copal, had been added.

An example of the first type is shown in FIG. 4, the chromatogram given by a sample of the upper varnish layer from *The Adoration of the Kings*, attributed to Girolamo da Treviso. The painting was varnished around the time it came into the collection in 1849 with 'Gallery varnish';[27] this was confirmed by GC–MS analysis of traces of a lower varnish layer, adjacent to the paint, discussed above. This varnish was largely removed during cleaning and repair by Dyer in 1887, at which time the painting was re-varnished. In this later varnish, mastic resin has been mixed with a significant quantity of dammar, indicated by the presence of dammarenolic acid, traces of hydroxydammarenone I and II, ursonic acid and various ocotillones; in addition various nor-compounds are present, showing that some degree of degradation has taken place over time.[28] For the dammar this composition seems reasonable for its age, but the degradation of the mastic has been partly inhibited by the presence of the dammar: the chromatogram shows not only the characteristic moronic and oleanonic acids of a *Pistacia* resin, but also that some measure of protection appears to have been afforded to the masticadienonic acids, which generally would have been expected to disappear when applied in such a thin film. When other triterpenoid resins, such as dammar, are found to have been mixed with mastic – in varnishes, for example – often the mastic components appear to have fared much better than in the case of mastic alone. It is possible that, under normal ambient conditions of ageing, some components within the dammar triterpenoids are acting as mildly stabilising elements, perhaps by sacrificial oxidation, setting up a local disproportionation or redox system. Curiously this appears not to be the case for artificially aged regimes.

One may speculate upon the reason for this mixture: perhaps insufficient made-up mastic was available so it was topped up with dammar. That this component was detected in combination with mastic on several occasions would seem to speak against the 'top-up' conjecture. The aim may have been to produce enhanced colour saturation by, in effect, increasing the refractive index of the coating. Compositions including a resin with a high refractive index are typical of so-called 'Crystal varnishes',

prized for their high refractive index, transparency and low colour; some late nineteenth-century recipes for Crystal varnish specified fir balsam, but some were based on mastic and dammar.[29] It is worth remembering, however, that earlier in the century mastic was often adulterated because of its high price, commented upon by the Baron de Klenze in his evidence to the Select Committee (mentioned above). The restorer Henry Farrer gave the adulteration as a reason for his preferring dammar.[30] By the late 1850s, it appears that dammar was increasingly being substituted for mastic and mastic varnish was much adulterated with it.[31] Consequently, if a mixture of mastic with another resin is present in the varnish, and the other resin has similar properties to mastic but is markedly cheaper, the possibility of adulteration cannot be ruled out.

The Madonna and Child with Saints Hippolytus and Catherine of Alexandria (NG 1165, FIG. 5), painted by Moretto da Brescia around 1538–40, was varnished by Horace Buttery in 1891, seven years after it was given to the National Gallery and after cleaning to remove the existing varnish; the earlier varnish is discussed below. Buttery's varnish was spirit-based and found to contain mastic resin, with an addition of another triterpenoid component, but, unlike the varnish found on *The Adoration of the Kings*, discussed above, the additive was not dammar. The total ion chromatogram (TIC) is illustrated in FIG. 6 and shows residual traces of elemonic acids, together with residual traces of amyrins and their oxidation products, indicating the presence of a resin produced by a member of the family Burseraceae. In the nineteenth century, the most widely available resin of this type in commerce would have been that from a tree of the genus *Canarium*, and in particular *C. luzonicum*, which produced the resin known as gum elemi. This tree grew mainly on the island of Luzon and some of the other islands of the Philippines and as it was exported via Manila it should, technically, be called Manila elemi. Other elemis also exist. Brazilian elemi, for example, was sometimes brought to Europe with other resins and balsams, such as *Copaifera* spp. products (copaiba balsam) and *Hymenaea* spp. resins (Brazil or Demerara copal), but it was probably never traded regularly. Similarly, Burseraceous resins from *Protium guanense* and *Amyris* spp., such as *Amyris elemifera* (Central American and Mexican elemis), as well as West Indian elemi (from *Dacryodes hexandra*), were brought to Europe intermittently, but not on a regular basis.[32]

Apart from the resin derived from *Canarium strictum*, misleadingly known as 'black dammar', which was much used in India, all elemis derived from the Burseraceae are soft, unctuous substances, with a slightly granular quality. They owe these soft, malleable characteristics to the high proportion of sesquiterpene essential oil present in the fresh resin. As a result they were frequently used as plasticising components to give elasticity and toughness to varnishes in the nineteenth and early twentieth centuries.[33] Unfortunately, the sesquiterpenes (principally the hydrocarbon β-elemene) slowly evaporate; the solid resin remaining is chiefly composed of α- and β-amyrins, which co-crystallise, forming a mass of interlocked crystals, and the material sets hard, like cement. This may account for the rather cloudy

FIG. 7 Jan Both, *Muleteers, and a Herdsman with an Ox and Goats by a Pool* (NG 957), *c.*1645. Oak panel, 57.2 × 69.5 cm.

PLATE 2 Jan Both, *Muleteers, and a Herdsman with an Ox and Goats by a Pool* (NG 957). Detail of goats to left of ox, showing thick, yellow, glossy varnish. Some milkiness is apparent in the varnish over the shoulders of the foreground goat and it shows a rectangular pattern of cracks in the region of the face of the rear goat.

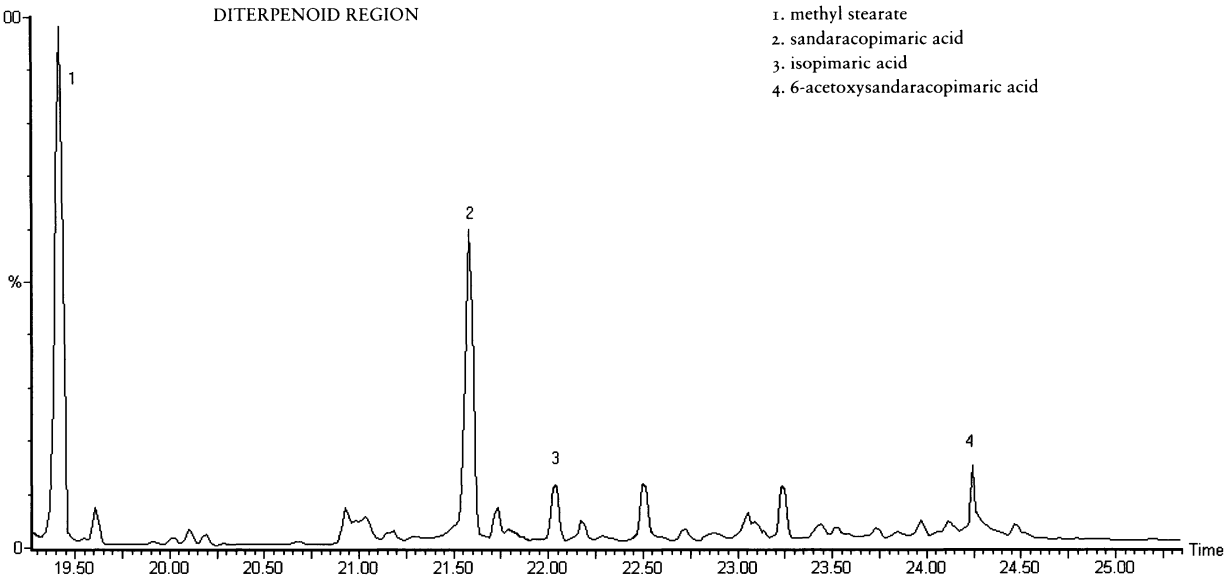

FIG. 8 Total ion chromatogram of a sample of varnish from Jan Both's *Muleteers, and a Herdsman with an Ox and Goats by a Pool*, applied in 1882. In addition to the moronic acid-rich mastic (*Pistacia* spp.) resin, the presence of pronounced residues of sandaracopimaric acid indicate the inclusion of a sandarac-type (Cupressaceae) resin.

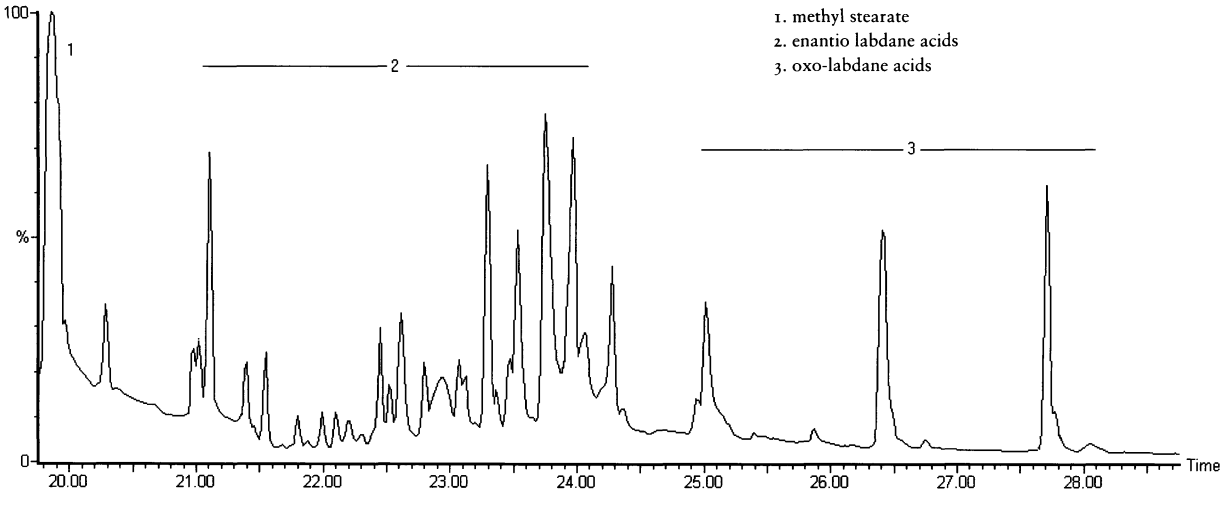

FIG. 9 Total ion chromatogram of the lower varnish layer on Moretto da Brescia's *Madonna and Child with Saints Hippolytus and Catherine of Alexandria*, applied in 1884. A linseed drying oil is present. From the ratio of suberic to azelaic acids, it has clearly been heat pre-polymerised and seems to have been combined with a diterpenoid, Leguminosae-derived hard copal. This mixture has been incorporated with mastic resin, presumably to toughen it and inhibit its natural tendency to bloom. The pattern of diterpenoids is similar to those of a 'run', aged Sierra Leone copal.

appearance of the varnish in places and the light-scattering micro-craquelure that has developed in patches.

Mastic with diterpenoid resins: sandarac and copal

Several examples of composite varnishes based on a mixture of mastic resin and diterpenoid resins were found in the paintings examined. Jan Both's *Muleteers, and a Herdsman with an Ox and Goats by a Pool* (NG 957, FIG. 7) was cleaned and varnished in 1882. The TIC obtained from a sample of the varnish, following work-up and derivatisation (FIG. 8), indicates the presence of sandaracopimaric acid, suggesting that the varnish is composed of mastic resin and sandarac, or, more accurately, a Cupressaceae resin from the genera *Tetraclinis*, *Juniperus* or, possibly, *Cupressus*. There was no evidence for the presence of a plasticising drying oil and it seems likely that the formulation was made up as a spirit varnish.[34] It is likely that the sandarac-like resin was added in an attempt to toughen the mastic film:

in chemical terms, by the inclusion of some dissolved polycommunic acid. The vehicle in which the resin was dissolved would have been alcohol or, more probably, oil of spike or some other flower-derived essential oil. This would be sufficiently polar to take up most of the sandarac polymer (polycommunic acid) without being so polar that the less functionalised polymer component of the mastic resin precipitated out. The varnish has a high gloss finish, explained by the polar nature of the resin acids and the polymer present in the diterpenoid component. It is also markedly yellow, giving an orange-yellow tone over the light areas, particularly in the sky. Some degree of blanching is apparent, particularly noticeable in the darks. The varnish is relatively hard and shows slight reticulation in some patches where it is a little thicker (PLATE 2).

Other polymer-containing resins might be used with mastic to toughen the varnish. The mastic/elemi varnish Buttery used on Moretto da Brescia's *Madonna and Child with Saints Hippolytus and Catherine of Alexandria* in 1891 has already been discussed; beneath this varnish, however, were residues of a dark varnish, trapped in undulations in the paint surface. The painting was cleaned and varnished following its acquisition in 1884. At this time it was described as damaged and abraded on the right-hand side.[35] From the chromatogram (FIG. 9) it is clear that the 1884 varnish contains both mastic and copal, together with pre-polymerised linseed oil. As discussed below, the copal varnish would probably have been prepared by melting the copal and mixing it with heated linseed oil.[36] This could then have been mixed with ready-prepared mastic varnish in turpentine, or the mastic may itself have been in the form of an oil varnish.[37]

The copal appears to derive from the Leguminosae group (for example, African copals) and not the sandaracopimaric- and agathic-rich Araucariaceae group, which includes Manila copal. Within the Leguminosae family there are many good, resin-producing species of tree, mostly located in tropical climes; botanically they are all members of the tribe Detarieae within the sub-family Caesalpinioideae. Geographically they are found in the continents of Africa and South America and the bulk of copal supply has originated from Africa. In general not only is the chemistry of these resins poorly studied, but also the origins of the various copals in trade in previous centuries is obscure. Such copals have always been prized for their hardness: that is, the durability and toughness of the varnishes which may be made from them. Because these resins are highly polymerised and insoluble in solvents like spirits of turpentine – defining characteristics of a 'hard' resin – they are almost invariably formulated as oil varnishes, where the resin is 'run' by heating it to its fusion point for a brief period and is then mixed with hot (pre-polymerised) drying oil.

The West African copals originate from a stretch of coast some 700 miles in length, from Cameroon in the north to Luanda in Angola in the south. Most of the resin was collected as 'semi-fossilised' material,[38] being buried in soil up to depths of ten feet and dug up by local people in the rainy season. It is quite likely that the resin originated from more than one botanical species, but by the end of the nineteenth century there was no resin-producing tree growing on that coast which could be the source of the buried material. Some of the semi-fossil resin was collected from river beds and their surrounds; this leads to the conclusion that either the source trees grew inland and the resin had been washed down to the coast, or the resin-producing trees had completely receded from the coastal regions by the end of the nineteenth century. After collection, the resin was then sent to various ports for export to Europe and it was from the names of these collection/export ports that the copals took their own names. Angola copal included white and the harder red varieties, the latter being among the hardest of all West African copals, giving a high-quality, durable and brilliant varnish, commanding a higher price. Loanga copal also came in red and white forms, in cylindrical pieces, the red being harder and more expensive; Benguela copal was yellow. Gaboon (now Gabon) was the darkest of this group of copals, being sherry-coloured; it was not homogeneous. Other varieties include Accra, Benin, Congo and Sierra Leone copals.[39]

On balance, the copal in the varnish strongly resembled authentic samples of Sierra Leone copal. A survey of the African copals conducted in this laboratory suggested that there was often no clear qualitative distinction between some of the commercial types. However, Sierra Leone copal appeared to be deficient in copalic acid and its possible oxidation products, as was the case here (FIG. 9). Sierra Leone copal was a colourless or pale yellow product, found in two forms in Europe, one of which is as rounded pieces of various sizes, called 'Pebble copal'. Clearly this variety is one that has been washed down and collected from river beds and their environs. More frequently, it was in the form of irregular angular pieces. It was thought to be the hardest of all West African copals and, once selected and graded, it was the most highly prized and expensive copal product

FIG. 10 Paolo Veronese, *The Rape of Europa* (NG 97), 1570s. Canvas laid down on wood, 59.4 × 69.9 cm.

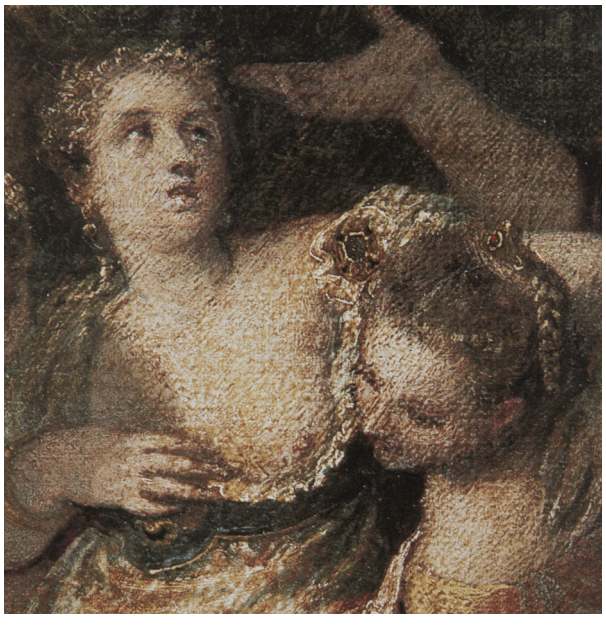

PLATE 3 Paolo Veronese, *The Rape of Europa* (NG 97). Detail of Europa and the left-hand attendant before cleaning, showing warm brown varnish containing mastic and 'African copaiba'.

from this region. It makes a very pale and durable varnish, which has little tendency to wrinkle and is excellent for producing a good uniform finish on textured and uneven surfaces; it also has a lower tendency to 'sink' on paint areas of variable absorbency. This is the likely reason for its incorporation in the mixture with mastic: to attempt to even out the damaged surface of Moretto's painting, although it is likely that the varnish would have darkened. Indeed, the fact that it was cleaned and revarnished seven years later suggests that it may already have darkened to an unacceptable extent.

Not all Leguminosae-derived oleoresins solidify into hard, copal-like material. The genus *Copaifera* produces a balsam-like product in pockets under the bark and in other parts of the tree; the principal sources were *Copaifera langsdorfii* and *C. multijuga* Haynes. The oleoresin contains a considerable amount of sesquiterpene material and little in the way of polymerising diterpenoids. Copaiba balsam is largely collected from the Amazon basin and was popular at one time as an additive to solvents used for the removal of old varnish and in the reforming of old varnish in the Pettenkofer process.[40] A balsamic material similar in appearance and properties, known as 'African copaiba', or illurin (illorin) balsam, was produced by the wood oil tree, *Daniellia oliveri* (Rolfe) Hutch. & Dalziel. This was identified in a sample of heavily discoloured varnish from Veronese's *The Rape of Europa* (NG 97, FIG. 10), painted in the 1570s. Above this varnish was an ordinary, slightly discoloured mastic varnish, presumably that applied in 1881.[41] The painting came into the collection in 1831 and the earlier varnish may have been applied before 1853, although it does not resemble the usual 'Gallery varnish'. It was found to contain mastic with the resinous matter from 'African copaiba'. It seems likely that this was added to the mastic both to make it less brittle and to give a warm tone to the varnish; unfortunately, however, it tends to darken relatively rapidly from an attractive reddish hue to a dark brown (PLATE 3). Copaiba balsam, in contrast, is relatively colourless when fresh, though it too darkens in the long term. It was also used as a plasticiser for varnishes.[42]

Copal varnishes

Many of the varnishes whose residues were examined during this study must have been applied before the paintings concerned came to the National Gallery. A number of these pictures were previously in Italian or French collections. Because it is quite impossible to date these earlier treatments and because the number of pictures studied is at present small, it is difficult to draw many conclusions about varnishes used by restorers in these countries. Some differences are apparent, however. One example studied is *The Nativity with Saints* (NG 1849), painted by Pietro Orioli between 1485 and 1495, which was in the Cerretani collection, Siena, before 1858, and bought for the National Gallery from Agnew's in 1901.[43] At this time the painting was cleaned and a few minor repairs were carried out. A local application of a mastic/elemi varnish was found in one area,

perhaps disturbed by a repair, and this may have been used in other similar areas; the painting was then varnished with a mastic varnish. However, during examination of the paint surface heavily browned remnants of an earlier varnish could be seen in isolated patches in the textured hollows of the paint. This was identified as an oil-containing varnish, based on a variety of copal and Venetian turpentine (larch resin), with heat-bodied walnut oil: quite different to any of the varnishes discussed so far. The copal component appeared not to be one of the Leguminosae-derived 'hard' African varieties described above. From its agathic acid content, still extant, the source of the resin was an *Agathis* sp., from the family Araucariaceae, perhaps Manila copal.[44]

Manila copal was also identified in remnants of varnish on a North Italian School painting, *The Adoration of the Shepherds* (NG 1887, probably painted early in the seventeenth century), under a later mastic varnish containing a little walnut oil. It is likely that both varnishes were applied before the picture was bought with other pictures in the Beaucousin collection in 1860 as it was lent to the National Gallery of Ireland, Dublin, in June 1860, shortly after it was acquired, only returning to London in 1926. No oil was present in the copal varnish, only a little polyterpene, indicating that the varnish was based on something like oil of spike lavender, or some other similar solvent. Given the difficulty of preparing pale copal/oil varnishes, it is hardly surprising that attempts were made to produce a pale, relatively tough varnish in a spirit-based vehicle. Spirits of turpentine alone are not suitable as a solvent for the relatively polar polymeric acids; alcohol or flower-derived essential oils, such as oil of spike or oil of rosemary, are, however, effective solvents, dissolving a substantial part of the resin. An artificial equivalent of the more heavily functionalised (that is, more alcoholic and ketone groups are present) flower oils was produced by dissolving camphor in the less polar spirits of turpentine.[45]

FIG. 11 Style of Van Dyck, *Portrait of a Woman* (NG 3132), after 1635. Copper panel, 59.7 × 47.2 cm.

PLATE 4 Style of Van Dyck, *Portrait of a Woman* (NG 3132). Detail of sitter's cheek, neck and ruff, below her right ear, showing discoloration and wrinkling of the varnish layers.

Varnishes with 'soft' conifer resins

A great many nineteenth-century recipes mention the inclusion of oleoresins such as fir balsam and larch resin (Venice turpentine), which were thought to toughen or plasticise the brittle varnish film produced by, for example, simple dissolution of mastic in turpentine spirits.[46] This is understandable in view of the balsamic, treacle-like consistency of the fresh oleoresin. All the turpentines, according to the

FIG. 12 Gaspard Dughet, *Landscape with a Storm* (NG 36), about 1653–4. Canvas, 135.9 × 184.8 cm.

PLATE 5 Gaspard Dughet, *Landscape with a Storm* (NG 36). Detail of foliage and light sky to left of mountains, showing very dark, wrinkled varnish.

Italian restorer Ulisse Forni, were widely used and were very important for varnishes used in restoration. By this, he would have meant particularly Venice turpentine (which, according to him, tended to be mixed with the spirit turpentine of other pines and firs) and fir balsam.[47]

The cheapest and most widely available soft resin was that derived from various species of pine (*Pinus* spp.). Distillation of the oleoresin (common or Bordeaux turpentine) gave spirits of turpentine; the solid residue, known as rosin or colophony, was soluble in both spirit and oil and was widely used in the production of cheap varnishes. Pine rosin was a frequent component in the formulation of varnishes; it may also have been an adulterant of other, more expensive resins. It was a convenient and versatile material.[48]

Venice turpentine was derived from larch trees, in particular *Larix decidua* Miller. It tends to produce a rather brittle varnish if made up as a spirit varnish on its own, similar, but more slowly drying and less yellowing than an equivalent pine resin varnish.[49] There is little evidence that it was used in this way at this time; it was, however, a frequent ingredient in recipes with other resins.[50] Because of its lack of polymerising components, Venice turpentine is liable to cause defects in any varnish film in which it is incorporated if present in excess, although when used in great moderation, no ill effects seem to occur. This appears to be the case with the varnishes present on two works by Adolphe Monticelli: *Still Life: Oysters, Fish* (NG 5013) and *Still Life: Fruit* (NG 5014). In both pictures the varnish was found to consist of mastic resin, mixed with an ocotillone-rich triterpenoid resin (possibly a dammar), pine resin, heat pre-polymerised linseed oil and a little larch resin – Venice turpentine. Apart from some discoloration of the varnish, there is no evidence of major varnish film defects.

However, extensive wrinkling of the varnish surface can be seen on *Portrait of a Woman* (NG 3132), a painting on a copper panel in the style of Van Dyck, dating from after 1635 (FIG. 11 and PLATE 4). Investigation of the composition of this varnish showed that two layers were present, the lower of which consisted of a mixture of mastic and dammar resins with a significant amount of larch resin. It seems that the film structure afforded by the other resin components is overwhelmed by substantial quantities of the Venice turpentine, resulting in wrinkling of the film. Above this layer was another, consisting of mastic resin with a little heat-bodied linseed oil. The tendency of larch resin to cause wrinkling is even more marked in the case of the varnish from Gaspard Dughet's *Landscape with a Storm* (NG 36, FIG. 12, PLATE 5), where wrinkling of the varnish has been compounded by excessive darkening. The painting was bought in 1824 and is known to have been varnished with mastic and drying oil ('Gallery varnish') before 1853.[51] Traces of this varnish, consisting of mastic with a linseed-based stand oil, were indeed identified, together with thin traces of similar mastic varnishes applied subsequently in 1868 and 1888, the last being applied by Horace Buttery. Below these layers were traces of an earlier varnish, perhaps dating from before the picture entered the National Gallery in 1824. Here, analysis indicated the use of a mixture of mastic resin with larch resin, toned with asphaltum, which would itself contribute to the dark appearance and perhaps the wrinkling.

Fir balsams are the oleoresins tapped from various fir trees (*Abies* spp.). There were two main

FIG. 13 Follower of Tintoretto, *Portrait of a Lady* (NG 2161), *c.*1550. Canvas, 98.4 × 80.7 cm.

PLATE 6 Follower of Tintoretto, *Portrait of a Lady* (NG 2161). Detail of sitter's bodice to left of pearl trimming, showing reflection in the markedly glossy varnish.

sources at this time: that from Europe was the product of *Abies alba* and was commonly known as Strasbourg turpentine, *olio d'abete* in Italian. In the sixteenth century the Italian writer and painter Giovanni Battista Armenini had referred to this material, known as *olio d'abezzo* in his day, as a useful and delicate varnish, and this was well known to nineteenth-century Italian restorers (and, incidentally, to some giving evidence to the 1853 Select Committee).[52] From the mid-nineteenth century a product known as Canada balsam, collected from trees of the species *Abies balsamea*, was imported into Europe. Unlike rosin and Venice turpentine, there are polymerising monoterpenes and diterpenoids in fir balsams. This means that the varnish film is not formed purely by evaporation of volatile essential oils alone, but by the joining together of components such as β-phellandrene (a monoterpene oil component) and *cis*-abienol (a solid diterpenoid component). This results in a much tougher and more resilient final varnish film if the resin is used alone to make a varnish, as it was in the case of some varieties of 'Crystal' varnish, for example.[53] Interestingly, Forni mentioned that the spirit distilled from fir balsam was superior to the usual variety distilled from pine.[54] If this spirit was indeed prepared, it would tend to produce a bodying polyterpene fraction during drying and oxidation, either on its own or in any varnish with which it was incorporated, due to its high content of β-phellandrene. Some American species of pine oleoresin yield a β-phellandrene-rich turpentine spirit, though these would not be generally available to Europe until the advent of the twentieth century.

Like Venice turpentine, fir balsam was also incorporated into varnishes on the assumption that it would toughen the film. It also has a high refractive index, which would add to the gloss of the varnish. This is demonstrated in the case of the *Portrait of a Lady* (NG 2161, FIG. 13), by a follower of Tintoretto, where the varnish was found to contain mastic resin with dammar and fir balsam, both of which have a high refractive index. This combination probably accounts for the marked gloss associated with the varnish of this work (PLATE 6). The fir balsam-containing varnishes identified in this study appear to show no particular film defects, unless they have been applied very thickly. In such cases the same problems occur as would be expected in thick applications of drying oil, resulting in wrinkling.[55]

Conclusion

As the number of results obtained from the analysis of nineteenth- and early twentieth-century varnishes increases, it becomes possible to know something of the practice of individual restorers, or the restoration practice in particular regions or countries. If the present-day restorer is faced with a picture treated a hundred years ago by one of these restorers he or she will have a very good idea of the type of varnish likely to be present and its probable characteristics. For example, the names of the Buttery family of restorers recur in the National Gallery archival records through the second half of the nineteenth

century and into the twentieth. Those pictures restored by Horace Buttery in the late 1880s and 1890s examined during this survey showed that, like many English restorers, he preferred a mastic-based varnish. He had an account with the colourman Roberson and Company from 1895 into the 1920s and many purchases of ready-made mastic varnish are recorded in their ledgers.[56] A feature of the National Gallery collection is that it includes several purchases and bequests of collections formed both in England and abroad; these too could show similarities in the restoration treatment of the pictures, but in most cases too few pictures from any one source have been examined for any clear pattern to emerge. Occasionally the owner of the collection is known to have used the services of a particular restorer: this is the case with the collection originally formed by Sir Austen Layard, bequeathed to the National Gallery in 1916. Layard used the services of the Milanese restorer Giuseppe Molteni, who also did work for Sir Charles Eastlake.[57] One example examined for this study is Bono da Ferrara's *Saint Jerome in a Landscape* (NG 771), restored by Molteni in Milan between 1860 and 1862;[58] another is Vittore Carpaccio's *The Departure of Ceyx* (NG 3085). Molteni, who died in 1867, is not the only Italian restorer known to have worked on National Gallery pictures: Raffaelle Pinti is another, but he was based in London and, judging from the short times needed for his assignments, may have done more retouching and similar work than revarnishing. It does appear, however, that most of the varnishes examined that can be related to Italian restorations of the 1860s or thereabouts have been found to contain fir balsam; this includes what is probably Molteni's work on the two paintings mentioned above.[59]

In general, it can be said that there was an overall preference for the use of mastic resin varnish, up until the first two decades of the twentieth century at least. This appears to support the views and opinions expressed in the Select Committee proceedings and the opinions of European restorers generally. Nevertheless, it is evident that the deficiencies of mastic, that is, its brittleness and tendency to bloom, were of some concern to restorers; as a result, drying oils, polymerising resins and balsamic additives were incorporated, presumably in an attempt to offset them. Such additions or modifications might also be made in response to a particular problem with the surface of the painting undergoing treatment. It is curious that, given that most of the varnishes examined were applied since the 1850s, there were few instances of the use of varnish composed of dammar resin alone. Although many English restorers may have been slow to recognise its good qualities, it was clearly available in London by 1859, when it was used, with a little poppy oil, as a retouching medium by Raffaelle Pinti on Crivelli's *Dead Christ supported by Two Angels* (NG 602).[60] This is particularly puzzling in view of dammar varnish's transparency, high refractive index, slower yellowing and lack of any tendency to bloom. Above all, it was also cheaper than mastic resin. On the other hand, the higher gloss given by a dammar varnish may not have been thought desirable in England. In his evidence to the 1853 Select Committee, Seguier commented that French varnish (which would have been based on mastic at this date, presumably) was 'more glossy than is generally approved of in this country'.[61] The lighting conditions prevailing in the room where the picture was displayed at the time it was varnished – whether this was in the National Gallery or in the previous owner's collection – may have influenced the restorer's choice. Dammar was found occasionally in combination with mastic and other resins, however, perhaps to increase the transparency or saturation of the underlying colours; or an enhanced gloss might have been desired.[62]

Few instances of the application of copal/oil-based varnishes were encountered in this survey. This tends to confirm the expressed opinion of nineteenth- and early twentieth-century restorers that, in spite of their toughness and resilience, their relatively rapid darkening and the extreme difficulty of removal of mature copal/oil varnishes without risk to the painting, rendered them unsuitable.

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Notes and references

1 *Report from the Select Committee on the National Gallery, together with the Proceedings of the Committee, Minutes of Evidence, Appendix and Index*, ordered to be printed by the House of Commons, London, 4 August 1853, p. xii.

2 C. Martel, pseud. [i.e. Thomas Delf], *On the Materials used in Painting, with a few Remarks on Varnishing and Cleaning Pictures*, London 1859 (1860 on cover), p. 47.

3 See, for example, S. Horsin Déon, *De la conservation et de la restauration des tableaux*, Paris 1851, pp. 61–3; H. Merritt, *Dirt and Pictures separated in the Works of the Old Masters*, London 1854, p. 29; M. Holyoake, *The Conservation of Pictures*, London 1870, pp. 20–1, 32–3; C. Dalbon, *Traité technique et raisonné de la restauration des tableaux*, Paris 1898, p. 117. Henry Merritt was one of the restorers used by the National Gallery from the late 1850s until the 1870s.

4 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, No. 3770, p. 232.

5 Op. cit., No. 500, pp. 32–3.

6 Op. cit., Nos. 988–92, p. 57.

7 Dalbon 1898, cited in note 3, pp. 116–17.

8 A.E. Dinet, *Les fléaux de la peinture: Observations sur les vernis, les retouches et les couleurs*, Paris [1904], pp. 16–17. Martel believed that 'a good varnish does not become discoloured by age', thus if all substances that might deteriorate were excluded, there should be no need for its removal: Martel 1859, cited in note 2, pp. 57–61.

9 N.W. Hanson, 'Some painting materials of J.M.W. Turner', *Studies in Conservation*, 1, 1954, pp. 162–73; and 'Some recent developments in the analysis of paints and painting materials', *Official Digest*, No. 338, 1953, pp. 163–74,: J.S. Mills and A.E.A. Werner, 'Partition chromatography in the examination of natural resins', *Journal of the Oil and Colour Chemists' Association*, 37, 1954, pp. 131–42.

10 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, Nos. 9419–29, p. 659.

11 Op. cit., Nos. 9376–82, p. 656; Appendix VIII, pp. 758–9, and IX, p. 767, Extract from letter from Baron de Klenze to Colonel Mure MP, Chairman of the Committee, 3 August 1853.

12 Op. cit., Nos. 10069–80, p. 709.

13 R.L. Feller, 'First description of dammar picture varnish translated', *Bulletin of the I.I.C. American Group*, 7, 1, 1966, pp. 8, 20, citing Lucanus's description of the varnish in *Schweigger's Journal*, 55, 1829, pp. 60–6; according to Feller, dammar was an ingredient of Crystal Varnish sold by the London colourmen Winsor and Newton in 1846. See also Fr.G.H. Lucanus, *Vollständige Anleitung zur Erhaltung, Reinigung und Wiederherstellung der Gemälde*, 3rd edn., Halberstadt 1842, pp. 34–5 (1st edn. 1828, in which dammar is not mentioned); Lucanus wrote that thirteen years of experience showed that a subsequent yellowing of the varnish appeared not to be a matter for concern. The paucity of information in other, slightly earlier, German handbooks suggests that details on the sources and properties were not yet sufficiently widely known to be discussed in much detail: see, for example, J.K. Stöckler, *Praktisches Hülfsbuch des Kunstfreundes*, Pesth/ Leipzig 1838, pp. 170 (on cat's eye dammar) and 179. This is, if anything, confirmed by the description of so-called '*dammar blanc*' or '*dammar-puti*' given by Guibourt, a pharmacist who was usually well-informed: the properties and solubility of the resin he describes are those of dammar, but the supposed source tree, a conifer, is certainly wrong. However, it grew in the right region (the Moluccas), so the confused botanical information Guibourt was given could have come originally from the local people gathering the resin, the trader who exported it or the person from whom he obtained it. See N.J.B.G. Guibourt, *Histoire abrégée des drogues simples*, 3rd edn., Paris 1836, Vol. 2, pp. 535–7.

14 C. Gould, *National Gallery Catalogues: The Sixteenth-Century Italian Schools*, London 1975, p. 23; the picture is described as having been 'withdrawn from exhibition' in 1929, and as 'never having been exhibited' in 1901 (MS Catalogue, National Gallery Archive).

15 Martel 1859, cited in note 2, p. 51; U. Forni, *Manuale del pittore restauratore*, Florence 1866, p. 91. The author had been trained by the well-known nineteenth-century restorer Giovanni Secco-Suardo; it seems from the foreword to Forni's book that there was some disagreement between the two on their respective books: the first edition of the first part of Secco-Suardo's own book, *Il restauratore dei dipinti*, appeared later the same year. Forni, who died in 1867, claimed that his book was based on practice, not on what he had learned from his teacher. The second part of Secco-Suardo's book was completed in the year of his death, 1873, but only published in 1894. Both parts appeared in a considerably re-worked third edition in 1918; a fourth edition appeared in 1927.

16 Horsin Déon 1851, cited in note 3, pp. 79–80; Dalbon 1898, cited in note 3, p. 43; Forni 1866, cited in note 15, pp. 124–5, 127–8; T.H. Fielding, *On the Theory and Practice of Painting in Oil and Water Colours*, 4th edn., London 1846, pp. 165–6.

17 Forni 1866, cited in note 15, p. 94. Oil of spike was also suggested as the solvent for a retouching varnish, with copaiba balsam and fir balsam (*olio d'abeto*), pp. 95–6.

18 M. Davies, *National Gallery Catalogues: The Earlier Italian Schools*, London 1961 (1986 reprint), pp. 291–3. It should be noted that at present it is not possible to identify the sources of polyterpenes securely: while oil of spike lavender is a good candidate, fir spirits, if these were indeed distilled from the oleoresin (see note 54, below), would also be a possibility, particularly in Italian restorations.

19 J.S. Mills and R. White, *The Organic Chemistry of Museum Objects*, 2nd edn., London 1994, pp. 105 B8; J.S. Mills and R. White, 'The Identity of the Resins from the Late Bronze Age Shipwreck at Ulu Burun (Kas)', *Archaeometry*, 31, 1, 1989, pp. 37–44; G.A. van der Doelen, *Molecular Studies of Fresh and Aged Triterpenoid Varnishes*, PhD thesis, University of Amsterdam, Amsterdam 1999, pp. 20–2.

20 Van der Doelen 1999, cited in note 19, pp. 16–19.

21 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, Appendix 4, p. 747. After listing pictures varnished, or presumed to have been varnished, with a simple mastic varnish, the Report states that the other paintings then in the collection, which would include the Bassano, 'have been, from time to time, varnished with mastic varnish mixed with oil'.

22 See, for example, P.F. Tingry, *The Painter and*

Varnisher's Guide, 2nd edn., London 1816, pp. 10–11; G.H. Hurst, *Painters' Colours, Oils and Varnishes: A Practical Manual*, 2nd edn., London 1896, pp. 439–40; A. Livache, *The Manufacture of Varnishes, Oil Crushing, Refining and Boiling and kindred Industries*, trans. J.G. McIntosh, London 1899, pp. 35–7 (the original French edition, *Vernis et huiles siccatives*, Paris 1896, was unavailable); Guibourt 1836, cited in note 13, Vol. 2, pp. 556–7; Martel 1859, cited in note 2, pp. 50–1; Forni 1866, cited in note 15, p. 229.

23 Mills and White 1994, cited in note 19, pp. 99, 106–8; M. Serpico, 'Resins, Amber and Bitumen', in P.T. Nicholson and I. Shaw, eds., *Ancient Egyptian Materials and Technology*, Cambridge 2000, pp. 430–74, esp. Table 18.2, p. 432, and pp. 434–6.

24 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, No. 10082, p. 710. Similar advice appeared in conservation literature: see, for example, Martel 1859, cited in note 2, p. 51.

25 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, p. xii, Nos. 2915–27, p. 171. 'Gallery varnish' was apparently also used on pictures in private collections. For an account of the problems with atmospheric pollution in the National Gallery during the nineteenth century see D. Saunders, 'Pollution and the National Gallery', *National Gallery Technical Bulletin*, 21, 2000, pp. 77–94, esp. pp. 77–81.

26 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, Nos. 1946–51, p. 106, Nos. 2952–4, p. 173. It is not known who the 'very old varnish-maker in Long Acre' (No. 2954) patronised by Seguier was: several colourmen had premises in Long Acre at this time. In 1843, for example, the list includes E. Wood, varnish maker and colourman (no. 5), C. Roberson and Co., artists' colourmen (no. 51), their former partner Thomas Miller, colourman (no. 56), and G. and T. Wallis, varnish and colourmakers (no. 64). We are most grateful to Clare Richardson, Department of Painting Conservation and Technology, Courtauld Institute of Art, for this information. There is no indication in the Archive of the Roberson Company (now kept at the Hamilton Kerr Institute, Cambridge University) that Seguier was one of their customers. For the recipe see, for example, Fielding 1846, cited in note 16, pp. 166–7; G. Field, *Chromatography; or, A Treatise on Colours and Pigments, and of their Powers in Painting*, London 1835, pp. 208–9.

27 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, Appendix 4, p. 747: see note 21, cited above.

28 Mills and White 1994, cited in note 19, pp. 106–7; A. Burnstock and R. White, 'A preliminary assessment of the aging/degradation of Ethomeen C-12 residues from solvent gel formulations and their potential for inducing changes in resinous paint media', *Tradition and Innovation: Advances in Conservation. Contributions to the IIC Melbourne Congress, Melbourne, 10–14 October 2000*, eds. A. Roy and P. Smith, London 2000, pp. 34–8; van der Doelen 1999, cited in note 19, pp. 86–103.

29 See, for example, *Recipes for the Colour, Paint, Varnish, Oil, Soap and Drysaltery Trades*, London 1902, p. 144. However, Hurst 1896, cited in note 22, p. 485, includes a Crystal Varnish recipe using Canada balsam (North American fir balsam).

30 *Report from the Select Committee on the National Gallery* 1853, cited in note 1, Nos. 9419 and 9430–3, p. 659; see also note 10. The price of mastic was still described as high at the end of the nineteenth century: see Livache 1899, cited in note 22, p. 202.

31 Martel 1859, cited in note 2, p. 51.

32 Mills and White 1994, cited in note 19, p. 108; R. Pernet, 'Phytochimie de Burseracées', *Lloydia*, 35, 1972, pp. 280–7; J.S. Mills and R. White, 'Natural resins of art and archaeology: Their sources, chemistry, and identification', *Studies in Conservation*, 22, 1977, pp. 12–31; Tingry 1816, cited in note 22, pp. 12–13; Guibourt 1836, cited in note 13, Vol. 2, pp. 537–40.

33 Hurst 1896, cited in note 22, p. 445; elemi and mastic are included (with sandarac or other ingredients) in recipes for white hard spirit varnish, paper varnish and white varnishes, pp. 482–3. See also Forni 1866, cited in note 15, pp. 229–30.

34 Martel 1859, cited in note 2, p. 50; Forni 1866, cited in note 15, pp. 228, 261–3: most sandarac recipes include a plasticising ingredient (Venice turpentine, for example); Hurst 1896, cited in note 22, p. 482, white hard spirit varnish; see also the recipes cited for elemi. Dalbon commented that varnishes in alcohol should be proscribed as they yellowed quickly and, as they very easily became incorporated with the paint, they were hazardous to remove: Dalbon 1898, cited in note 3, p. 117.

35 The comment appears in the conservation dossier for the picture, copied from the MS Catalogue in the National Gallery Archive. See also Gould 1975, cited in note 14, pp. 161–2.

36 See, for example, Livache 1899, pp. 343–51, 355–60; Hurst 1896, pp. 464–71, 473–6; Tingry 1816, pp. 98–9; 107–8, all cited in note 22.

37 A preparation of this type was perhaps available ready-made, although not necessarily described as a varnish; there are several mentions of so-called copal preparations in recipe books in the Roberson Archive (see note 26), which were intended as vehicles for painting: for example, HKI MS 788-1993, f. 55v: '4 G[allons?] Copal and 1 G Mastic. Try small quantities first to see if they will mix(?) clear'; see also HKI MS 789-1993, f. 34v; HKI MS 778-1993, f. 26v. In all cases the resins were already in solution.

38 Fossil resins, such as Baltic amber (succinite), 65 million years old, and Claybourne amber, 5 million years old, are indeed genuine fossil resins. A semi-fossil resin is one that has fallen off a tree within historic times, become covered by soil and detritus, then dug up perhaps 100–1000 years later. This is typical of kauri.

39 Mills and White 1994, cited in note 19, pp. 103–5; A. Tschirch and E. Stock, *Die Harze*, 3rd edn, Berlin 1933–6, pp. 798–856; Tingry 1816, pp. 89–108; Hurst 1896, pp. 430–2; Livache 1899, pp. 14–30, all cited in note 22; Guibourt 1836, cited in note 13, Vol. 2, pp. 523–9; Martel 1859, cited in note 2, pp. 51–2; Forni 1866, cited in note 15, pp. 231–3, 267–9, 273–5.

40 Mills and White 1994, cited in note 19, p. 105; M. von

Pettenkofer, *Über Ölfarbe und Conservirung der Gemälde-Gallerien durch das Regenerations-Verfahren*, Braunschweig 1870; S. Schmitt, 'Examination of paintings treated by Pettenkofer's process', *Cleaning, Retouching and Coatings: Preprints of the Contributions to the IIC Brussels Congress, 3–7 September 1990*, eds. J.S. Mills and P. Smith, London 1990, pp. 81–4; L. Keith, 'Andrea del Sarto's *Virgin and Child with Saints Elizabeth and John the Baptist*' in this *Bulletin*, pp. 42–53.

41 Conservation dossier, held in the National Gallery Conservation Department.

42 Forni 1866, cited in note 15, pp. 225–7. Forni categorised Copaiba balsam as a variety of turpentine. He commented on its darkening, and noted also that it was falsified by admixture with drying oil or common turpentine and adulterated with castor and poppy oils.

43 Davies 1961, cited in note 18, pp. 399–401; here the painting is ascribed to Giacomo Pacchiarotto.

44 Mills and White 1994, cited in note 19, p. 103; Hurst 1896, cited in note 22, p. 440.

45 Tingry 1816, pp. 80–90; Livache 1899, pp. 186–92; Hurst 1896, p. 483 (with other ingredients), all cited in note 22.

46 A.H. Church, *The Chemistry of Paints and Painting*, 3rd edn., London 1901, p. 114. For a discussion of all the soft conifer resins and spirits of turpentine see Mills and White 1994, cited in note 19, pp. 95–102; Tingry 1816, cited in note 22, pp. 17–21; Guibourt 1836, cited in note 13, Vol. 2, pp. 574–85.

47 Forni 1866, cited in note 15, pp. 223–7.

48 See, for example, the recipe for mastic varnish including pine resin in a recipe book in the Roberson Archive, cited in note 26: HKI MS 788-1993, f. 47r.

49 Mills and White 1994, cited in note 19, pp. 100–2.

50 See, for example, Forni 1866, cited in note 15, pp. 261–2; Hurst 1896, cited in note 22, pp. 482–3.

51 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, Appendix 4, p. 747: see note 21 cited above.

52 G. B. Armenini, *De' veri precetti della pittura*, Ravenna 1587, pp. 128–9; Forni 1866, cited in note 15, pp. 223–4; *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, nos. 7525–63, 7645–6, pp. 536–9, 543.

53 Forni 1866, cited in note 15, p. 266; Hurst 1896, cited in note 22, p. 485.

54 Forni 1866, cited in note 15, pp. 234, 246.

55 L. Campbell and J. Dunkerton, 'A famous Gossaert rediscovered', *The Burlington Magazine*, CXXXVIII, no. 1116, March 1996, pp. 164–73, esp. p. 168.

56 See, for example, entries for 'Horace Buttery, 173 Piccadilly W.', HKI MS 121-1993, April 1895 to December 1899. This is followed by entries for A.H. Buttery from 1900 to 1908, HKI MS 133-1993 (and so forth): see note 26.

57 J. Anderson, 'Layard and Morelli', *Symposium internazionale: Austen Henry Layard tra l'oriente e Venezia, Venezia 26–28 ottobre 1983*, eds. F.M. Fales and B.J. Hickey, Venice 1987, pp. 109–37.

58 J. Dunkerton, 'L'état de restauration des deux Pisanello de la National Gallery de Londres', *Pisanello, Actes du colloque, musée du Louvre, 1996*, Paris 1998, pp. 657–81; J. Dunkerton, 'Cosimo Tura as Painter and Draughtsman: The Cleaning and Examination of his *Saint Jerome*', *National Gallery Technical Bulletin*, 15, 1994, pp. 42–53, esp. pp. 42–6.

59 Dunkerton 1994 and 1998, cited above in note 58. It is therefore likely that similar fir balsam-containing varnishes were used on Tura's *Saint Jerome* (NG 773) and Pisanello's *Virgin and Child with Saint George and Saint Anthony Abbot* (NG 776), both restored by Molteni at the same time. No analysis of his varnish on these pictures has been carried out, although an earlier varnish on the *Saint Jerome* was found to contain an African copal (probably Congo copal) and linseed oil: see Dunkerton 1994, p. 46. See also J. Dunkerton and R. White, 'The Discovery and Identification of an Original Varnish on a Panel by Carlo Crivelli', *National Gallery Technical Bulletin*, 21, 2000, pp. 70–6, esp. p. 70. For another Molteni restoration see J. Dunkerton, 'The Technique and Restoration of Bramantino's *Adoration of the Kings*', *National Gallery Technical Bulletin*, 14, 1993, pp. 42–61, esp. pp. 43–4: the varnish was not analysed.

60 Dunkerton and White 2000, cited in note 59, p. 70.

61 *Report from the Select Committee on the National Gallery*, 1853, cited in note 1, No. 495, p. 32.

62 It is notable that British varnish literature of the later nineteenth century contains very few recipes in which dammar is even a minor ingredient. Dammar is not mentioned in the recipe books held in the Roberson Archive (see notes 26 and 37, cited above), and dammar varnish is not mentioned by name in a selection of colourmen's catalogues (published by Winsor & Newton, George Rowney and James Newman) consulted, dating from 1849 to the early twentieth century. Crystal Varnish and White Spirit Varnish are listed, but these did not necessarily contain dammar.

Table of varnish compositions

Picture	Date of acquisition and previous owner	Varnish composition i) lower varnish ii) upper varnish	Date(s) of treatment (approximate)[1] and source
NG 36 Gaspard DUGHET, *Landscape with a Storm*, *c.*1653–4	1824; J.J. Angerstein collection	mastic + larch + asphaltum mastic + a little heat-bodied linseed oil mastic + a little heat-bodied linseed oil	pre-1824 1824–53 1868, 1888
NG 60 Leandro BASSANO, *The Tower of Babel*, after 1600	1837; Lt.-Col. J.H. Ollney	mastic + linseed oil mastic only	1837–53 after 1853
NG 218 Attributed to GIROLAMO da Treviso, *The Adoration of the Kings*, probably 1525–30	1849; Edmund Higginson	mastic + heat-bodied linseed oil mastic + dammar	1849 1887
NG 248 Fra Filippo LIPPI, *Saint Bernard's Vision of the Virgin*, probably 1447	1854; E. Joly de Bammeville, Paris	oxidised polyterpene on the tempera paint mastic mastic + heat-bodied linseed oil	pre-1854 1856 1882
NG 269 Imitator of GIORGIONE, *A Man in Armour*, probably 17th century	1855; Samuel Rogers	Manila copal + heat-bodied linseed oil mastic, tinted (with accroides)	pre-1856 pre-1856
NG 624 Workshop of GIULIO Romano, *The Birth of Jupiter*, probably 1530–9	1859; Duke of Orléans	mastic + fir balsam + heat-bodied walnut oil[2] mastic, yellowed strongly dammar, less yellowed	pre-1859 1859[3] 1889
NG 644.1 Follower of GIULIO Romano, *The Rape of the Sabines*, *c.*1555–75	1860; Edmond Beaucousin collection, Paris	mastic + Manila copal + walnut oil, partially heat-bodied mastic + dammar + toning (aloes?)[4]	pre-1860 1887
NG 644.2 Follower of GIULIO Romano, *The Intervention of the Sabine Women*, *c.*1555–75	1860; Edmond Beaucousin collection, Paris	mastic + walnut oil, partially heat-bodied mastic mastic + dammar, but no toning[6]	pre-1860 1877 1887
NG 750 ITALIAN, VENETIAN, *The Virgin and Child with Saints Christopher and John the Baptist, and Doge Giovanni Mocenigo*, 1478–85	1865; Conte Alvise Mocenigo di S. Eustachio, Venice	some fir balsam + mastic + linseed oil mastic + linseed oil, partially heat-bodied	1866[7] 1890
NG 771 BONO da Ferrara, *Saint Jerome in a Landscape*, perhaps 1440–50	1867; Lady Eastlake	mastic polyterpene mastic + some dammar + fir balsam	pre-1860–2 pre-1860–2? 1860–2
NG 819 Ludolf BAKHUIZEN, *An English Vessel and a Man-of-war in a Rough Sea off a Coast with Tall Cliffs*, probably 1680s	1871; Sir Robert Peel Bt	mastic + some heat-bodied linseed oil mastic + a little elemi	pre-1884 1884

NG 868, Adriaen van de VELDE, *Peasants with Cattle fording a Stream*, *c.*1662	1871; Sir Robert Peel Bt	mastic + a little dammar	pre-1871
NG 957 Jan BOTH, *Muleteers, and a Herdsman with an Ox and Goats by a Pool*, *c.*1645	1876; Wynn Ellis Bequest	mastic + Cupressaceae resin (i.e. sandarac-type)	1882
NG 1165 MORETTO da Brescia, *The Madonna and Child with Saints Hippolytus and Catherine of Alexandria*, *c.*1538–40	1884; Francis Palgrave	mastic + African copal + heat-bodied linseed oil mastic + elemi	pre-1884 1891
NG 1206 Style of Salvator ROSA, *Mountainous Landscape with Figures*, after 17th century	1886; Mrs. F.L. Ricketts	mastic mastic + some heat-bodied linseed oil	pre-1886 1886
NG 1308 Attributed to Ignacio de LEON y Escosura, *A Man in 17th-Century Spanish Costume*, 1850–90	1890; Charles Henry Crompton-Roberts	mastic + toning (accroides?) dammar + trace of heat-bodied linseed oil	pre-1890 1890
NG 1699 Attributed to Michiel NOUTS, *A Family Group*,[8] *c.*1655	1900; left half: Charles Fairfax Murray 1910; right half: bought	left half: mastic + traces of dammar + fir balsam mastic right half: mastic	pre-1900 1915 1915
NG 1849 Pietro ORIOLI, *The Nativity with Saints*, probably *c.*1485–95	1901; Cerretani collection, Siena	Manila copal + larch resin + heat-bodied walnut oil mastic mastic + elemi locally	pre-1901 pre-1901 probably 1901
NG 1858 Follower of the BASSANO, *The Adoration of the Shepherds*, 17th century	1847; Sir John May	mastic + dammar + fir balsam	pre-1847?
NG 1879 After Caspar NETSCHER, *A Musical Party*, after 1665	1847; Sir John May	mastic	1892
NG 1887 ITALIAN, NORTH, *The Adoration of the Shepherds*,[9] probably *c.*1600–25	1860; Edmond Beaucousin collection, Paris	Manila copal + polyterpene mastic + a little poppyseed oil	pre-1860 pre-1860
NG 2161 Follower of TINTORETTO, *Portrait of a Lady*,[10] *c.*1550	1855; Heirs of the Signori Capello	mastic + dammar + some fir balsam	pre-1855
NG 2292 Michiel van MIEREVELD, *Portrait of a Woman*, 1618	1908; George Fielder collection	mastic + partially heat-bodied linseed oil mastic + dammar[11]	pre-1908 1908
NG 2544 Isack van OSTADE, A *Landscape with Peasants and a Cart*, 1645	1871; Sir Robert Peel collection	dammar + mastic + larch resin dammar	pre-1910 pre-1910?
NG 2608 After Robert CAMPIN(?), *The Virgin and Child with Two Angels*, *c.*1500?	1910; Salting Bequest	Leguminosae (African) copal and oil (probably linseed) mastic + a little heat-bodied linseed oil	pre-1910 pre-1910

NG 2903 ITALIAN, *A Concert*, mid-1520s	1912; Bequeathed by Lady Lindsay	heat bodied linseed oil + pine resin + larch(?)	pre-1872[12]
		pine resin + mastic + some polyterpene(?)	pre 1912
NG 3080 Style of Ambrogio BERGOGNONE, *Saint Paul*, late 15th century	1916; Layard Bequest	mastic	pre-1916
		polyterpene (varnish refreshment)	1916
		dammar	post 1916
NG 3081 Style of Ambrogio BERGOGNONE, *Saint Ambrose(?)*, late 15th century	1916; Layard Bequest	See NG 3080	
NG 3085 Vittore CARPACCIO, *The Departure of Ceyx*, probably *c.* 1500	1916; Layard Bequest	mastic + pine resin + some fir balsam	pre-1867
		mastic	1916
NG 3099 Attributed to Gentile BELLINI, *The Sultan Mehmet II*, 1480	1916; Layard Bequest	mastic + larch resin + fir balsam	pre-1865
		mastic + fir balsam	*c.*1866?[13]
		polyterpene (varnish refreshment)	1916
		mastic + linseed oil	post-1916
NG 3100 Attributed to Gentile BELLINI, *Doge Niccolò Marcello*, probably 1474	1916; Layard Bequest	polyterpene	pre-1916
		polyterpene + mastic + a little dammar(?)	pre-1916
NG 3132 Style of Anthony van DYCK, *Portrait of a Woman*, after 1635	1916; Layard Bequest	mastic + dammar + larch resin	pre-1916
		mastic + a little heat-bodied linseed oil	pre-1916?
NG 5013 Adolphe MONTICELLI, *Still Life: Oysters, Fish*, *c.*1878–82	1939; Tate Gallery; transferred 1956 to National Gallery	pine + larch + mastic + a little heat-bodied linseed oil[14]	pre-1939
NG 5014 Adolphe MONTICELLI, *Still Life: Fruit*, *c.*1878–82	1939; Tate Gallery; transferred 1956 to National Gallery	See NG 5013	

Notes to Table

1 Dates of treatment are those recorded in the conservation dossier for each picture, occasionally amplified by information from the Manuscript Catalogue in the National Gallery Archive, unless otherwise indicated.

2 An adjacent, more light-scattering, area had just mastic and non-bodied linseed oil in place of the mastic, fir balsam and heat-bodied walnut oil varnish. This varnish layer was probably removed locally for blister treatment; revarnishing was then carried out using mastic and linseed oil.

3 C. Buttery was paid £25 for the restoration of the picture in September 1859; the account is dated 11 October 1859: see the private diary of the then Keeper, Ralph Wornum, entry for 25 September 1859 and National Gallery Account Book entry for 11 October 1859. As this was not recorded in the Manuscript Catalogue it was not transcribed into the conservation record. The diary and the Gallery Account Books are kept in the National Gallery Archive.

4 Mastic alone was present in less glossy areas, perhaps applied during local repairs carried out in 1877.

5 No copal could be detected with certainty.

6 The 1877 mastic varnish was thick and rather yellow, the chromatogram showing extensive oxidation. It is interesting that this picture has less of an orange-yellow tone than NG 644.1 and that no toning element was present in the 1887 varnish, unlike that on NG 644.1. It seems plausible that the restorer (Dyer) had to tone the varnish used on NG 644.1, which was not varnished in 1877, apart perhaps from local repairs, and was therefore less yellow than its companion piece, NG 644.2.

7 The picture was restored by Raffaele Pinti between 18 January and 28 March 1866: this is recorded in entries in Wornum's diary and the National Gallery Account Books, cited in note 3 above.

8 The left half was presented in 1900. The right half was purchased in 1910, at which time it was given the National Gallery number of 2764. The two halves were joined in 1915 and given the number 1699.

9 This picture was lent to the National Gallery of Ireland, Dublin, from June 1860 to March 1929.

10 This picture was lent to the National Gallery of Ireland, Dublin, from February 1857 until 1925. The thickness and discoloration of the varnish were noted during a technical

examination of the picture; see J. Plesters, 'Tintoretto's Paintings in the National Gallery (Part III)', *National Gallery Technical Bulletin*, 8, 1984, pp. 24–35, esp. pp. 32–3.

11 In less glossy areas mastic alone was found, instead of mastic + dammar.

12 The conservation dossier refers to a note in Russian on the back 'transferred from wood'. Analysis by GC–MS suggested the presence of heat-bodied linseed oil with pine and larch resins; the latter is indicated by the appearance of larixol in the TIC. It has been claimed that the resin from the Siberian pine, *Pinus russica*, contains larixol, surprisingly, and that this component is virtually absent in *Larix sibirica*. This varnish may date from the time the picture was in St Petersburg. Above this is a varnish containing pine resin, mastic and some polyterpene, unlike any varnish known to have been used by National Gallery restorers. It probably also pre-dates 1912.

13 The picture was relined by C. Morrill and restored by Raffaelle Pinti, presumably in London, probably shortly after the painting had been bought by Layard, so around 1866. It is not clear whether it was varnished at this time and the varnish is perhaps not of the usual kind used in England. We cannot say, therefore, whether this varnish may not also pre-date Layard's purchase of the picture.

14 Seemingly some other, degraded triterpenoid resin also included: this is ocotillone-rich and is possibly a dammar.