ARCHAEOLOGY

# Pigments of the imagination

*Paul Bahn*

THE first direct dating of Ice Age cave-art in Europe has been carried out as part of a French programme of pigment analysis in the Quercy region of France[1] and the French Pyrenees[2,3]. These results follow the recent discovery of human blood in red pigments in some Australian caves and rock-shelters, which was dated by radiocarbon to 10,730 and 20,320 years before present (BP)[4], and show that the study of cave art has entered a new and highly promising phase of research.

As in Australia, it was the discovery of organic material in pigment used in French caves which produced the radiocarbon date. Analyses of pigments have consistently revealed the use of iron oxide (red) and manganese dioxide (black). But the improved analytical methods of recent years have produced far more detailed results, most notably from Lascaux cave[5], and some years ago it was discovered that some of the black figures in the Pyrenean cave of Niaux contained charcoal[6].

The research programme of pigment analysis in the decorated caves of Quercy[7] revealed that charcoal was used here too, in the cave of Cougnac. It is a sample of 100 mg from a black dot on the cave wall, between a megaloceros (giant deer) figure done in charcoal and a 'speared human' figure, that has produced a radiocarbon date of 14,300 ± 180 years BP[1].

Samples of pigment from red figures on Cougnac's walls were compared with a deposit of red ochre on the cave floor, and with ochre sources outside the cave and 15 km away; the floor deposit was probably related to production of the red figures, and the ochre used was most likely obtained from local clays. Two points to emerge are that the large red animal figures in the centre of the cave's main panel were drawn with the same pigment and were therefore probably a composition, done in a single production event. And whereas stylistic studies had assigned Cougnac to the Early Magdalenian period, the date (together with one of 15,000 years BP from a reindeer bone in the cave) points to the Middle Magdalenian. Further dates, however, will be needed for confirmation.

Similar results have emerged from pigment analyses in the Pyrenees[2,3], especially in the caves of Niaux and Réseau Clastres. Dates have not yet been obtained from the charcoal figures at Niaux, but analyses of samples, carried out by scanning electron microscopy, X-ray diffraction and proton-induced X-ray emission, have revealed four specific 'recipes' of pigments mixed with mineral 'extenders' and binders: talc; baryte with potassium feldspar; potassium feldspar; and potassium feldspar with biotite (a kind of black mica). Beyond making paint go further, extenders have other advantages; for example, adding biotite makes red paint spread easily when wet, produces a darker colour than pure red ochre, improves adhesion to the wall and stops the paint cracking as it dries.

In Niaux's famous 'Salon Noir', most of the animal figures were first sketched out in charcoal, and then manganese paint using recipe 4 was added on top. It therefore seems that the Salon Noir was indeed a 'sanctuary', a special place where the figures were carefully planned ahead of execution. The figures in all other parts of this huge cave were done more spontaneously, without preliminary sketches.

So these analyses are helping to establish how the caves were decorated: the Salon Noir contains all four recipes, though most of it was done with number 4, as was a sign at the far end of the cave; the Réseau Clastres, on the other hand, had only recipe 4, without preliminary sketches, confirming that it was visited very briefly. Another important application is helping in the detection of fakes: only one painting in Niaux, a red-painted fissure interpreted as a vulva, proved to have no extender. As the figure was not mentioned by the first scholars to study the cave, and there are initials nearby, it is clearly modern.

It is possible to 'date' recipe 4, because the occupation site of La Vache, directly across the valley from Niaux, has that same extender used with red and black paint on bones from layers dating to 12,850–11,650 years BP[8], the Upper Magdalenian; Niaux had traditionally been assigned to the Middle Magdalenian on the basis of style. Recipe 2 does seem to belong to the Middle Magdalenian, as it has been found on a bead from the cave of Enlène in levels of 13,940–12,900 years BP, and also in the Middle Magdalenian of the cave of Le Mas d'Azil.

One difference between the two projects is that the Quercy team believe the composition of its pigments to be entirely natural, because the mineral components discovered exist in the same proportions in local sediments. The Pyrenean team, on the other hand, insist that their compositions and recipes contain associations of components which it is quite impossible to find in nature. These claims are not necessarily contradictory — artists in Quercy may have been content to use natural pigments, whereas those in the Pyrenees may have concocted new ones.

Pigment analysis is providing a tool, applicable at least regionally, for dating Magdalenian paintings, and is revealing that behind apparent stylistic homogeneity there is technological heterogeneity. Styles lasted longer than was thought, and are of limited use in dating. □

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BLACK HOLES

# Making a compelling case

*Charles D. Bailyn*

BLACK holes, although perhaps the most spectacular theoretical constructs in astrophysics, are by their nature elusive to observers. They can be detected only indirectly, by their gravitational influence on their surroundings. Currently the most convincing black hole candidate is one member of a binary star system known to X-ray astronomers as A0620−00. New work by Haswell and Shafter[1] adds yet another brick to what has become an impressive edifice of data demonstrating that this system must contain a black hole.

Strong compact X-ray emitting objects are good places to start looking for black holes. The energy requirements for producing large numbers of X-rays in a small volume are severe. The only viable energy source for such emission is the gravitational energy released by material accreting onto a compact object. Models along these lines have been used to account for quasars (sufficiently far away from us to require galaxy-sized black holes to account for their apparent luminosity) and for compact X-ray sources in our Galaxy. In a few cases, detailed studies of the latter systems have produced virtually airtight evidence for the existence in nature of black holes.

The strongest galactic X-ray sources are binary stars bound sufficiently closely for one member of the system to accrete material from the other. The accreting gas typically forms a disk around the accreting star, and becomes hotter as it spirals inwards. The immense X-ray emission observed from these systems implies that the accreting star must have an enormous gravitational field, and hence must be