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EXCLUSIVE

LASERS FIND STONEHENGE CARVINGS

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THE STONEHENGE LASER SHOW

They were created nearly 4,000 years ago and rediscovered in 1953. Yet 50 years on they still have not been recorded or studied and are rarely seen. In an exclusive for British Archaeology, Thomas A Goskar, with Alistair Carty, Paul Cripps, Chris Brayne and Dave Vickers, search for the lost Stonehenge carvings

CARVED IN STONE

A dagger carved on one of Stonehenge's largest megaliths (centre of photo, left) was discovered in 1953. Archaeologists Stuart Piggott, Richard Atkinson (with cigarette) and J F S Stone (with pipe), who were then excavating at Stonehenge, took a latex mould (above)

Laser technology might not be the first thing that pops into one's mind when thinking about archaeology. However, an increasing number of archaeologists are adopting lasers as efficient measuring devices. It is still early days, but already one process known as 'laser scanning' enables the recording of sensitive objects from our past more accurately than ever before, without physical contact. The results are high-resolution, digital 3-dimensional (3D) models for analysis, interpretation and display.

Last summer, late evening passers-by at Stonehenge might have seen a group of people carrying a strange array of futuristic-looking boxes, cables and computer equipment towards the monument. One onlooker peering through the fence, perhaps noticing the number of long-haired archaeologists, asked if the Stonehenge festival rock band Hawkwind would be playing amongst the stones.

It was in fact the beginning of a project to look at the ancient carvings, run jointly by Wessex Archaeology and Archaeoptics. It is the most hi-tech investigation ever conducted at Stonehenge.

The first discovered and best-known Bronze Age carvings at the site are the dagger and axehead found by Richard Atkinson in 1953, on the inner face of Stone 53, one of the imposing Trilithon sarsens. Existing records show about 13 other axes on the same stone, some very hard to see. About 26 axes have been claimed on the outer face of sarsen Stone 4, and three on the outer face of Stone 3, both in the stone circle. Known axes vary from 8 to 36 cm long.

Whilst most of the prehistoric carvings at Stonehenge are axes, with the blade pointing upwards, other shapes are known, such as a possible trellis or lattice pattern on Stone 3, hollows, a shallow rectangle, ribs, and cup-marks. There are doubts as to

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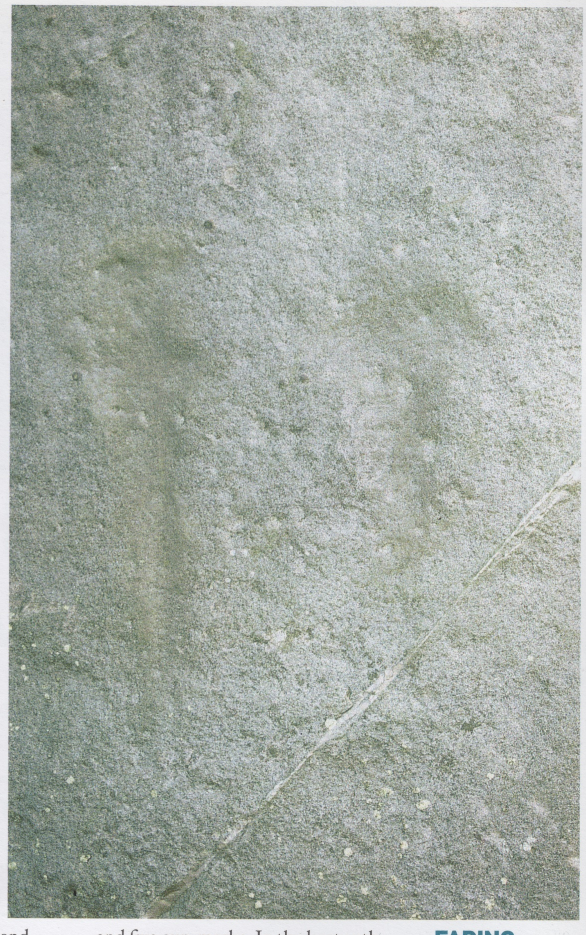


whether many of these are real carvings, and over the years some have been completely dismissed. Are these shapes natural, left over from the monument construction process, unfinished carvings, or later additions?

To put the carvings at Stonehenge in their wider context, we must look for comparable Bronze Age examples elsewhere in Britain. So far, despite the wealth of rock art from this period, there are few firm comparisons. Just seven other sites have been identified which have stones with carved shapes similar to the Stonehenge axes.

In 1830, seven clear axe shapes were found at Ri Cruin, in the Kilmartin valley, Argyll. They were located at one end of a stone burial cist, which was covered with a cairn. In contrast to the Stonehenge carvings, the blades point to the right.

Close by, the cairn of Nether Largie North revealed another stone cist onto which were carved 14 axes. Like those at Stonehenge, they vary in size, but there is no common orientation; the end slab has two axes whose blades point upwards. The chambered cairn of Nether Largie Mid, also in the Kilmartin valley, contains one other axe.

Axes–or mushrooms?

There are some rare examples closer to Stonehenge. When in 1845 a barrow was excavated near Badbury Rings, Dorset, inside was found a decorated stone bearing two dagger shapes (the larger similar in size to that at Stonehenge), two axe-like triangles,

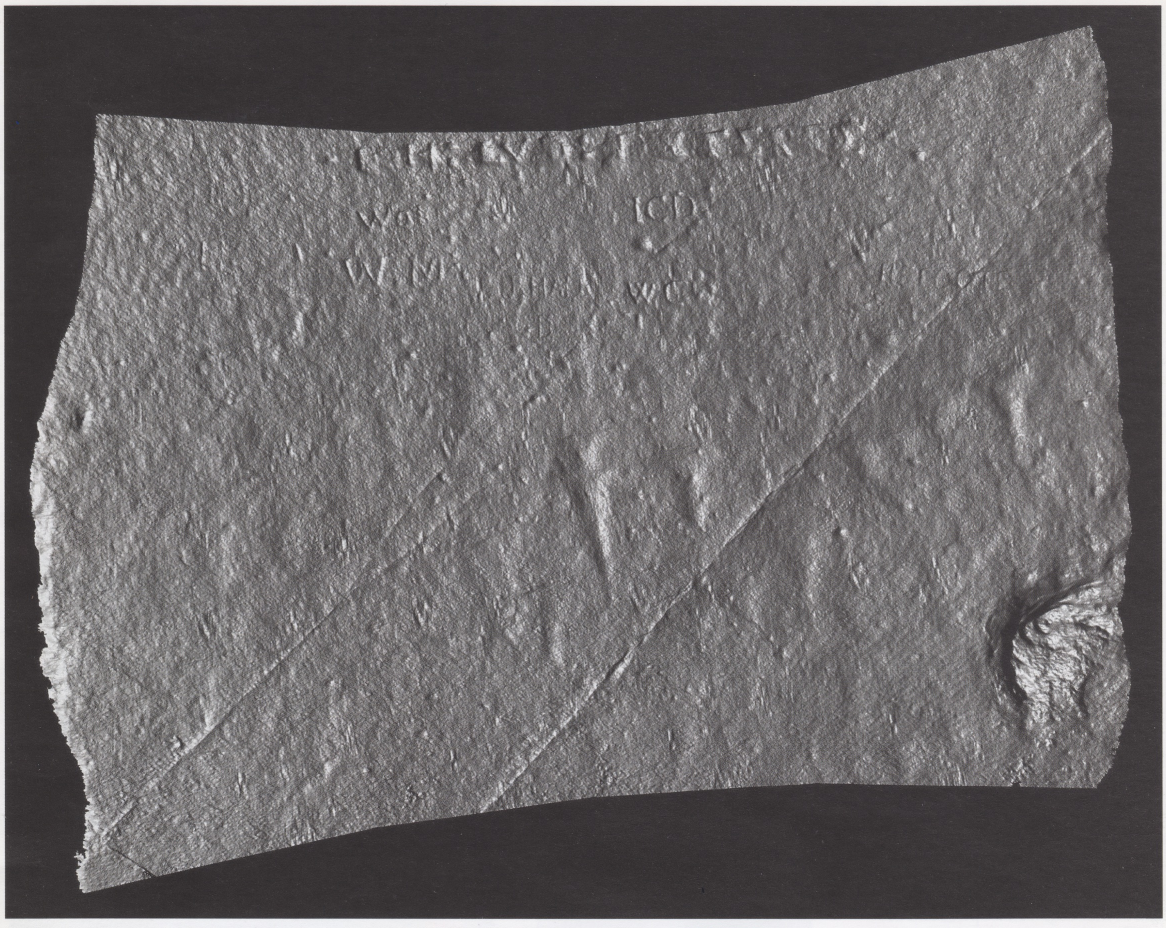
and five cup-marks. In the best 19th century tradition, the 'interesting' part of this stone was sawn off, and is now displayed in the British Museum.

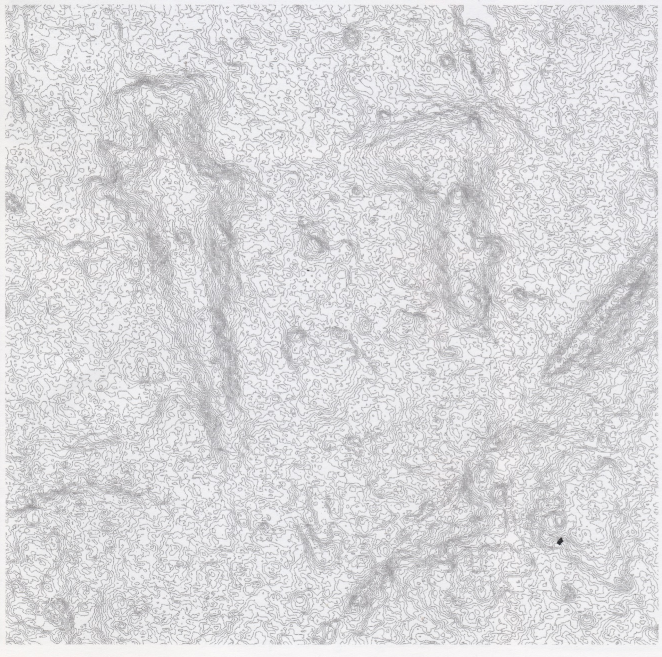
Also found in a stone cist inside a barrow, at Pool Farm, Somerset, was a slab decorated with seven feet and about ten cup-marks (on display in the City of Bristol Museum and Art Gallery). Another foot-shaped carving was found on a cist slab at Harbottle Peels, Northumberland, and ten were found at a Late Neolithic barrow known as the Calderstones in Liverpool, amongst some spirals and circles. These feet are similar in size to the Stonehenge axes.

What did the Stonehenge carvings mean? The axes are almost certainly crude representations of contemporary Bronze Age metal flanged axeheads. The dagger could be compared to examples found in the nearby Bush Barrow. Here an apparently powerful man was buried with an exceptionally rich group of artefacts, including three

FADING EVIDENCE

A photo taken by archaeologist O G S Crawford in 1953 soon after lichen had been removed shows dagger and axe clearly (above left). Today (right) they seem less distinct. Laser scanning in progress (below left)





DIGITAL IMAGES

The laser scanned section of Stone 53 showing the dagger and axes, with 'modern' graffiti at the top (above). Automatically generated contour plot of the dagger and axe at 0.3mm intervals (left)

copper or bronze daggers and an axehead.

Carvings at the other sites, assuming the slabs had not been reused, have funerary associations. The tenuous suggestion that Stonehenge may thus be a sepulchral monument, is perhaps strengthened by the large number of burial mounds in the surrounding landscape. One of many other theories suggests that the carvings, and Stonehenge itself, represent sacred or ceremonial mushrooms, reminiscent of a fairy ring.

We must remember that while the sarsens are thought to have been erected around 2,300 BC, metal axes were not in common circulation for generations after this. Whatever the carvings mean, accurate recording is vital to our understanding of the monument as a whole.

Plaster casts to lasers

Since Atkinson's discoveries in 1953, several ways of recording the carvings

have been used, with varying degrees of success. Robert Newall soon made rubbings of the portions of stones known to contain carvings. From these he constructed scale drawings. At about the same time plaster casts were made of known carvings on Stones 3, 4, and 53, enhanced by a novel method of applying silver leaf. In 1956 latex moulds were made for further study by Atkinson and his colleagues. None of this work was published.

In 1967 staff from the Department of Photogrammetry and Surveying, University College, London, used a stereometric camera to produce a very fine contour plot of the carved dagger and adjacent axe on Stone 53, with a resolution of just 0.5 mm.

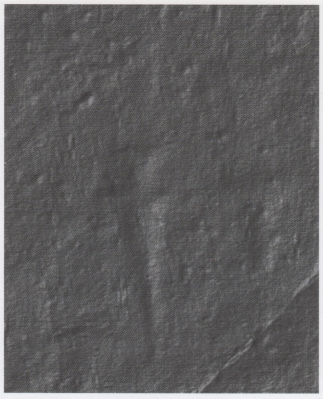
More recently English Heritage's Metric Survey Team, led by Paul Bryan, completed the first photogrammetric survey of all the stone surfaces. They used a semi-automated, but still rather laborious, digitisation process to produce a surface model of each stone based on a grid density of around 2 cm. Placed into a common coordinate system and combined with existing landscape survey data, this information was subsequently used for the Virtual Stonehenge developed by English Heritage in 1996.

In 2002 Wessex Archaeology decided to investigate the potential of laser scanning the Stonehenge carvings, and contacted Archaeoptics Ltd of Glasgow, who had scanned Seahenge timbers the year before. Thus Alistair Carty and Dave Vickers came to Wessex Archaeology's headquarters at Old Sarum, near Salisbury in Wiltshire, with an impressive array of equipment, including their Minolta VI-900 scanner, capable of capturing millions of points in 3D space, taking measurements just microns apart.

Atmospheric recording

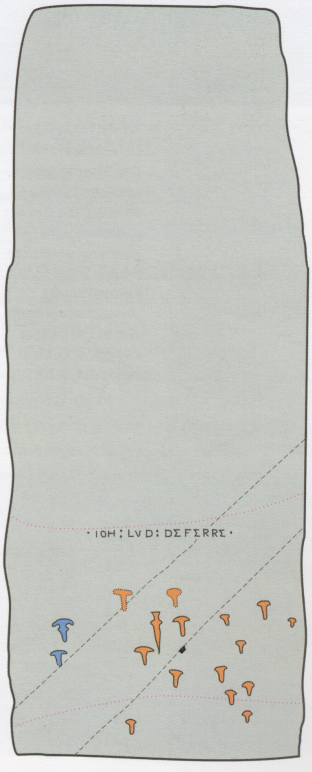
We decided to pick the stones which contained the greatest number of known carvings, Stones 3, 4, and 53, and scan a section of each of them to see what the results were like, and how clearly the carvings could be displayed on a computer. We had no agenda other than to see how well the carvings could be recorded, and we hoped that at least we could see them all, and take some measurements from the digital model. We were all in for a surprise.

With the permission of English Heritage, we started recording at 8 pm,



with about an hour to collect as much data as possible. The Minolta, on its industrial looking tripod, was placed a metre from the outer face of Stone 4, and, since this was more a test of the technology than a planned survey, we began to record, section by section, a strip across the carvings about 0.7 m high by 2 m wide.

The scanner emits a stripe of eye-safe laser light which is panned vertically across the stone. At each vertical step, the 3D position of points along the laser stripe is automatically computed using a triangulation principle and logged. The stripe then advances to the next vertical position. The procedure is fast, each scan taking 3 seconds to complete and acquiring 300,000 discrete 3D points per scan. A total of 9 million measurements were collected in just 30 minutes.



The carved portion of Stone 3 and the dagger and most of the axes in the middle of Stone 53 were similarly recorded.

Stonehenge is always an atmospheric place to undertake fieldwork whatever the weather, but this evening was especially fine. The day had been hot and sunny, and the sunset within the stones was spectacular. Looking at the sunlight and shadows on the surfaces of the stones gave us the idea that we could play with light to look at the 3D models we were capturing.

Odd depressions

The process over, the equipment was packed away. Back at their headquarters, Archaeoptics could stitch together the sections on a computer, in a process known as 'registration', to create an accurate 3D model from which detailed analysis could begin. After a few days of serious number crunching, the results arrived at Wessex Archaeology via the internet. They were impressive. The raw data acquired by the scanner are in the form of 'point clouds', unconnected 3D points. To be more useful for visualisation and analysis and to allow for more accurate registration, these were converted in a computer into 'solid' surfaces formed from millions of triangles.

After a few hours of manipulating these digital models in Demon, a powerful piece of software developed by Archaeoptics, we realised that all of the carvings which Newall planned could be identified clearly. We could move a virtual light into any position, adjust its colour, introduce shadows, take cross-section measurements, produce contour plots and even exaggerate the depth of the carvings to make them stand out more clearly. We were looking at the most revealing and accurate record of the carvings ever made.

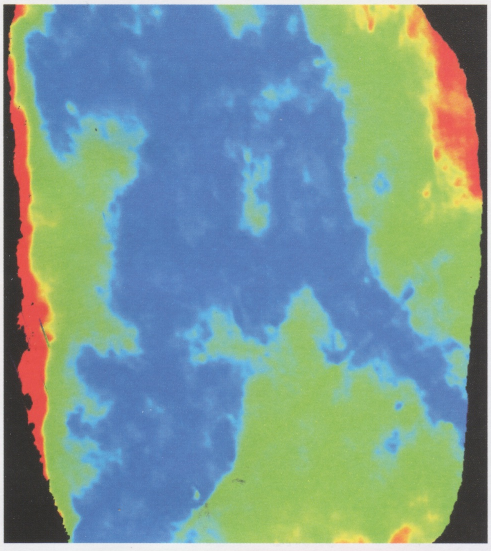
Over the following months, many methods were used to analyse the digital carvings, using advanced 3D techniques on some powerful computers. The surfaced 3D models were taken into modelling software, and various lighting techniques were

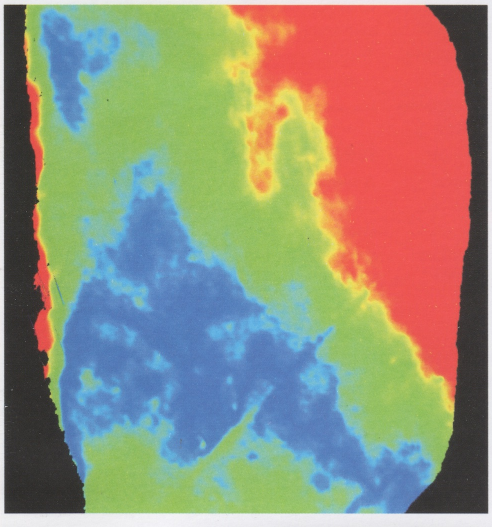
STONE 53

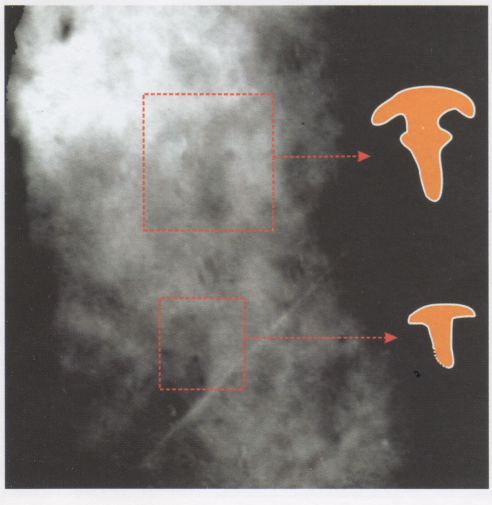
Detail of axe and dagger scan (left). The dagger acquired notoriety after Atkinson argued unconvincingly that it was carved by a visiting Mycenaean architect. Sketch of carvings shown in Newall's 1950s tissue rubbings (below). Lines of red dots show area of laser scan

NEW CARVINGS

Range colouring at different distances, with two new axe carvings showing down centre, light and dark blue (above right), and orange and light blue (centre right). Greyscale plot (below right) of same area (note natural oblique ridge running centre right to bottom left), with interpretation of carvings







developed at Wessex Archaeology to further enhance the outlines of the carvings. By shining bright virtual lights, the edges and depressions of the axes and dagger could be made quite pronounced. Several interesting factors were noted when the stone surface was made 'shiny', similar in concept to the silvered casts of the 1950s.

Because of the natural curvature and irregularity of the stones, lighting from one angle would enhance some carvings but hide others. So we made animations of a directional light circling the surface of each of the three stones, on which we could watch carvings appear and disappear as the light changed. It was hard to produce a single lighting angle that shows all the carvings well, but it was an interesting process to follow. It allowed us to become intimately familiar with the positions of the carvings, and 'get our eye in'. We noted some odd-shaped depressions on the left hand side of Stone 53, though Newall's plans indicated nothing there. Excited, we shifted our study to the 'blank' areas.

More secrets?

The animation of the light circling Stone 53 showed the outlines of two new axe-like shapes. They were hard to see, and it was easy to blame one's eyes and see axes everywhere on the surface of the stone. We had to employ a fresh set of eyes before we set about using a different method to enhance what we had found. A colleague saw just what we did: two previously unrecorded axes. They are badly eroded, and certainly not visible to the naked eye under normal conditions.

We decided to employ a method know as 'range colouring', which involves colouring the face of the stone according to the distance from a 'virtual camera' at a set distance from the virtual stone face. By doing this, we were able to produce a psychedelic-looking plot of our discovery.

The first carving is 15 by 15.3 cm, with a broad upturned blade, and a form of 'rib' a third of the way down the length. Although further analysis is needed, this shape could represent two axes, one carved over another. The second carving, 10.6 by 8.6 cm, is very faint indeed, but seems to be a normal flanged axe, as we find elsewhere on the stone. The lower left part of this carving appears to have been chipped and further eroded by two small indentations. The illustration shows an interpretation of their shapes.

Research continues to further enhance the data, and to check the remainder of the scanned surface for other previously undiscovered carvings.

There was something poetic about the juxtaposition of the most advanced Early Bronze Age technology, with the most advanced 21st century archaeological recording methods. What was intended as an investigation into how well the carvings would be recorded by a laser scanner, turned into a major discovery. It makes one wonder what could be found if the entire monument were recorded in this way?

The implications of having such a detailed model of the monument are enormous. As well as revealing more new carvings, and allowing us to study historic and more recent graffiti, the data could be used for decay monitoring to help us understand the extent of erosion of the stones. Fitted into the surrounding landscape, the model would produce a phenomenal resource for future study.

Recording the monument as it is today, that is the stones and the ground on which they stand, is arguably more important than eye-catching reconstructions of how it might have looked in the past. While Stonehenge has been the focus of much research over the years, there are still many questions to be answered, some of which depend on more detailed study of the surviving remains.

Given the potential of increased visitor numbers associated with the planned improvements to the landscape, it would appear sensible to begin this detailed study sooner rather than later, before the surfaces of the stones are further eroded. What other secrets do the stones and the Stonehenge landscape still hold? Maybe laser scanning can help us discover some of them.

Goskar (multimedia) and Brayne (IT) work at Wessex Archaeology; Carty and Vickers at Archaeoptics; Cripps (GIS) at the English Heritage Centre for Archaeology. Previous knowledge of all carvings is described by K Walker & A Lawson in 'Stonehenge & its Landscape', ed R Cleal et al (English Heritage 1995). For special access to the Stones, contact English Heritage tel 01980 626267. For more on the laser study see www.stonehengelaserscan.org/