Rebuilding Rome

The pieces of an ancient archaeological puzzle are falling into place to reveal the secrets of the imperial city says **Erica Klarreich**

Some features are easy to spot, but how do you recognise ancient suburbs?

IN 1562, workers in a vineyard near Rome unearthed some ancient marble fragments. They were pieces of the Severan Marble Plan, a detailed map of Rome created in the 3rd century AD. Those fragments, together with others that emerged in later centuries, are the most important topographical record of ancient Rome, and they date to the pinnacle of the empire's power. They are an unrivalled archaeological treasure.

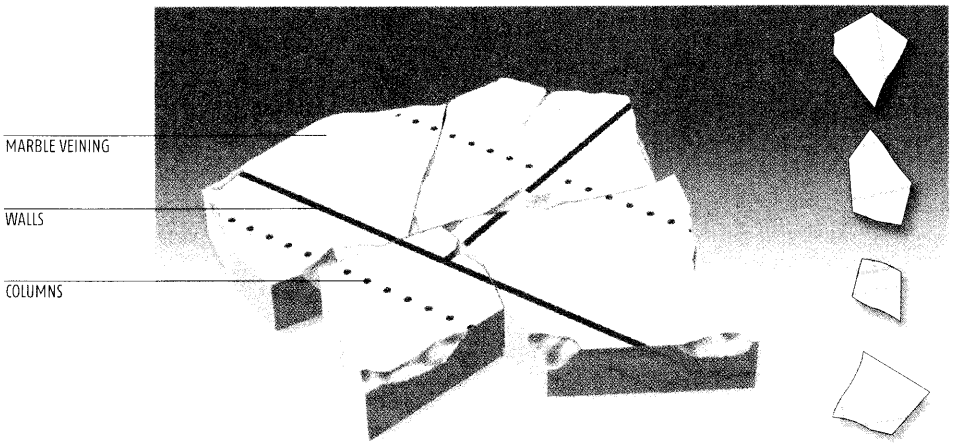
The problem is, no one knows how to fit most of the surviving pieces together. "It's like a puzzle where the puzzle-maker sells it to you without a picture on the box," says Bernard Frischer, a classicist at the University of California, Los Angeles. "You have thousands of fragments to join up, but you don't know what you are aiming for."

Yet help may now be at hand. Over the last few months, a team at Stanford University in California claims to have made huge progress in fitting together pieces of the Severan Marble Plan. This heralds a major leap forward for anyone who wants to understand what ancient Rome was really like. "It's recreating the Rome of the Roman empire, which is a fantastic thing," says Peter Barber, head of map collections at the British Library in London.

It is no ordinary jigsaw puzzle. Created for the emperor Septimius Severus between AD 203 and 211, the Severan Marble Plan was carved into marble slabs and mounted onto a wall in the Temple of Peace just north-east of the old Roman Forum. It was over 18 metres wide and more than four storeys, or 13 metres, tall. It depicted the entire city, which covered several square kilometres, and was bounded not by administrative boundaries but, like a page in a modern atlas, by the available space and the chosen scale of 1 to 240. It shows ▶

PICTURE PUZZLE

Surviving fragments of the Severan Marble Plan are so eroded that they cannot be easily matched together. But the incisions on their surfaces and veining of the marble make the job easier



Rome in immense detail, right down to the individual rooms, staircases and even columns of the ancient city.

Sadly, less than 15 per cent of the original map survives, in around 1200 pieces. Some 250 of them were put in their correct places by Renaissance scholars and those who followed them, mainly because they recognised the outlines of Rome's most famous buildings. But for the last hundred years there has been little progress on the rest. "The residue are the hardest bits, the pieces that scholars have been trying for a long time to join, and couldn't," says Fischer.

By the late 1990s, placing a single piece was viewed as a major breakthrough. "Putting in a new piece was worth an article, and putting in 10 pieces could get you a professorship," says Elizabeth Fentress, an independent scholar and archaeologist based in Rome. Even so, not many people worked on the problem. Many of the surviving pieces are gigantic marble chunks weighing several hundred kilograms. Attempting to fit them together is physically as well as mentally exhausting.

The Stanford team set out to try and change this. Their project began when Marc Levoy, an expert in the use of laser scanning to create digital models of three-dimensional objects, became interested in the Severan Marble Plan. Levoy had already used laser scanning to create a 3D image of Michelangelo's *David* (*New Scientist*, 10 June 2000, p 9), and he realised the same technology could be used to make a model of the Severan pieces. Once this was done, Levoy reasoned, scholars could play with the pieces and fit them together virtually. And perhaps jigsaw-puzzle solving algorithms might be able to see fits that had eluded the human eye.

In 1999, Levoy's team went to Rome and made high-resolution scans of every nook and cranny of the whole collection. A digital file was created for each piece describing every detail of its shape and surface. The final dataset contained more than 8 billion geometric shapes, totalling 40 gigabytes of information.

At first glance, the most obvious approach to joining the pieces was try to match them together by shape as if they were part of a traditional jigsaw puzzle. But this turned out to be impossible. As the Roman empire began to disintegrate in the 5th century, the Severan Marble Plan was abandoned. Many marble slabs were probably removed and used to build walls, or ended up buried. By the time pieces resurfaced in the vineyard over a thousand years later, many of their edges were worn.

So David Koller, one of Levoy's students in computer science, decided instead to focus on the equivalent of the picture on the jigsaw puzzle – the map itself. Unfortunately, outside the main archaeological sites, little is known of ancient Rome, so not much could be achieved by comparing the pieces to existing ruins. But they could be compared to each other.

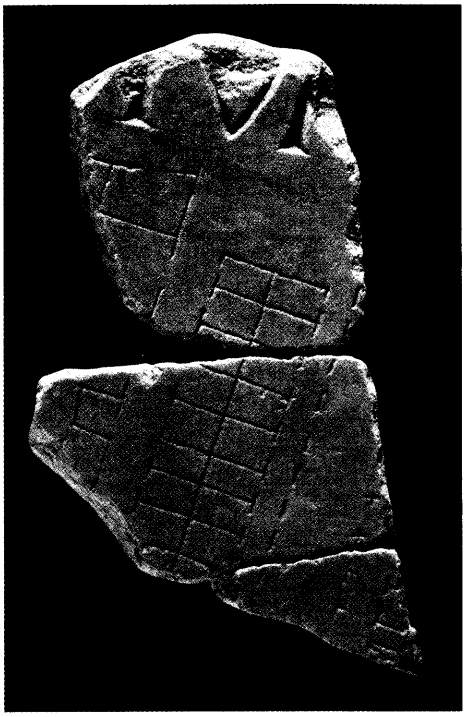
The incisions on the marble surface sketch out the walls of theatres, alleyways and monuments. Different features are represented by different kinds of line. For example, a thick line is often an external wall, while a row of dots shows a row of columns. Wide, wavy incisions are aqueducts, and small triangles with lateral notches represent staircases. Before the team turned the computer loose on the models, Tina Najbjerg, an archaeology research fellow at Stanford, fed in information about what kind of feature was represented by each type of line.

The computer measured the angles between lines that reached the outer edge of a fragment, then searched for lines of the same type at the same angle on other fragments. This way, it could spot associations between fragments even where their connecting surfaces were chipped or eroded away.

Koller's algorithm produced many dozens of possible matches. But he could see that several were not true matches just by looking at them. So to winnow down the possibilities further, he introduced a second set of checks. Marble has veins of different colours which form a grain, so it should be possible to identify fragments broken off from the same original slab. Also, some of the fragments have holes in them made by the clamps that fixed the original slabs to the wall of the Temple of Peace. Because the researchers know where the clamps were on the wall, the clamp holes give them clues to the location of some of the pieces.

Numerous matches came up based on these criteria, but the team wanted to ensure they

STANFORD DIGITAL FORMA URBIS ROMAE PROJECT



Shops along the north side of the Circus Maximus. Staircases (right) were indicated by notched triangles

It is very satisfying when you pick up the pieces in your hands and feel them lock together"

were correct. In June 2003, they went back to Rome to physically test them. Although erosion makes this hard, there is often a good fit between at least some parts of adjoining pieces. "It is very satisfying when you pick up the pieces in your hands and feel them lock together," Koller says. The result was two confirmed matches. The team were able to confirm another 10 by visually comparing the grain and incisions on the pieces.

Finding a match

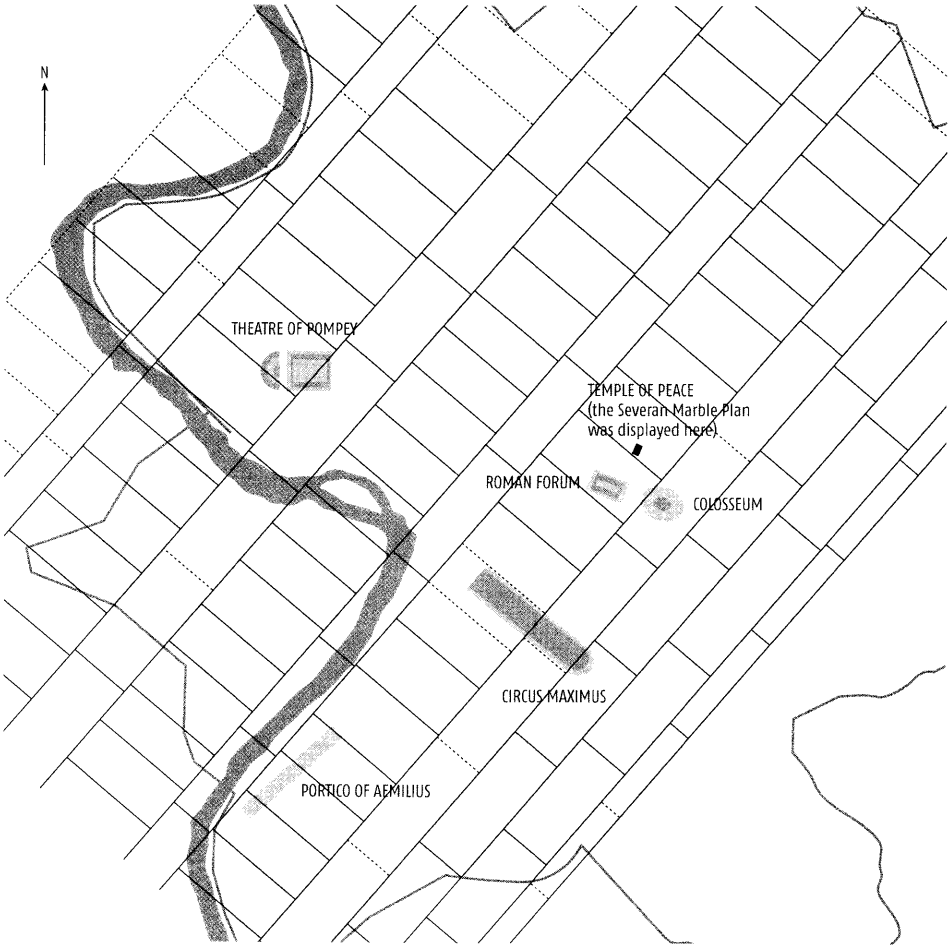
The Stanford team has announced these findings at several conferences, and have submitted them for publication. As well as the 12 matches they feel confident about, they have presented more than 30 other possibles. "It was met with unanimous acceptance. I heard nothing but applause and compliments on the team's work," says Frischer. And these findings are only the beginning. "They have speeded up the process exponentially," says Fentress. "It's a really spectacular advance."

Koller has spent a long time going through the hundreds of potential matches the computer has churned out, verifying them by eye. "It doesn't seem so bad compared to the hundreds of thousands of possibilities the computer search is culling out," he says. But Barber warns that lines that seem to match may be deceptive. "I think you have to be pretty careful. Lots of things will apparently fit," he says. "The only way you can do it is by shape and context and what you know about the structure of Roman buildings."

Scholars are still examining the new matches to find out what they say about ancient Rome. One feature the map brings to light is the apparent lack of differences between neighbourhoods, says Trimble, a Stanford classicist who co-directs the project with Levoy. "No matter where we look on the map, we see a mix of wealthy and poor residences, and a mix of shops and private spaces," she says. The wealthy houses are easy to identify, because they show features like internal courtyards, gardens surrounded by columns, entrance halls and reception rooms. Buildings with long corridors are apartments where poorer people lived. This intermingling illustrates the city's patronage system, in which poor people depended on the favours of a powerful patron, and offered their ▶

A TO Z OF ANCIENT ROME

The Severan Marble Plan showed the entire city of Rome as it was in the 3rd century AD, carved onto huge marble slabs. Of the fragments that survive, those depicting Rome's most famous buildings proved the easiest to identify and place



SOURCE: STANFORD DIGITAL FORMA URBIS ROME PROJECT

services in return. Tradition dictated that a patron's dependants visited every day, so they had to live nearby. "The focus of living was organised not by socioeconomic separation but by hierarchical relationships," Trimble says.

To Koller the most exciting possibility arising from the new matches is the chance to find out about Rome's suburbs. "We know so much about the Colosseum from other sources, but what we don't know is the life of the man on the street," he says. "He lived off in some shanty, on an alley on the other side of the Tiber from the monuments." It is almost impossible to excavate these regions. "You can't just go and dig up someone's home," Koller says. "In the outlying parts of the city, the map is our only clue to what is out there."

Sometimes fitting a piece is the only way to be sure what it is depicting. One of the new matches seemed to show two rows of rooms with a passage between them, but there was no way to tell whether the picture represented a street with shops or a warehouse with storage bins coming off a central passageway. Koller's algorithm located the fragment near others that showed part of the Tiber. "There are lots of warehouses by the river," Koller says. "That means we can say with very high confidence that it is a warehouse."

Koller is now trying to find a way to integrate human expertise and computer algorithms. Knowledge of the topography and population distribution of ancient Rome may lead to new proposals for matches. "For example, if a fragment has lots of staircases, scholars know it is from a very dense part of the city where they need multilevel buildings," Koller says. "They will know it doesn't belong in a region where the Romans could build out instead of up."

He is hoping to build a computer program that would allow scholars to move pieces around online, reflecting their own knowledge, while the program indicates whether attempts are favoured geometrically or not.

The team are also pursuing the idea of fitting the edges of the pieces together in a way that takes account of erosion. One idea is to convert each fragment edge into a string of numbers that correspond to the changes in angle along it. Doing this would enable the team to implement the type of string-matching algorithms used by Google and the Human Genome Project, which work well even if there are gaps in the strings – in this case caused by erosion. "I think we will find some new matches this way," Koller says.

But even if the map itself is deciphered, there is still one question that remains elusive. Why did the Romans make the map in the first place? It couldn't have been to help people find their way around the city; most of the map's features are unlabelled and the top parts would have been more than 12 metres off the ground. In addition, carving a map in marble is fairly impractical, because the city would have evolved even as the map was being carved. "If you carve something in marble you really fix it in time," says Barber.

"We know about the Colosseum, but not the life of ordinary people"

So the Severan Marble Plan was probably a showpiece, meant to commemorate the city and perhaps to advertise the abilities of the surveyor and the emperor's omnipotence. "It's a visual power play that says: 'We have extraordinary information both about public and private spaces...The imperial eye can map the city,'" Fentress suggests. "If so, then the Severan marble fragments are not only a window on ancient Rome but a key to understanding the mind of one of history's most powerful emperors. ●

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