



Brian Pratt/Nottingham Trent University

# HOW ROME POLLUTED THE WORLD

We tend to think of industrial pollution as a modern phenomenon but, as **David Keys** reveals, the ancient Romans were already contaminating the air, land and sea with toxic metals two millennia ago

**U**nder the relentless desert sun of southern Jordan lies a poisoned landscape that looks for all the world like a vast shattered mass of black volcanic lava. But the nearest active volcano is in Sicily, almost 2,000 kilometres to the west and the nearest genuine

major lava fields are 500 kilometres to the north in northern Syria.

In reality, this vision of the apocalypse is 100 per cent man-made. But it isn't the handiwork of modern humanity. This wrecked environment, one of the most polluted on the planet, is the

**Above:** Wadi Faynan in southern Jordan. The dark material in the foreground is ancient smelting spoil, evidence of Roman metal production. It's believed that the Romans' copper and lead output wasn't matched until the 18th century; **Right:** a slab of copper slag recovered from Wadi Faynan



B. Anthony



product of the world's first industrial revolution – that of ancient Rome. At its height, the Roman Empire was producing up to 80,000 tonnes of lead and 15,000 tonnes of copper each year, a level of output not achieved again until the 18th century.

One of the Roman industrial revolution's greatest production complexes – Jordan's Wadi Faynan, 120 kilometres north of the modern Red Sea port of Aqaba – is now being investigated by scientists from the universities of Leicester, Nottingham and Aberystwyth, who are determined to discover what impact industrial pollution had on the Roman world. Their work, along with parallel research by other scientists, suggests that hundreds of thousands, perhaps millions, of people living in Europe and the Middle East between the first century BC and the second century AD were blighted, or had their lives cut short, by high levels of pollution and contamination that sometimes surpassed those of the 19th-century Industrial Revolution.

Pollutants were produced and dispersed in a variety of ways. Initially, when ore-bearing rocks were moved into the open air, substantial quantities of dust would have been blown into the atmosphere. This was a particular problem at Wadi Faynan, where desert dust storms are a frequent occurrence.

Then, when the ore was smelted, large quantities of waste material escaped from the operation as very fine dust and were lifted into the atmosphere by the heat generated by the smelting furnaces. The techniques the Romans used to smelt the metal resulted in emissions of ultra-fine-dust pollution that were at least ten times higher than those seen in 19th-century Europe; the smelting pollution rate for copper was extraordinarily high – 15 per cent – while that for lead was five per cent.

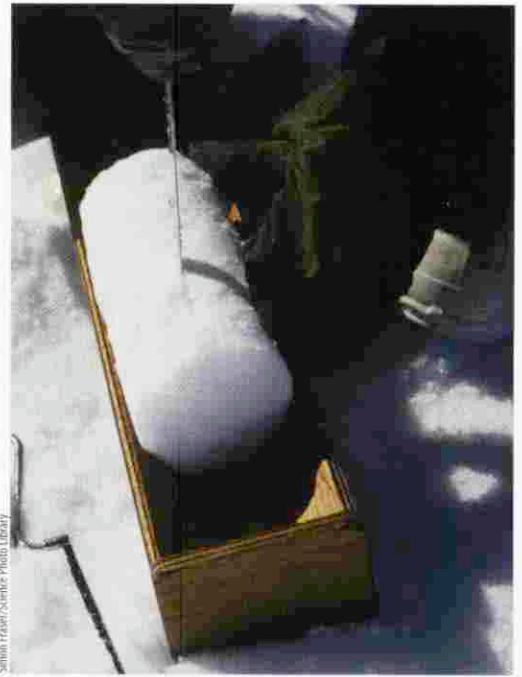
The main metal mined in Wadi Faynan was copper, and estimates suggest that up to 2,300 tonnes of the metal were released into the atmosphere each year. The major production centres for lead were in Spain, with smaller ones located in Greece, the Balkans and Britain. The combined emissions from these operations could have been as high as 4,000 tonnes per year.

Some of this material found its way

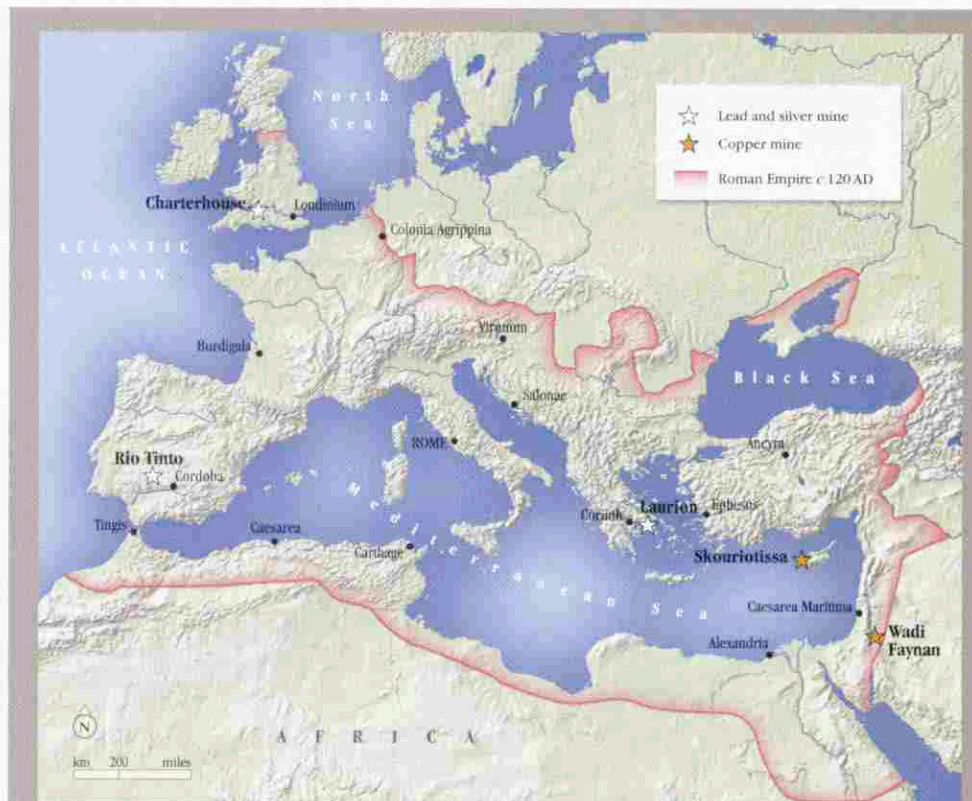
into the middle troposphere – about six kilometres up – and then fell to Earth hundreds, or even thousands, of kilometres away. French researchers studying ice cores from Greenland estimate that something in the region of 800 tonnes of Roman copper and 400 tonnes of lead 'rained' down on Greenland in the form of polluted snow between 500 BC and 300 AD.

However, the vast majority of the

**Right:** studies of ice cores have shown that pollution from Roman lead and copper production in southern Europe reached Greenland; **Opposite, left:** the Romans' penchant for feasts and banquets would have left them with more than liver damage and a weight problem given the extent to which lead was used in dining implements; **Opposite, right:** a lead-lined water pipe in Roman remains at Paphos, Cyprus



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**Right:** the remains of a miners' cemetery in Rio Tinto, southern Spain. The Rio Tinto region has been mined for lead and silver for millennia, from prehistoric times right up to the Industrial Revolution. Estimates put the Roman silver haul from the mine at more than 165,000 kilograms



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## Rome's industrial revolution: the major centres

### Charterhouse, England

A Roman lead-and-silver-mining area in what are now the Mendip Hills in southwest England. The mines were owned by the imperial government and the lead was exported to the continent via Southampton Water. Imperial exploitation began within six years of the invasion. A small Roman mining town located immediately adjacent to one mine had its own amphitheatre and a military garrison.

### Laurion, Greece

A large silver-and-lead-mining complex 32 kilometres southeast of Athens. First exploited as early as 1000 BC, the mines operated until the second century AD. Although still important in Roman times, their main contribution to history was to provide the wealth that made Athens great.

### Rio Tinto, Spain

The Roman world's largest lead-and-silver-mining complex, located 64 kilometres west of what is now Seville in southern Spain. This and other mines on the Iberian Peninsula produced 40 per cent of the empire's lead – at their peak, around 32,000 tonnes per year. The mining complex was also vital to the Roman economy because of the massive quantities of silver produced there. The Roman mining town at the site – Corta Lago – was almost a kilometre in length.

### Skouriotissa, Cyprus

An enormous copper mine 43 kilometres west of Nicosia. The island as a whole was one of the Roman Empire's most important industrial regions. Scattered around Cyprus are some three million tonnes of Roman copper slag – up to a third of which has been used to surface the island's roads. Reminders of Roman pollution survive today in such place names as Phougassa – the Hill of Fumes – near Polis in northwestern Cyprus.

### Wadi Faynan, Jordan

An ancient copper-mining centre around 50 kilometres south of the Dead Sea. Mining at the site started in the third millennium BC but expanded greatly under the Romans. Mineral extraction and smelting took place around the Roman mining town of Phaino (formerly the biblical Punon). In Roman times, it probably had a population of 2,000–4,000 inhabitants, the majority of whom were almost certainly free wage labourers. However, some slaves (including early Christians) were used in the mines, and later a number of churches were built, possibly as martyr pilgrimage destinations. At the centre of the town and adjacent to the mines themselves were Roman fortresses. The remains of the town, the mines themselves, agricultural terracing and a vast, 30-metre-high, 200,000-cubic-metre slag heap still survive.

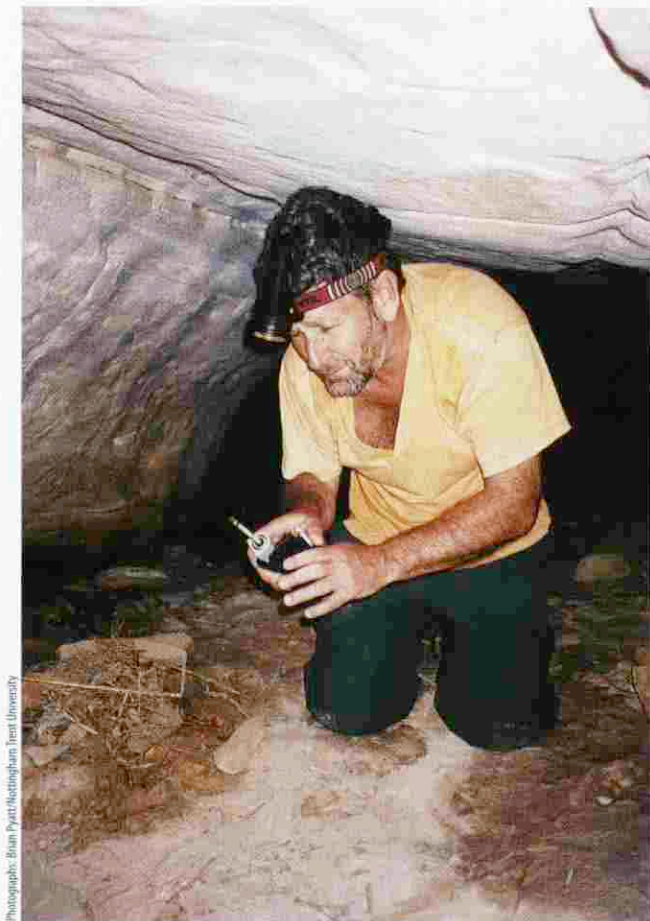
## The Empire's legacy

The Roman Empire's industrial revolution continues to pose a threat today. Analysis of modern plants and animals at and around Wadi Faynan has revealed that the 2,000-year-old pollution is just as harmful in the 21st century as it was in the first.

The growth of plants is stunted and their reproductive systems severely damaged, with very low seed production. Sheep grazing in the area had high concentrations of copper in their faeces (up to 25 parts per million) as well as in their urine and milk. The area's goats are highly prized because their stomachs are parasite free, but this is almost certainly because their guts are poisonous through being contaminated with mineral pollutants. In some areas near Wadi Faynan the surface soil has a copper content in excess of 300 parts per million.

"The Greenland ice-core data now illustrate in graphic style the global scale of Roman metallurgical production," says the co-director of the Wadi Faynan Research Project, David Mattingly, professor of Roman Archaeology at the University of Leicester. "What our studies in Jordan demonstrate are the huge local impacts of that activity. We can now put numbers on the extent of contamination of the landscape and of people and animals living within it. The implications for human health in Roman times are significant, but the pollution is also still active in today's environment, with implications for modern population centres near ancient mining and smelting sites."





Photograph: Brian Pyatt/Nottingham Trent University



Scientists from Nottingham Trent University have been studying the remains of the Roman mining activity in Wadi Faynan, southern Jordan;

**Above left:** Professor Brian Pyatt monitors the gases present inside an old Roman mine; **Top right:** a pile of slag left by the Romans remains today, continuing to pollute the Wadi some 2,000 years later; **Above right:** the tell-tale blue of copper deposits stands out against the Wadi's pink rock

pollution would have fallen within a few kilometres of the production sites, contaminating water sources and plants. Livestock that grazed on polluted pastures would have produced polluted milk and meat. Contaminated manure from these animals would also have been used as fertiliser, further contaminating crops. Humans and animals were poisoned by simply breathing in toxic fumes and particulates.

Other toxic metals produced as unintended by-products of Roman mining and smelting operations included arsenic (from lead/silver mining) and thallium (from copper mining).

All of these toxins have appalling health implications. High levels of copper cause convulsions, severe sweating, vomiting, diarrhoea, a reduction in fertility – the metal reduces the production and speed of sperm – and possibly liver and lung cancers. It is thought that it also stunts foetal growth, which


could lead to a reduction in the size and mental ability of children.

Lead, meanwhile, causes extensive and profound damage. In particular, it harms the central nervous system and brain, the reproductive organs and the kidneys. It can damage memory, cause anaemia and probably cancer and is especially dangerous for children and unborn babies. Exposure of entire populations to significant levels of lead pollution would significantly reduce average IQ and help produce a range of learning and behavioural problems.

And it's highly possible that lead would have had an impact on people all over the Roman Empire, not just in the highly polluted industrial centres. Although the metal was primarily used for civil engineering and construction projects and for military purposes (lead sling shot and javelin weights), it was also used to make pipes through which drinking water flowed, in the drinks

and cosmetic industries and in the production of salt.

The degree to which people in non-industrial areas were exposed to lead has been revealed by archaeologists who've analysed bone and tooth samples of ordinary Romano-Britons living between the first and fourth centuries AD. Samples show that some had ten times more lead in their bodies than did the average British city-dweller at the peak of lead-petrol pollution in the 1960s.

The cumulative health effects of direct and indirect contamination were almost certainly catastrophic for the millions of individuals affected. But many now suspect that it had a wider social and political impact on history. By reducing average IQ and causing learning and behavioural problems on a substantial scale, it may have been one of the factors that led to the demise of the Roman Empire and the ancient classical world as a whole. 

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