An oil painting of London viewed from Southwark in the mid-1600s before the Great Fire. The foundations of centuries of civilisation are not simply ignored by modern developers.

Construction of Crossrail – a new railway line for Greater London – is more than picking a route and laying track. Meet the company's archaeologists as they uncover bison bones – and Black Death. By **Crispin Andrews**

TRACK RECORDS

ARCHAEOLOGISTS working for Crossrail hit the headlines last March with a gruesome discovery. Just outside Farringdon tube station, the team unearthed the remains of 23 people believed to have died during London's 1348 Black Death epidemic.

In the four years since archaeologists started working on sites ahead of the government's £14.8bn project to relieve rail congestion in the capital, they have also discovered traces of an ancient river containing prehistoric bison bones and a manor house confiscated during the English Civil War. Most recently, in North Woolwich, they unearthed evidence that humans lived on the Thames some 9,000 years ago.

To run trains to Abbey Wood, Crossrail is building a 2.6km tunnel under the Thames between Plumstead and North Woolwich. This tunnel will sit off the main line that goes from Maidenhead in Berkshire and Heathrow Airport through central London, via Paddington and Liverpool Street, along the edge of the medieval and Roman cities, and finally out to Romford and Shenfield in Essex. The first trains are due to start running in 2018 and Crossrail expects 200 million commuters will eventually use the lines every year. But, however grand the project, construction crews are not permitted to just come in and start digging.

The Town and Country Planning Act and the 2008 Crossrail Act require developers to

At Liverpool Street, Crossrail archaeologists encountered the 16th century Bedlam burial ground

undertake an archaeological investigation of their site that meets best-practice standards, published by English Heritage.

In August 2013, Crossrail contractors from Museum of London Archaeology (MOLA) found 150 flints while working on the North Woolwich portal. They deduced that 9,000 years ago, people used this site to find, test, divide and prepare the river cobbles they needed to make flint-tipped hunting tools. "It's one of only a handful of sites that show early humans returning to the Thames Valley after the Ice Age," says Jay Carver, Crossrail's lead archaeologist.

It's not the oldest Crossrail discovery, though. Oxford Archaeology, the main Crossrail contractor on the western parts of the project, discovered a Pleistocene river containing bison, reindeer and mammoth bones. Marks on the bones showed they had been scavenged by predators, probably wolves and bears. MOLA archaeologists found something even older: a piece of amber from the Eocene – a time when carnivorous sheep, pygmy elephants and snakes the size of a bus roamed the planet.

Crossrail archaeologists have also discovered ancient wooden stakes, believed to be part of a track, which people used while hunting on the London wetlands 3,500 years ago. There's also a Roman Road at Liverpool Street, built using rammed earth made of clay and brush wood, with the occasional human bone thrown in.

Medieval ice skates, also found at Liverpool Street site, show how a marshland area known as Moorfields once froze over in winter. Moorfields, the archaeologists believe, often flooded due to poor maintenance of drainage channels after the Romans left the city. There's a lot more: a Venetian gold coin; a 16th century burial site used by the infamous Bedlam hospital; and 8,000 19th century Crosse and Blackwell jars.

"We're looking at a complete cross section of London's history that dates back 55 million years," Carver says. "It's the biggest east-to-west cross-section we've ever done in this city."

Integrated teams

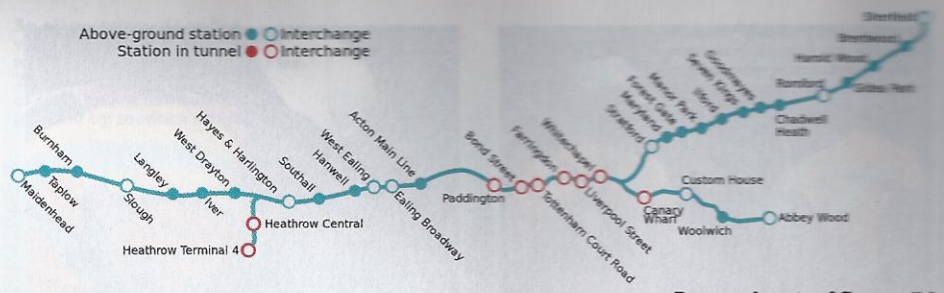
Crossrail's archaeological contractors work onsite, alongside construction workers, engineers and designers. It's not just a case of calling someone in whenever a digger unearths a few pots and pans, though. The archaeology team is fully integrated with the civil site teams. An initial archaeological assessment provides a good idea of what's likely to be at each site.

"We have a reasonably good idea at Liverpool Street where the general areas of archaeological interest are before we start digging, but not the detail of precisely what is present below ground," says MOLA's Nick Elsden. "We dig trial pits to field-test our predictions, and also monitor the construction workers carrying out their initial work diverting gas, electric and water supplies," he adds.

Jay Carver explains that the archaeologists work on specific parts of the site while construction continues around them. How long the archaeologists are on site for depends on what they find. "To avoid costly delays, take time researching the site in detail beforehand," Carver advises.

Rail construction projects elsewhere have also led to significant archaeological finds. A Roman freight ship was unearthed in Cologne, while a Paris project encountered the foundations of the Bastille. Mammoth, mastodon and giant sloth bones littered Los Angeles, and 50 million-year-old crocodile remains were uncovered in Brisbane.

An entire Aztec pyramid sits between platforms one and two of the Pino Suarez station in Mexico City. In Oporto, Naples and Prague, too, it was easier to build around the remains than remove the artefacts. >



Proposed route of Crossrail 1

< Earlier this year, Australian archaeologists used LIDAR remote sensing technology attached to a helicopter to create a 3D image of Mahendraparvata, a lost medieval city in Cambodia. Dense forests, knee-deep bogs and landmines restricted groundwork, but the LIDAR model showed up an ancient city once connected by canals and dykes, 12 new temples and a landscape once devoid of vegetation.

In Peru, researchers had unmanned aerial vehicles mapping ancient ruins, and in Egypt archaeologist Sarah Parcack used satellites, fitted with infrared and thermal cameras, to discover 17 new pyramids, 1,000 tombs and 3,200 settlements.

Low-tech excavation

"Ground-penetrating radar doesn't work too well in urban environments," Nick Elsden says. "There is too much demolition debris and services in the ground to highlight most archaeological features." Elsden adds that in rural parts ground radar can help distinguish between archaeology and the natural geology, rock, soil or sand that surrounds them.

The Crossrail excavations have been done in the traditional way: with spades, picks and basic construction equipment. Jay Carver adds that experts have used vacuum excavation to get rid of the soil from dig sites more efficiently. Rockworks computer modelling software has also been used to give the archaeologists a clearer picture of where significant deeply buried finds are likely to be found.

Things get a bit more high-tech once the remains have been excavated and sent to the Museum of London Archaeology for analysis. Historical records reference a burial ground in the Farringdon area dubbed 'No Man's Land'. It opened in 1348 when the Black Death epidemic that would eventually wipe out half of London's population first hit the capital. The cemetery was used, records show, until the 1500s. Some 50,000 people were buried there between 1348-51. The Black Death killed over 150,000 in London and 25 million across Europe.

The 23 skeletons MOLA archaeologists uncovered at Charterhouse Square are thought to have come from this burial ground. "The graves were laid out in a similar formation to skeletons discovered in a Black Plague burial site in east Smithfield in the 1980s," Carver says. "Over two levels, about three metres below the surface."

To establish that this is indeed a Black Death burial ground, DNA experts from the University of South Carolina are looking for traces of Yersinia pestis, the pathogen that caused the 1348 epidemic, in teeth taken from the Farringdon skeletons. The scientists also hope to provide insights into whether Black Death and bubonic plague are one and the same, both caused by the same pathogen. And whether the British strain of Yersinia pestis is the same as, or different to, that found in Black Death victims on the continent.

Isotope analysis

Durham University scientists have taken samples from the same teeth and are using stable isotope analysis to work out what people ate and where they came from.

Carbon stable isotope ratios vary in plants that use different photosynthetic pathways to manufacture carbohydrates from atmospheric carbon dioxide. Most temperate-zone vegetation uses the so-called C_3 metabolic pathway. Some plants from warmer regions use the C_4 pathway. Carbon and nitrogen stable isotope ratios also differ in marine and terrestrial foods.

Collagen, naturally occurring proteins found in flesh and connective tissues, preserves carbon and nitrogen stable isotope ratios, long after death. "Teeth can provide a chemical signature of a person's diet and where they lived during childhood," says Natasha Powers, MOLA's Head of Osteology.

All the nitrogen in collagen and most of the carbon come from dietary protein. Stable isotope ratios in bone collagen may prove a useful indicator of the meat-to-vegetable ratio of an individual's diet. Depending on local geology, sulphur stable isotopes may be different in terrestrial and freshwater foods.

Bone and tooth samples from burials on English archaeological sites usually contain enough intact collagen. It is extracted from the dentine, then purified and burnt. Experts use an isotope-ratio mass spectrometer on the resulting gases to measure the different isotopes present.

"The surrounding geology affects the chemical signature of the groundwater people drank," says Powers.

Strontium isotope ratios vary in different types of rock, and also therefore in the plants and animals that live in areas with different geology. These are then passed on to the tissues of people who eat the plants and animals. Oxygen isotopes vary in rainwater in different regions according to climate, altitude and distance from the coast. Strontium and oxygen isotopic analyses normally require dental enamel, not bone. It is also possible to look at evidence of environmental pollutants. "When we find teeth with low deposits of lead in a city grave, we think a person most likely migrated from a rural area," Powers adds.

The London Museum will store the 'Black Death' bodies for two years before they are reburied in another London cemetery. Jay Carver expects to uncover another 3,000 skeletons from the Liverpool Street Bedlam site.

In the coming months, Crossrail's archaeologists also hope to unveil evidence of Bronze- and Iron-Age settlements, a medieval leather works and a Roman timber bridge. Nick Elsden wants to find out more about what people were doing in the suburbs of Roman London. He thinks the area around what is now Liverpool Street may have been stabling - a place where people transported goods to and from Ermine Street for distribution around the city. Ermine Street was a major Roman road that connected London with northern Britain. What the archaeologists find over the next year will provide further insights.

Elsden says that nearly all modern archaeology happens in response to development. "It's unlikely anyone would have constructed a new building on a busy roadway outside one of London's main stations, or on a cobbled area part of the Charterhouse conservation area," he adds. "Without the Crossrail project, we'd never have got in to these parts of London, let alone unearthed so many hidden secrets." *

PLANNING PERMISSION

CAN YOU DIG IT?

There are many cases where a company will have to carry out an archaeological investigation before being granted planning permission for a proposed site.

This can either be a heritage statement or a desk-based assessment, where an archaeologist employed by the company or the local authority, investigates available records on the site – or, if necessary, a physical investigation of the site will be undertaken.

By law, a planning application that will affect archaeological remains has to include a heritage asset assessment. This is a description of the site's archaeological significance, using all known data, and an assessment as to whether planned excavation works will damage any archaeological remains.

This also includes standing monuments, structures and buildings under the catch-all term 'heritage': visual effects as well as physical. In 'conservation areas', the proposed work must be visually sympathetic.

"Construction works will usually have a negative and irreversible impact on archaeological remains, although sensitive foundation design can lessen this impact," says archaeologist David Gilbert from John Moore Heritage Services. "Although in some cases heritage assets can be made into features of construction projects enhancing their unique qualities and increasing their value."

Gilbert adds that once the archaeologists have assembled the necessary information on the site, they can assess the proposed development's impact. "The archaeologist needs as much information as possible about the proposed development," he says. "That's dimensions of foundations, whether there'll be underground services, or ground reductions to create features like driveways."

"Heritage concerns should be planned into construction projects from the outset, just as environmental and sustainability aspects are. Research and fieldwork can take time, and the larger the project the longer it is likely to take. Many applicants have had their projects delayed by not programming heritage into their plans."