Beneath the Euphrates Sediments: Magnetic Traces of the Mesopotamian Megacity Uruk-Warka

By Jörg W.E. Fassbinder

By 3000 BCE Uruk-Warka was one of the largest megacities of Mesopotamia. It was also the setting for the oldest saga of humankind, the famous “Epic of Gilgamesh.” More than 100 years of archaeological research and excavations by the German Archaeological Institute (DAI) have revealed the ruins of this metropolis. New techniques now peer further beneath the surface without excavation.

The city was center for a multitude of technical innovations, including irrigation canals, plaster mortar, astronomy, writing, literacy and numeracy. About 40,000 residents inhabited Uruk already by 3000 BCE, in an area of some five square kilometres. The diameter of the city is 4-5 kilometers, the enclosing wall has a length of some 11 kilometers. Meanwhile surface surveys, excavations and texts have confirmed the presence of canals, houses, temples and gardens even outside the city wall.
Map of Mesopotamia showing the main ancient cities and the extent of the Persian Gulf ca. 5000 B.C. Uruk marked in red. ([Wikipedia](https://en.wikipedia.org/wiki/Uruk))

Uruk, satellite view via Google Earth.
Archaeological research into such an enormous site cannot be restricted to excavation and archaeological survey. Excavations are time consuming and must be aimed at the optimal targets. All kinds of remote sensing techniques must therefore be used to understand the city in its entirety. Aerial photography may be done in suitable weather
conditions during the year, along with high-resolution satellite image analysis and Airborne Laser Scanning. But these methods are limited not only by temporary weather conditions; they provide information only about the uppermost centimetres of the subsurface. Deeper features and those covered by sediments remain unseen.

Geophysics provides us with a wide range of prospecting methods that can peer beyond the near surface underground. Magnetic, electric, and radar prospection are highly developed geophysical tools to survey the first 1-3 meters beneath the ground with sufficiently high spatial resolution. Unfortunately radar prospecting at Uruk will fail, since the Euphrates sediments are extremely salty and contain such a high amount of clay minerals that the energy of the waves are attenuated in the first upper 20 cm of the ground. The first tests with resistivity prospecting (ERT = Earth Resistance Tomography) in the spring season of 2019 revealed promising results with respect to measuring the exact depth of features, although resistivity values are extremely low due to the high salt concentration of the sediments. But these prospecting methods are time consuming and thus of limited use for such a large area. Magnetometer prospecting remains the most suitable method to trace archaeological structures up to 3 meter beneath the ground.

Magnetometry for archaeological prospecting using total field caesium magnetometers was developed and refined at the Bavarian State Department of Monuments and Sites in a close cooperation with the Geophysics Institute of the Ludwig-Maximilians-University Munich since the late 1970’s. The caesium magnetometer probes, compared to commercial models, provide up to 100 times higher resolution. These types of instruments, adapted to the specific requirements of archaeological prospecting, must be carried manually approximately 30 cm above the ground. Ideal ground conditions are soft, muddy or dusty soils, conditions that make it impossible to use a wheeled system, which will either stick in the soft mud and sand and damage the archaeological features.
Magnetometer prospection in action by modified handheld caesium magnetometers (Scintrex and Geometrics) in “Duo-sensor” configuration. Courtesy of Jörg W.E. Fassbinder.

Magnetometer prospecting in Uruk was initiated by the archaeologist Margarete van Ess (director of the DAI in Baghdad) and carried out by the Munich prospecting team in 2001-2002, resumed after the Iraq war in 2016, and continued in 2018 and 2019. The geophysical survey was started in the southwestern part of the city and focused on an area north of the Sinkashid Palace. A large canal passes this area to the east, and it includes the canal and its branches, a harbour and settlement area east of Sinkashid palace and a settlement area southwest of the palace. A second, large area was measured across the southern city wall, bringing to light construction details, a water gate, as well as nearby gardens and fields. In the south, outside the city, a large burial ground and a huge building complex of the city wall were detected.

Excavation of coffins from the burial ground. Courtesy of Jörg W.E. Fassbinder.
The magnetogram image provides insight into settlement areas, gardens and fields close to the city wall, as well the network of canals that obviously served as the main arteries of Uruk. This network of waterways and canals cross the city from north to south and makes the city quarters accessible, but also provide water for the irrigation of gardens inside the enclosed city. The main canal was traced in the eastern part of the magnetogram for a length of 400 m. It is 10 m wide and, at several points, slightly smaller canals branch off to the west. Left and right of the canal are settlement areas, divided by the smaller canals that led to fields and gardens west of the settlement areas. Canals of three or four different widths, the smallest belonging to the field irrigation systems, can be distinguished.

The central part of the magnetically scanned area is characterized by two different main features. In the south, a large structure, running East – West, seems to accompany the canals into the city centre. A similar shorter structure some metres to the west obviously blocks part of the main canal. None of these structures are visible neither from the air nor from the ground, which is very flat in this part of the city. However, they seem to control or guide the water flow and the canals. Here a selective excavation could determine the date and the nature of these structures.

In the south, the city wall and a small canal crossing the city wall can be seen. Here, the course of the city wall and, at regular intervals, its bastions known from previous excavations and documentation elsewhere in the city, are clearly visible. The high intensity of the signal over parts of the wall on its inner and outer faces seems to indicate the presence of fired bricks, a detail that was not known before. Recent excavations brought to light that these bricks were composed of ancient, burnt pottery. It is also apparent that the fortification complex was constructed using more separate walls than were previously known, and that the canal circling the city ran just outside it. The entire wall complex was nearly 40 m wide. The wall itself, with its inner and outer shells of bricks, is ca. 9 m thick, an observation that corresponds to the excavation findings.
Magnetogram detail of the city wall (left) and from the floodgate in the south of the city (right). Courtesy of Jörg W.E. Fassbinder.

Excavation trench at the city wall that revealed that mud bricks are composed by ancient pottery instead of burned brick as previously assumed and interpreted from our magnetometer measurements. Courtesy of Jörg W.E. Fassbinder.
Further details about Uruk’s structure are provided by the magnetogram of the southwest gate, which is nearly 15 m wide and can be interpreted as a floodgate, where the inner city’s large west and central canals flowed out through the wall. On the outside, the gate was flanked by towers and was probably strengthened with fired bricks.

Downstream of the floodgate, a small side canal branches off to the southeast, expanding roughly midway in front of a large building of fired bricks into a small harbour-like structure. A precise inspection of the building reveals a slight shift in the orientation of the walls, indicating two building phases, while a closer view on the harbour seems to reveal vague traces of buried ships.
Supplementary “Earth Resistance Tomography” (ERT) profiles allow to verify and to validate the depth of archaeological features such as the extension and the depth of the city wall or the shape and depth of the ancient canals. Detailed analysis of the magnetograms, supplementary measurements with resistivity prospections or seismic methods combined with satellite remote sensing, UAV surveys, topographical information and the integration of archaeological data from selected and targeted excavations, will allow for closer insights into the development, the structure and the functions of the city, even without large and costly excavation. The magnetometer survey hopefully will be continued and will offer a comprehensive picture of the structure of Uruk through time.

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