

# Satellite-based geophysical prospection of the Roman fortress of Qreiye-<sup>c</sup>Ayyāš in Syria

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The fortress of Qreiye is situated near the modern village of <sup>c</sup>Ayyāš 12 km north of the Syrian provincial capital Deir ez-Zor. It was part of the Roman Limes arabicus and belongs to a multitude of similar forts along the Euphrates River. Qreiye was founded in the early 3rd century AD during the expansion of the Roman Empire towards the east. It was swiftly abandoned a few decades later in the middle of the 3rd century AD during the Parthian wars. The fortress illustrates the excellent opportunities such sites in the Middle East can provide for geophysical prospection, as it has not been built upon since the Roman period. Furthermore it is one of the rare examples of a Roman fortress in this area that has not been integrated into an existing settlement like e.g. Raphanea (Syria), Zeugma (Turkey), Antiochia (Turkey), Dura Europos (Syria) or Palmyra (Syria). Between 2002 and 2006 there have been archaeological excavations of a cooperation project between the German Archaeological Institute (DAI) and the "Direction Générale des Antiquités et des Musées de la Syrie" (DGAMS). The fortress of Qreiye has been constructed of mud bricks, as these material absorbs the effect of siege machines much better than stone walls.



Fig. 1: Topographical map of Syria showing the location of Qreiye near Deir ez-Zor at the Euphrates River.

Since the launch of the German radar satellite TerraSAR-X in 2007 the possibilities of satellite radar in archaeology widened enormously. The reason is that with the sensor's High-resolution Spotlight mode and 300 MHz bandwidth a resolution of up to 1 m is achievable and SAR therefore gets suitable for the archaeological prospection. The aim of the presented project is to evaluate the penetration depth of the used X-band waves. This fact is essential for the detection of buried archaeological remains.



Fig. 2: Artist view of the TerraSAR-X satellite showing the X-band radar antenna (towards the sun) and the downlink antenna (at a 3 m long boom).



Fig. 3: GPR depth slice between 20 and 30 cm depth. GSSI SIR-3000 with 400 MHz antenna; Sensor&Software Noggin with 500 MHz antenna; PulseEKKO 1000 with 900 MHz antenna. Sample density: 5 x 25 or 50 cm.

As the entire fortress covers an area of ca. 5 ha, it could not be surveyed only by excavations. Therefore geophysical prospection should complement the work. As a result of the geological circumstances only Ground-penetrating radar could provide reasonable results. So the whole fortress has been surveyed between 2002 and 2005 by Sirri Seren of the ZAMG in Vienna with a Sensors & Software PulseEKKO 1000 and a 900 MHz antenna, a GSSI SIR-3000 and a 400 MHz antenna and a Sensors & Software Noggin and a 500 MHz antenna. The GPR profiles have a crossline spacing of 25 or 50 cm and are orientated 45° to the archaeological remains to be able to detect all buried features. The radargrams show a detailed layout of the fortress buried in a depth of 0 - 100 cm. As a result of the varying size of the detected barracks, there has been a mixed garrison of infantry and cavalry in Qreiye.



Fig. 4: The fortress Qreiye has been discovered in 1929 by the French aerial archaeology pioneer Antoine Poidebard while his systematic flights over all archaeological sites in Syria. It has a size of ca. 220 x 220 m, is orientated ca. 22° towards north-northeast and is surrounded by a double rampart-ditch fortification system in the east, south and west. In the northern part a steep slope towards the Euphrates forms a natural barrier.



Fig. 5: While the area of Qreiye has not been built in the 1920s, the modern optical satellite image of OrbView-3 of 2005 shows that the village of Ayyāš nowadays has reached the archaeological site and has destroyed already parts of the fortification system in the west and south. The visible features are the rampart-ditch-system in the west, the fortification wall as a slight sandy hill, the excavation trenches and several looting holes. Date of data take: 19/03/2005; cloud coverage: 0 %; panchromatic image with 1 m spatial resolution (Data available from the U.S. Geological Survey).



Fig. 6: TerraSAR-X image. High-resolution Spotlight mode with experimental 300 MHz bandwidth; spatial resolution: 1 m; polarization: horizontal; inclination angle: 34.87°; stacking of nine data takes; time of data take: February - May 2012 (© DLR, 2012).

To improve the signal/noise ratio of the TerraSAR-X data, we performed a stacking of all nine data takes between February and May 2012. The SAR image of the fortress Qreiye shows at the first glance of course the upstanding houses of the modern village. Furthermore the superficial western part of the ditch system (brown) can be resolved. In addition several buried features like the fortification wall itself (not only the sandy hill) can be identified. As there are no still upstanding archaeological structures visible in the optical image of OrbView-3 (Fig. 5) inside of the fortification system, the SAR image shows the buried walls of the internal buildings (blue, green and red; according to the corresponding depth in the GPR). A detailed comparison with the GPR depth slices shows that the penetration depth of TerraSAR-X in desert regions is ca. 20 - 25 cm. But this value can only be achieved with dry soils without any vegetation, as already a small leaf or grass would reflect all the energy of the high-frequency X-band waves.