

# 3D resistivity anomaly probability tomography at the archaeological site of Sagalassos (Turkey)

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**Abstract – The archaeological site of Sagalassos is a very important settlement located in a magnificent mountain landscape, 7 km north from a little village named Ağlasun (province of Burdur, SW Turkey). Since 1990 the University of Leuven (Belgium) carry out an interdisciplinary archaeological research programme that study the uninterrupted occupation of more than 1000 years in all its aspects from daily life to architecture, from trade and its mechanisms to environmental conditions of the past. The ancient roman city is a site covered under erosion layers and preserved many secrets that need to be revealed. A geophysical campaign was planned along the south facing terraces of the mountain slopes, in order to f highlighting the structure of the city still covered. Site conditions (high slope, high grass, several obstacles) and the need to investigate high depths led to the choice of the most suitable geophysical methods. Particularly a 3D distribution in the subsoil of resistivity tensor probability was esteemed.**

## I. INTRODUCTION

The archaeological site of Sagalassos is located in the southwestern Turkey, about 100 km north of Antalya, and 30km from Burdur and Isparta (Fig. 1). The ancient ruins of Sagalassos are 7km from Ağlasun on Mount Akdağ, in the Western Taurus mountains range, at an altitude of 1450–1700 metres. In Roman Imperial times, the town was known as the "first city of Pisidia", a region in the western Taurus mountains, currently known as the Turkish Lakes Region. Already during the Hellenistic period, it had been one of the major Pisidian towns. Human settlement in the area goes back to 8000 BC, before the actual site was occupied. Hittite documents refer to a mountain site of Salawassa in the fourteenth century BC and the town spread during the Phrygian and Lydian cultures. Sagalassos was part of the region of Pisidia in the western part of the Taurus Mountains. During the Persian period, Pisidia became known for its warlike factions.

Sagalassos was one of the wealthiest cities in Pisidia when Alexander the Great conquered it in 333 BC on his way to Persia. It had a population of a few thousand. After Alexander's death, the region became part of territories of Antigonus Monophthalmus, possibly

Lysimachus of Thrace, the Seleucids of Syria and the Attalids of Pergamon. Archeological record indicates that locals rapidly adopted Hellenic culture.

The Roman Empire absorbed Pisidia after the Attalids and it became part of the province of Asia. In 39 BC it was handed out to Galatian client king Amyntas, but after he was killed in 25BC Rome turned Pisidia into the province of Galatia. Under the Roman Empire Sagalassos became the important urban center of Pisidia, particularly favoured by the Emperor Hadrian, who named it the "first city" of the province and the center of the imperial cult. Contemporary buildings have a fully Roman character.

Around 400 BC Sagalassos was fortified for defence. An earthquake devastated it in 518 and a plague circa 541-543 halved the local population. Arab raids threatened the town around 640 and after another earthquake destroyed the town in the middle of the seventh century, the site was abandoned. The populace probably resettled in the valley. Excavations have found only signs of a fortified monastery—possibly a religious community, which was destroyed in the twelfth century. Sagalassos disappeared from the records.

In the following centuries, erosion covered the ruins of Sagalassos. It was not looted to a significant extent, possibly because of its location.

Explorer Paul Lucas, who was traveling in Turkey on a mission for the court of Louis XIV of France, visited the ruins in 1706. After 1824, when Francis Vyvyan Jago Arundell (1780–1846), the British chaplain at Izmir and an antiquary, visited the site and deciphered its name in inscriptions, Western travelers began to visit the ruins. Polish historian of art, count K. Lanckoroński produced the first map of Sagalassos. However, the city did not attract much archaeological attention until 1985, when an Anglo-Belgian team led by Stephen Mitchell began a major survey of the site (for more see [www.sagalassos.be](http://www.sagalassos.be)).

In the site a new way to imaging resistivity data was used. The method, described in [1, 2] was the 3D probability tomography imaging approach based on apparent resistivity tensor concept [2]. This approach, applied for the first time in a great area and in the archaeological field, done interesting results.

## II. RESULTS AND DISCUSSION

The measurements were collected along 2 lines (Fig. 1). The first line was an ERT profile that cross the hill and it is 115 m. The second line was acquired around the hill in roll along mode in order to cover the whole area. It is long 320m and consists of 5 lines, each 64 m long. For this line the electrode spacing was variable from 2 to 3m. This was due to the inaccessibility conditions of the site (bushes, stones etc.). A total of 300000 apparent-resistivity measurements were collected (n=1 to n=9). The relative standard deviation for each stack is a good indicator of the quality of the data. In the site we note several bad data whit high relative standard deviation (greater than 12%). This was due to the high values of the resistance contact between the electrode and soil. Apparent resistivity tensor was esteemed in 3D mode from the measured apparent resistivity data through an

algorithm written in matlab. The results were presented as horizontal slices (parallel to the surface) through the ground (Fig. 2).

Fig. 2 shows the apparent resistivity tensor model at four different depths. It is possible to note several anomalous zone (dashed dark lines) with a moderately high apparent resistivity tensor (150-200ohm m). The shape of these anomalies suggest a probable presence of structures of archaeological interest at depth ranging between 0.5 and 2.0m. At 4.0m in depth the apparent resistivity tensor values increase until 250 ohm m. These values could be related to bedrock.



*Fig. 1. The surveyed area*

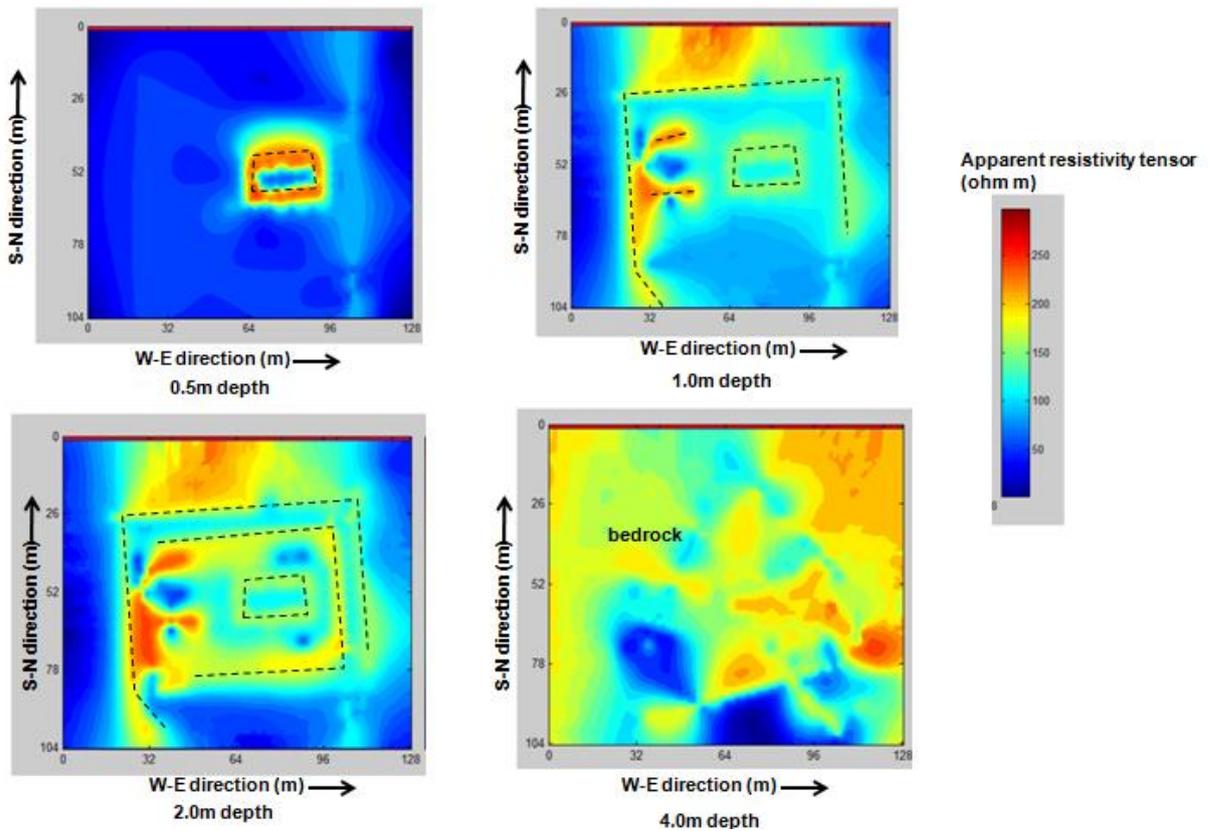


Fig. 2. 3D apparent resistivity tensor distribution in the subsol

### III. CONCLUSIONS

The results of the archaeo-geophysical survey at the archaeological site of Sagalassos are presented in this paper.

In the surveyed area data acquisition has been very difficult due to the presence of many obstacles such as bushes, rocks, and fear of snakes, spiders and scorpions. The high contact resistance related to the coupling soil electrode. This make ERT method unsuitable in this area. Despite, the ERT data were not thrown. In fact a new approach was applied. It considered the apparent resistivity tensor parameter. The results seem encouraging and indicates several anomalous zones probably related to archaeological structures. In fact the

results suggest the presence of an important structure with a probably fortification walls.

### REFERENCES

- [1] Di Fiore B., Mauriello P., Monna D., Patella D., 2002. Examples of application of tensorial resistivity probability tomography to architectonic and archaeological targets. ANNALS OF GEOPHYSICS, VOL. 45, N. 2, 417-429
- [2] Mauriello P. and Patella D., 2005 Introduction to tensorial resistivity probability tomography 2http://arxiv.org/physics/0512147, 1-8