GPR research around the Hawara pyramid (Fayum, Egypt)

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Geological and GPR studies around the mud-brick pyramid of the Twelfth Dynasty pharaoh Amenemhat III, (19th century BC) at Hawara in the Fayum were performed for the Faculty of Archaeology of the University of Cairo in Egypt, the objective being to identify areas of groundwater inflow into the tomb under the pyramid (for the purposes of a salvage project) and to verify possible links between the pyramid and a structure identified by some archaeologists as the labyrinth of Herodotus. Geological data was obtained from core drilling (in 2002 and 2008) in the vicinity of the pyramid (Figs 1, 2) through the courtesy of Ain Shams University, Faculty of Engineering, Soil Mechanics and Foundation Laboratory and Mohamed A. Hamdan, Geology Department of Cairo University.

GPR research around the pyramid used SIR with multifrequency antennas and RAMAC/GPR with unshielded 100 MHz antennas. Linear profiles were performed down to a depth of 20 m (Figs 3, 4 for two section examples).

The geological data indicates that the tomb and facilities existing beneath the pyramid at Hawara were located in trenches cut into bedrock composed of cohesive schists and mudstones of the Eocene age. Eocene limestone is present beneath these rocks, at a depth of approximately 12 m to 15 m. On the western, northern and southern sides of the pyramid, the natural surface of Eocene rocks is about 1–3 m above the water level in the Selah canal (Bahr Wabach). On the southern side of the pyramid, Eocene rock surface is about 0.5 m–1.0 m above the water in the canal (Figs 1, 2). Eocene rocks are covered. The Holocene gravels and sands covering Eocene rock are approximately 3–5 m thick. They probably also covered the lower part of the mud-brick pyramid.

Groundwater is 3.4 m higher than the water in the Selah canal on the northern and eastern side of the pyramid and about 0.7 m to 1.5 m higher on the southern side. The tomb and rooms under the pyramid are currently flooded with water, and the water level beneath the pyramid is 1 m higher than the water level in the canal (Figs 1, 2). The water in the tomb and in the rooms beneath the pyramid could come from the Selah canal, which when constructed in the late 19th century AD, presumably destroyed the southwestern corner of walls shielding the pyramid from the inflow of groundwater into the tomb (Fig. 3).

Part of the water in the tomb and rooms beneath the pyramid may also come from groundwater flow from the plateau surrounding the pyramid (Fig. 1). GPR data demonstrated the existence of such channels letting water seep into the pyramid underground. For example, there is a very strong and clear anomaly on the north side of the pyramid (N1 in Fig. 4). On the eastern and southern side of the pyramid, the survey also traced anomalies that could reflect architectural remains. There is, however, nothing to support the idea that this was Herodotus's labyrinth.

The data from the survey will be used to prepare a project for the protection of the pyramid against the disastrous effects of groundwater.

Figures

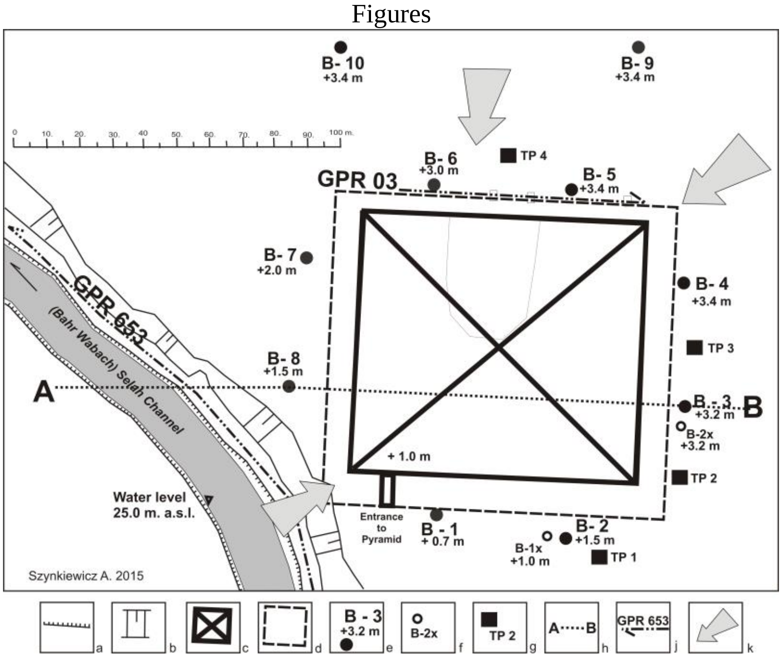

Fig. 1. Hawara pyramid (Fayum). Inflow of groundwater into the tomb: a) Selah canal embankment, b) inclined embankment surface, c) mud-brick pyramid, d) part of mud-brick pyramid covered by sand, gravel and overburden, e) geological bore-hole (2002), number and ground water level above the water level in the Selah canal, f) geological bore-hole (2008), g) geological test pit, h) simplified cross-section, j) GPR transect, k) direction of ground water flow

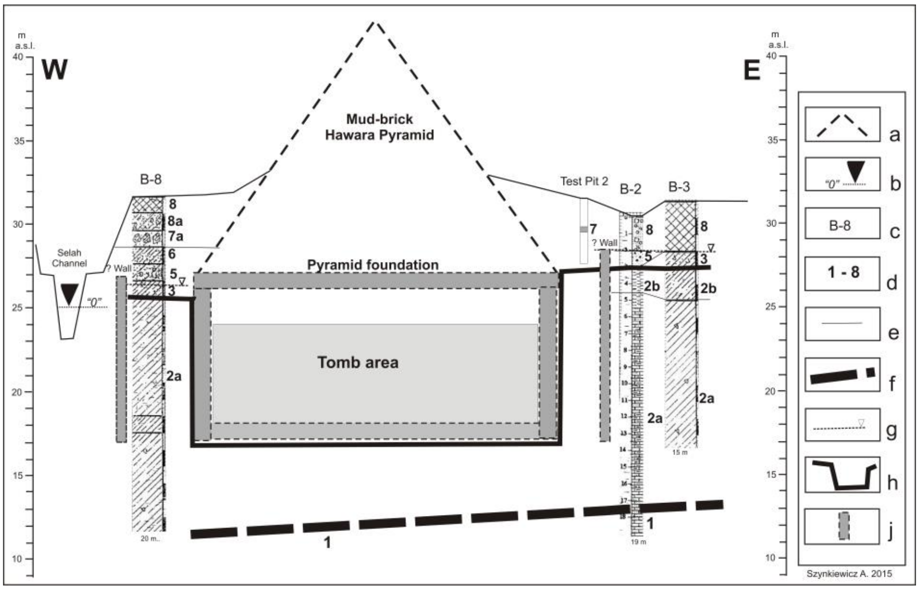

Fig. 2. Hawara pyramid (Fayum). Schematic cross-section (A. Szynkiewicz 2015): a) mud-brick pyramid, b) water level in the Selah canal, c) number of bore-hole, d) geological layers: 1 – Eocene limestone, 2a – Eocene mudstone, 2b – Eocene claystone, 3 – mixed layers of calystone, anthropogenic overburden, 4 – Holocene river sand, 5 – sand and gravel, flood period, 6 – clay with rest of flora, 7 – limestone blocks, 7a – fragments of limestone, 8 – mixed layers, anthropogenic overburden; e) boundary of layer, f) top of Eocene limestone, g) ground water level, h) trench for the tomb cut in Eocene rocks, j) presumed wall

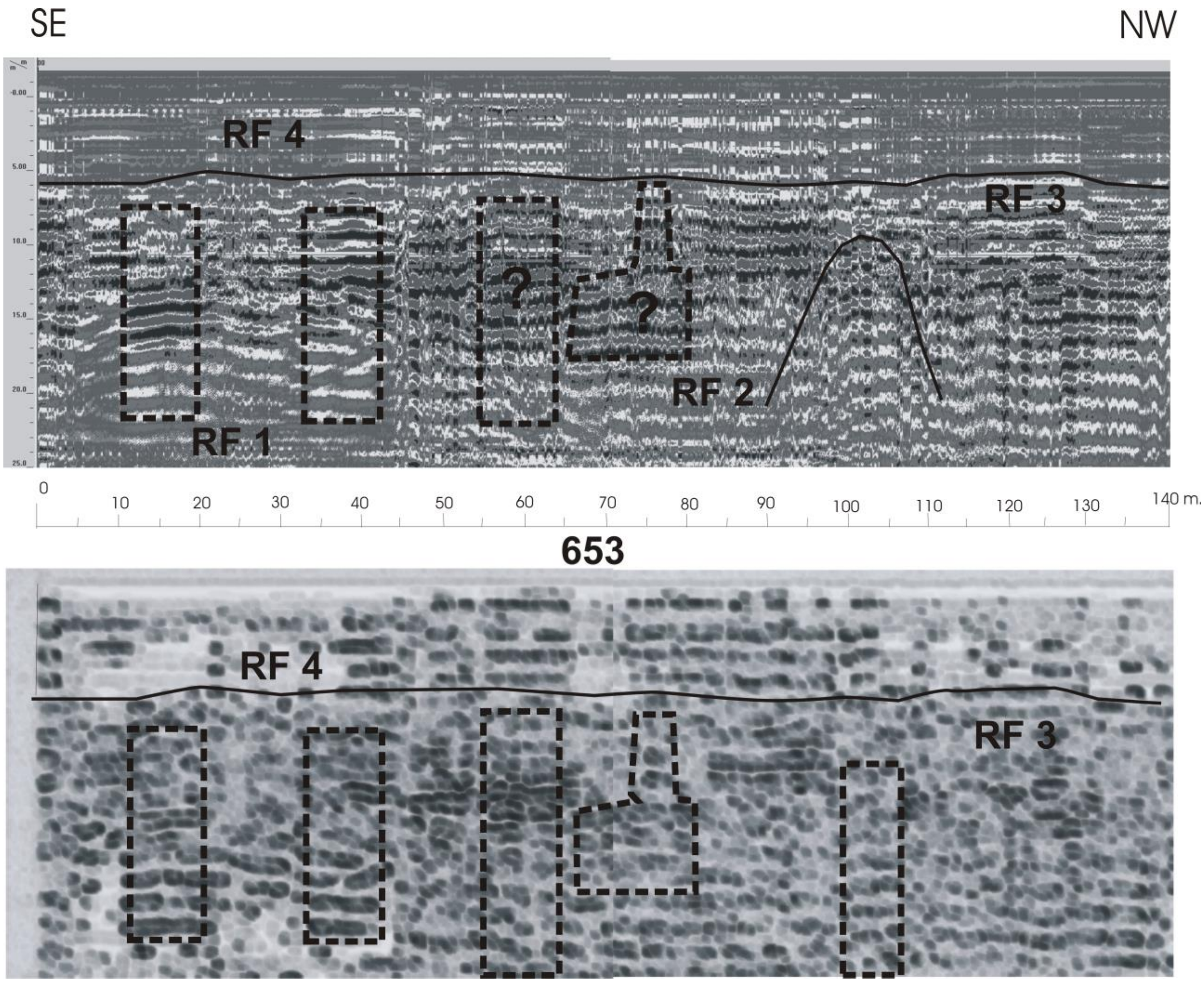

Fig. 3. Hawara pyramid (Fayum). GPR cross-section 653 (A. Szynkiewicz 2015). SIR 2000 with multifrequency antenna. Postprocessing using RADAN software. RF – radar facies: 1) claystone, 2) anthropogenic layers with structures, 3) clay with remains of flora and mollusks, 4) sand, gravel and mixed anthropogenic overburden. Black dotted line indicates possible wall-type structures.

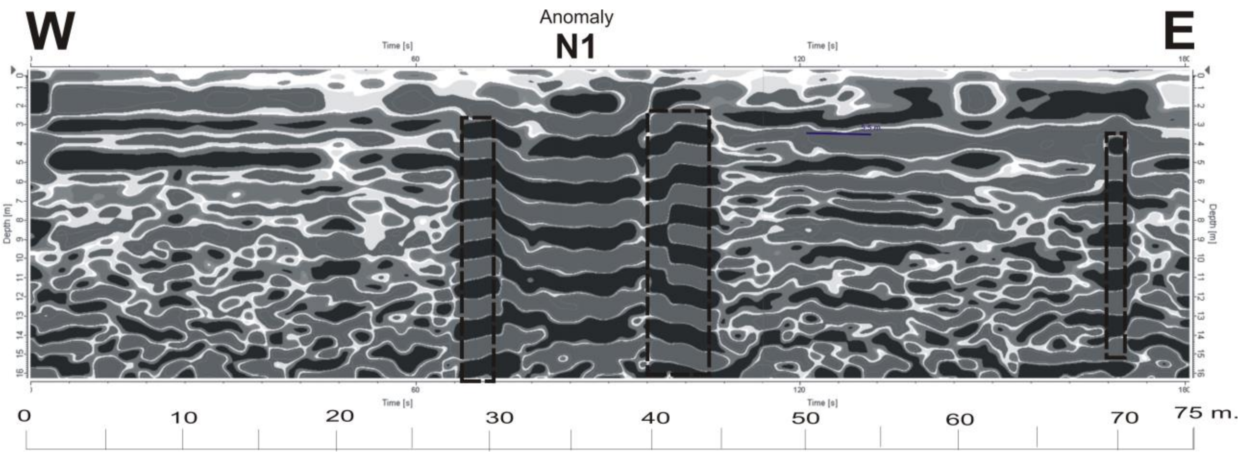

Fig. 4. Hawara pyramid (Fayum). GPR cross-section 03 (A. Szynkiewicz 2015). RAMAC/GPR with antenna 100 MHz. Post-processing using GroundVision software. Anomaly N1 on the north side of the pyramid. Black dotted line indicates possible wall-type structures.