

Figure 35. SAR images. (a): SLC SAR image (magnitude). The tomographic line 1 is oriented along the Western-side of the pyramid. (b): Tomographic result (magnitude).

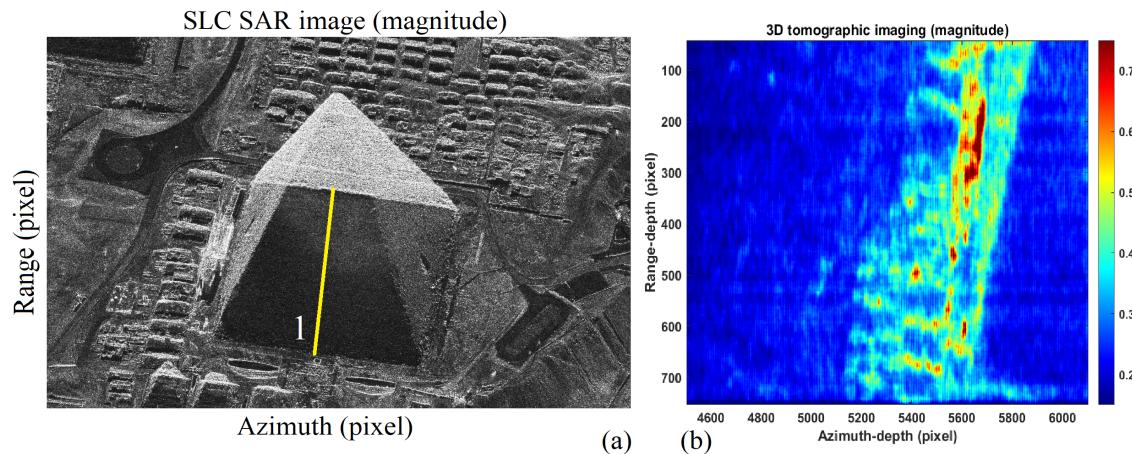


Figure 36. SAR images. (a): SLC SAR image (magnitude). The tomographic line 1 is oriented along the Eastern-side of the pyramid. (b): Tomographic result (magnitude).

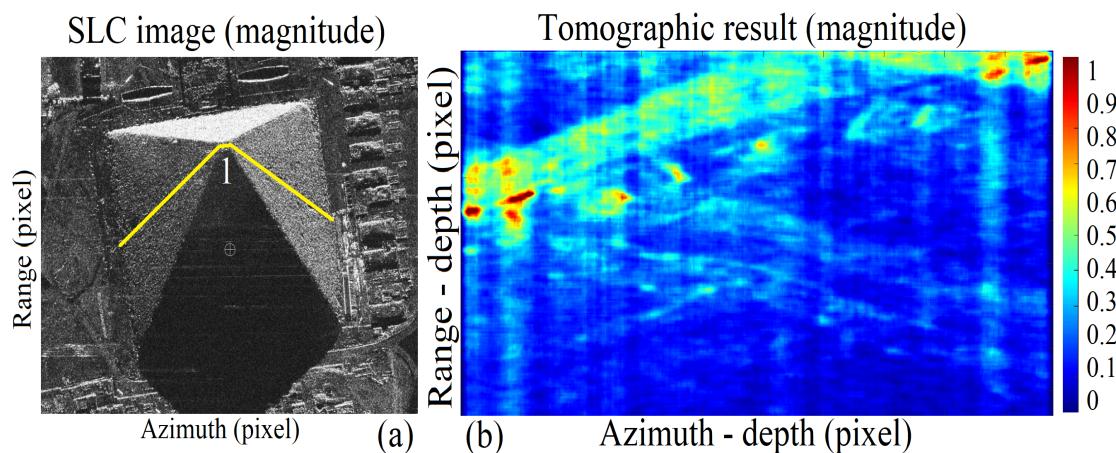


Figure 37. SAR images. (a): SLC SAR image (magnitude). The tomographic line 1 is oriented along the Northern-Southern-sides of the pyramid. (b): Tomographic result (magnitude).

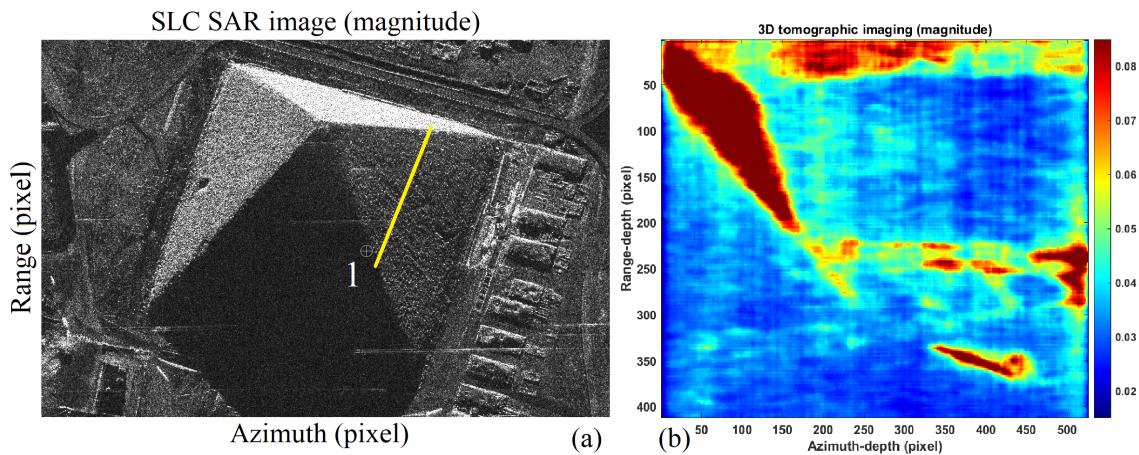


Figure 38. SAR images. (a): SLC SAR image (magnitude). The tomographic line 1 is oriented along the Southern-side of the pyramid. (b): Tomographic result (magnitude).

5.4. Eastern and Western Ascending Ramps (Tag 1, Tag 2)

Two inclined and diverging ramps (identified with the numbers 1 and 2 in the 3D reconstruction depicted in Figure 22), characterized by an approximate slope of about 42 degrees, are located inside the west and east sides. For both ramps, the lower part starts from the ground level on the north side and reaches half the height of the pyramid on the south side. The reference images are Figure 39a,b, for the eastern side and Figure 40a,b, for the western side, where the 3D models are compared to measured tomograms. From the figures, tags number 1, 2, 3, 4, 5, 7 and 9 are recognized.

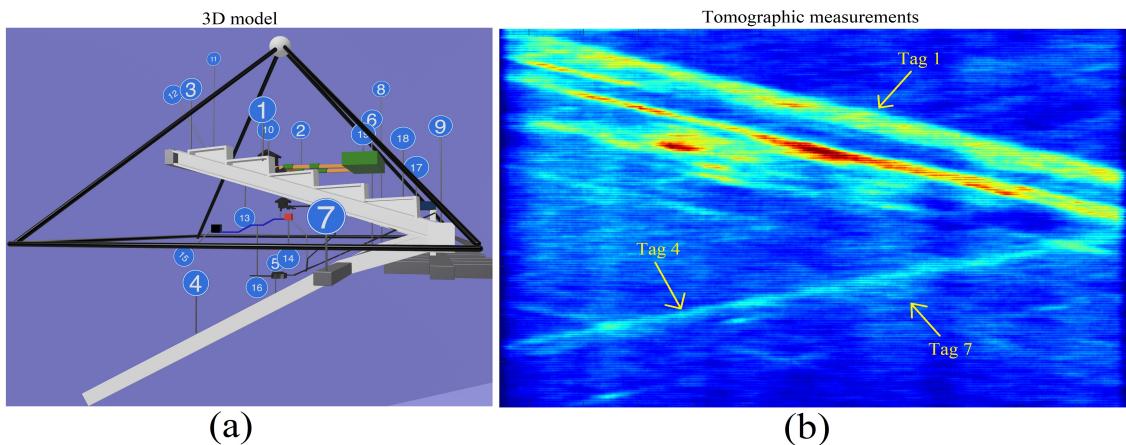


Figure 39. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (East-side orientation). (b): Tomographic reconstruction (magnitude).

5.5. Southern Corridor (Tag 3)

The ascending corridors are connected to each other by means of a horizontal structure placed at a height of about 90 m and located near the south side of the pyramid (identified with the number 3 in Figure 22). The corridor is recognized in Figure 41b, where the 3D reconstruction can be seen in Figure 41b.

5.6. Eastern and Western Descending Ramps (Tag 4, Tag 5)

Two ramps that are both connected to the previous ones run parallel to each other and also to the east and west base sides that run through a descending underground section with variable slope (numbers 4 and 5 in the 3D model). Figures 42a and 43a are the 3D reconstruction models showing the descending corridors from two different view angles,

while Figures 42b and 43b corresponds to tomographic measurements of the same tags, corresponding to the same descending corridors.

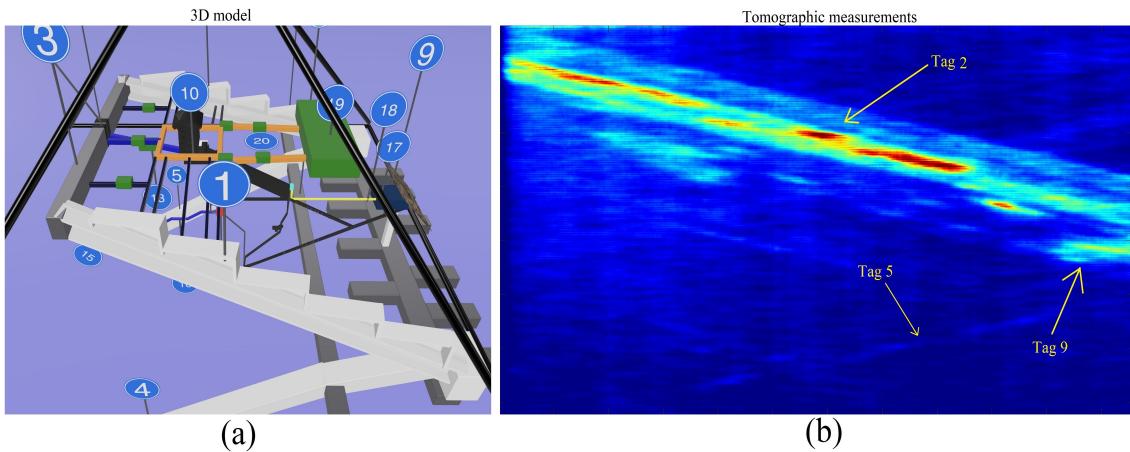


Figure 40. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (Top-East-side orientation). (b): Tomographic reconstruction (magnitude).

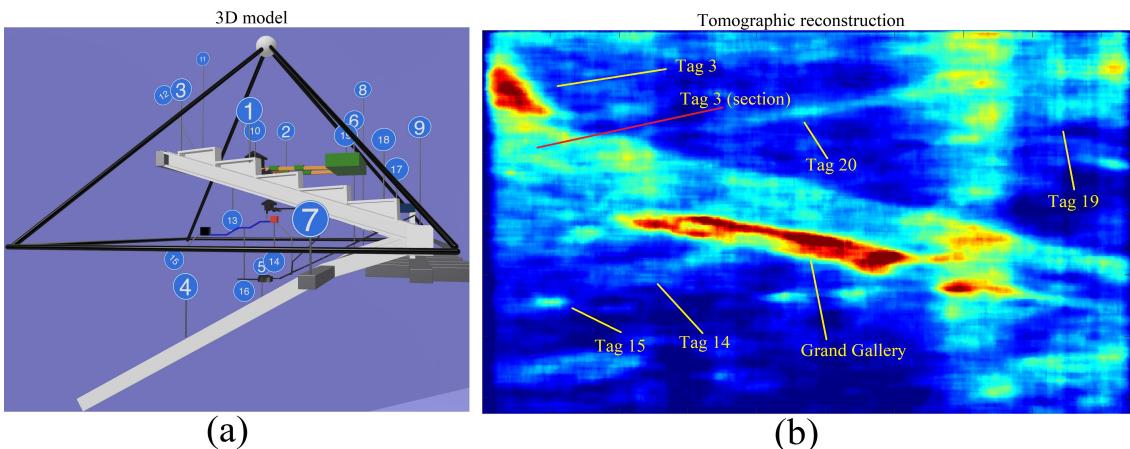


Figure 41. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (East-side orientation). (b): Tomographic reconstruction (magnitude).

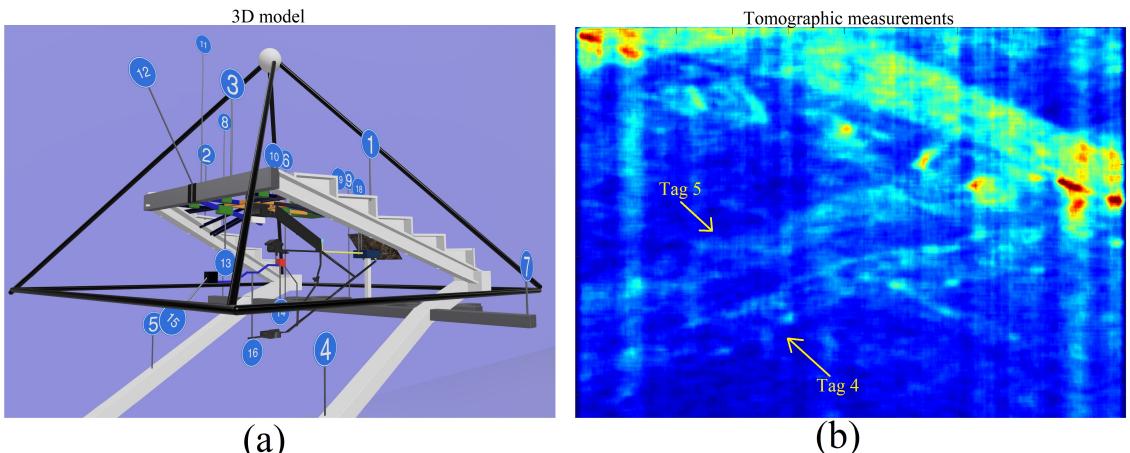


Figure 42. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (South-East-side orientation). (b): Tomographic reconstruction (magnitude).

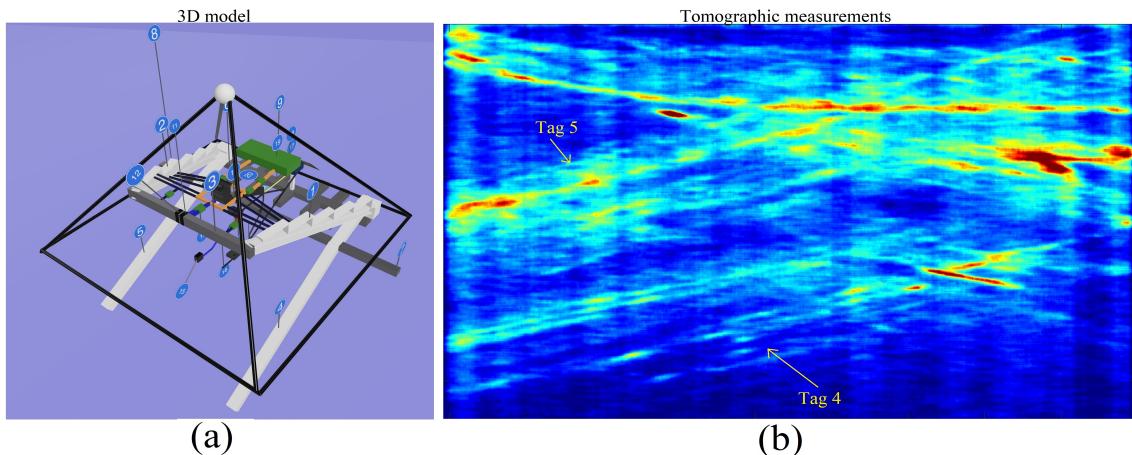


Figure 43. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (South-East-Top-side orientation). (b): Tomographic reconstruction (magnitude).

5.7. Northern Underground Corridor (Tag 6) and Northern–East and Northern–West Underground Corridors (Tag 7, Tag 8)

At the point where the descending ramps (tags 4 and 5) increase slope, they appear connected with the northern underground corridor (tag number 6 structure), parallel to the north side of the pyramid. The northern underground corridor is characterized by two extrusions, which are still located underground. Figure 44a is the 3D reconstruction model showing the structures tagged by numbers 6, 7 and 8, while Figure 44b corresponds to tomographic measurements of the same tags, corresponding to the same descending corridors. The section of this structure is deducted on the tomogram of Figure 45b, while the corresponding 3D model is showed in Figure 45a.

5.8. Northern Underground Complex Structure (Tag 9)

Immediately below the base of the pyramid structure, at the north side, a complex structure appears consisting of a horizontal body from which several identical bodies branch off, extruded perpendicularly to the main structure and characterized by a geometry, also present in other Egyptian pyramids, such as the pyramid of Zawyet El-Aryan [7,8,11] and the Sekhemkhet pyramid [10]. This complex structure (Number 9 in the 3D model) is characterized by a small conduit placed in a central position that runs a short distance in a vertical direction, in analogy with the presence of a similar building also in El-Aryan [7,8,11] and Saqqara [10]. The reference tomography is shown in Figure 46b, while the 3D model is depicted in Figure 46a.

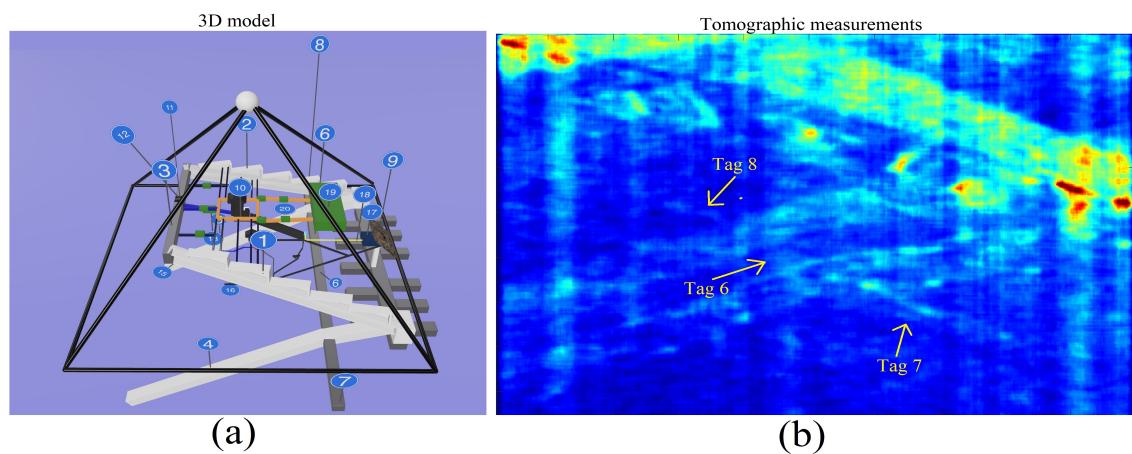


Figure 44. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (Top-East-side orientation). (b): Tomographic reconstruction (magnitude).

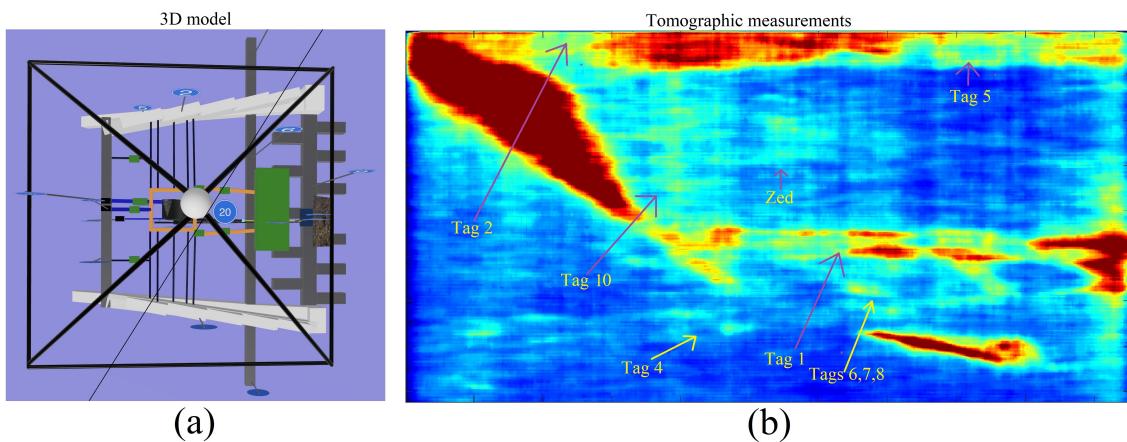


Figure 45. Tags association from tomography to 3D model. (a): Three-dimensional (3D) model of Khnum-Khufu (Top-side orientation). (b): Tomographic reconstruction (magnitude).

Table 4. List of discovered structures detected in figures.

Structure Number	Structure Name	Detected in Figures
1	Eastern ascending ramp	Figures 39, 45, 47 and 56.
2	Western ascending ramp	Figures 40, 45, 47 and 56.
3	Southern corridor	Figures 41 and 54–56.
4	Eastern descending ramp	Figures 41–43, 45, 47 and 56.
5	Western descending ramp	Figures 40, 42, 43, 45 and 47.
6	Northern underground corridor	Figures 44 and 45.
7	Northern–East underground corridor	Figures 39, 44 and 45.
8	Northern–West underground corridor	Figures 44 and 45.
9	Northern underground complex-structure	Figures 40 and 46.
10	Zed complex structure	Figures 45, 48, 55 and 56.
11	Eastern sarcophagus passage facility	Figure 49.
12	Western sarcophagus passage facility	Figure 49.
13	Bottom sarcophagus room facility	Figure 50.
14	Queen’s bottom room	Figures 41 and 52.
15	Southern bottom room	Figures 41 and 52.
16	Southern connection	Figure 52.
17	Little void	Figures 51 and 54.
18	Front corridor	Figure 51.
19	Big void	Figures 41, 47, 55 and 56.
20	Zed-big void double connection	Figures 41 and 47.

5.9. Zed Complex Structure (Tag 10)

A complex square structure (identified with the number 10 tag), which connects itself to structure number 11, belongs to the structure of passage number 3. The structure 10 develops around the Zed, approximately at the height of the lowest room (Davison’s Chamber) [17]. The reference tomography is shown in Figure 45b, while the 3D model is depicted in Figure 45a. The structure is also detected through different tomograms depicted in Figure 48b,c, where the reference SLC image is shown in Figure 48a, and the tomographic lines 1 and 2 are shown on the northern and southern pyramid surfaces, respectively.

5.10. Eastern and Western Sarcophagus Passages Facility (Tag 11 and Tag 12)

Structure number 3 also seems to contain two sub-structures, which are identified with the numbers 11 and 12, connected, through corridor 13, to the King’s room, through a passage that seems located under the floor of the latter. The reference tomography is shown in Figure 49b, while the 3D model is depicted in Figure 49a.

5.11. Bottom Sarcophagus Room Facility (Tag 13)

A room located below structures 11 and 12, connecting facilities 3 to 13. The reference tomography is shown in Figure 50b, while the 3D model is depicted in Figure 50a.