

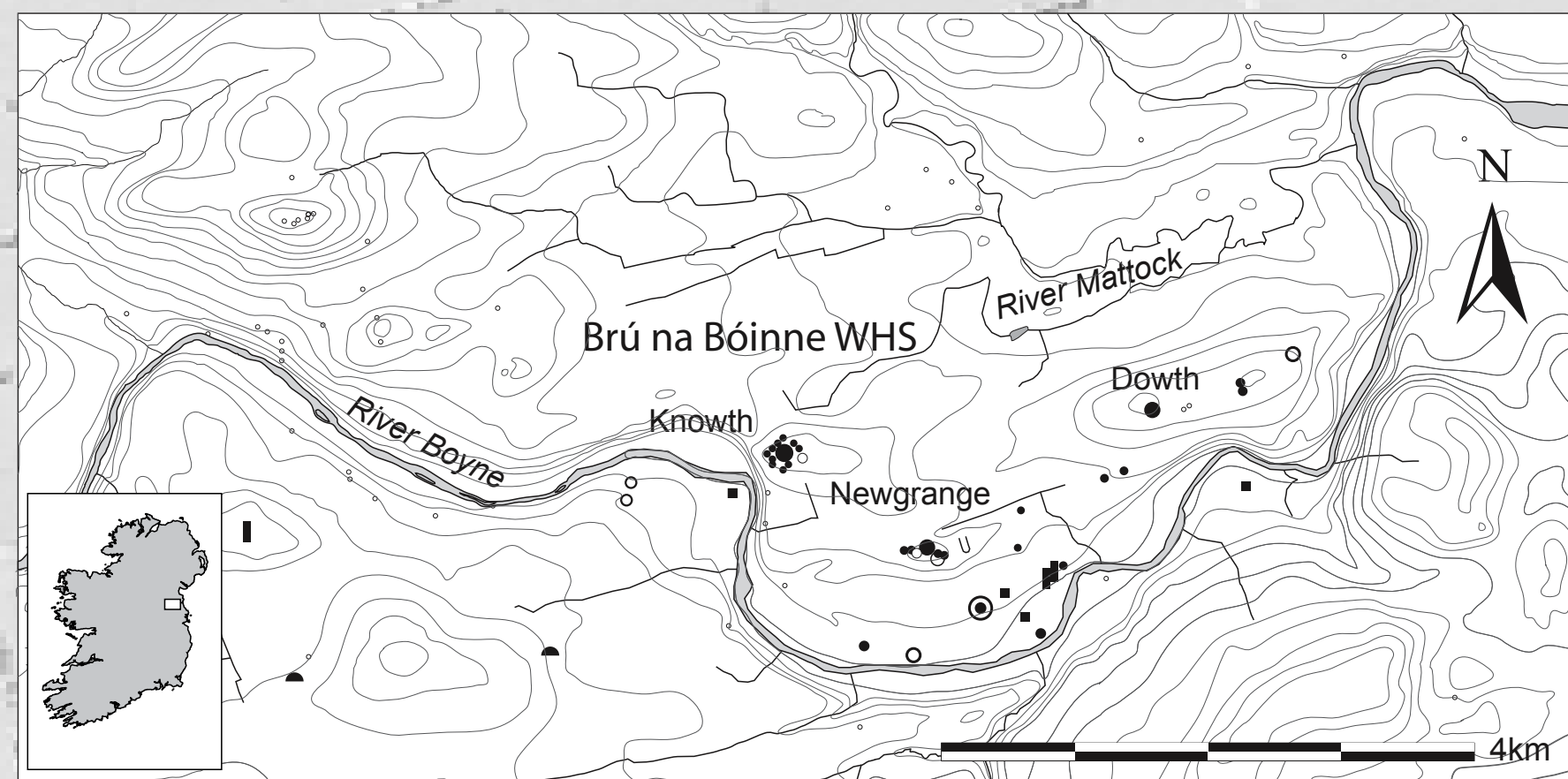
Searching for hidden chambers at Newgrange Passage Tomb; some results with an evaluation of the multi-method geophysical techniques used.



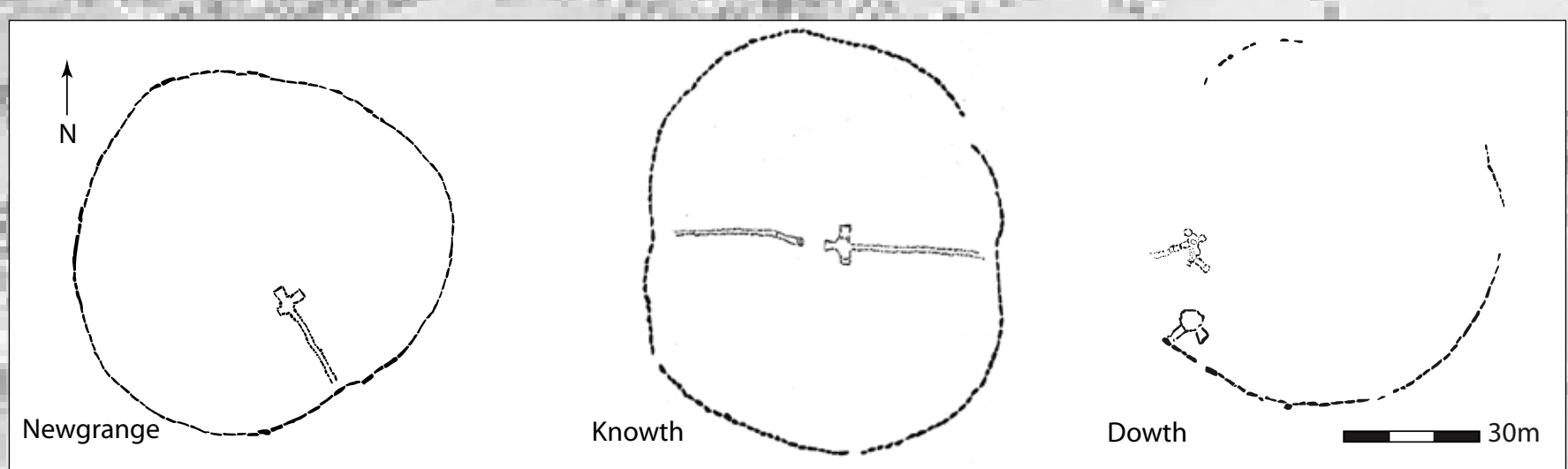
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1. Introduction



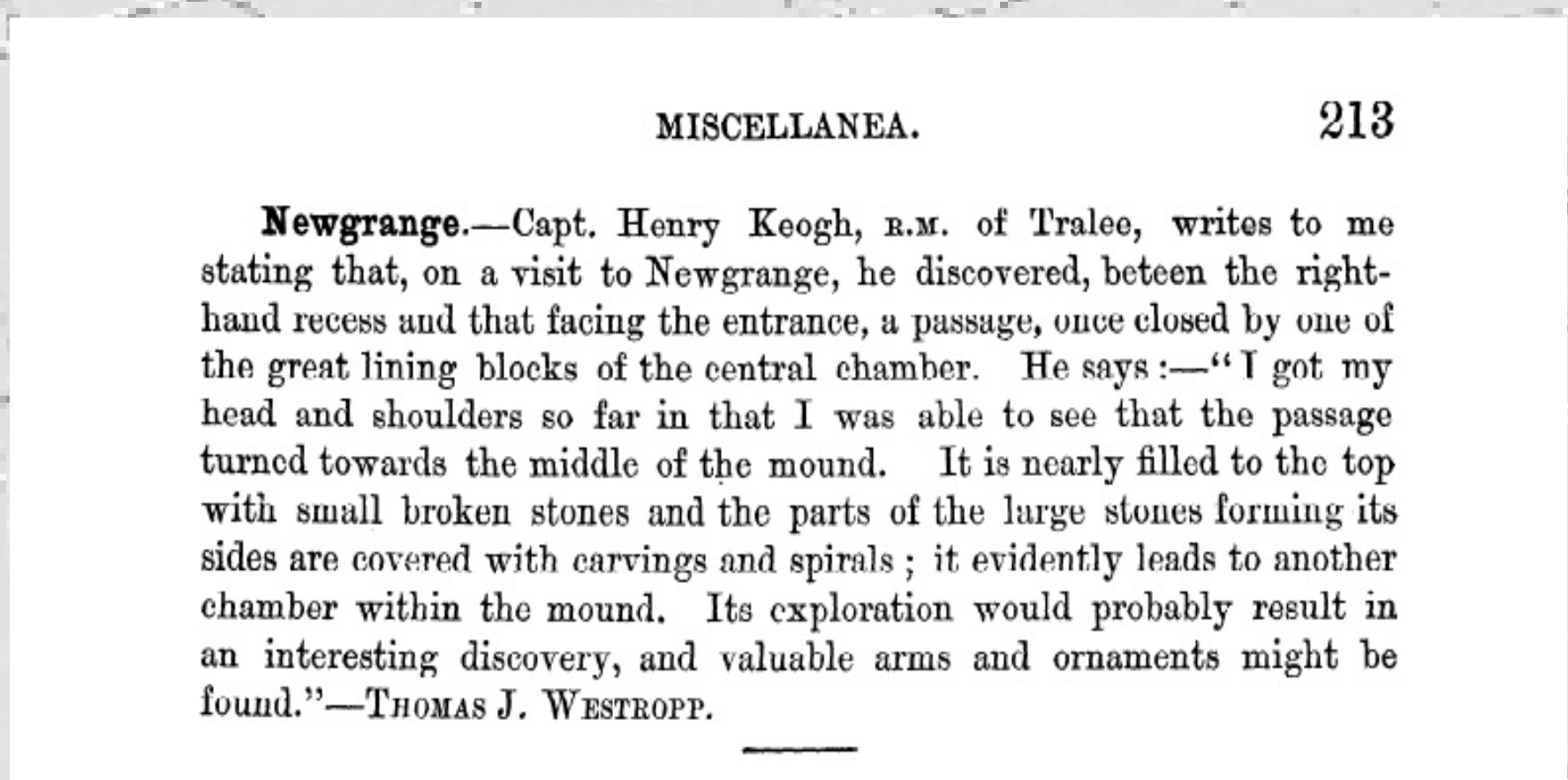
Brú na Bóinne, has been an important ritual, social and economic centre for thousands of years. It was designated a UNESCO World Heritage Site (WHS) in 1993. The WHS contains a broad range of archaeological monuments, spanning over 6,000 years from the Neolithic passage tombs to the Battle of the Boyne (AD 1690) battlefield. Extensive excavation has been undertaken at a number of sites, most notably at the great mounds of Newgrange and Knowth. The third great mound at Dowth has not been scientifically excavated. The large sites at Knowth and Dowth both have two passages each beneath their mounds while Newgrange has just one passage beneath its mound, despite its large diameter. An outline of each mound with known passages is shown below.



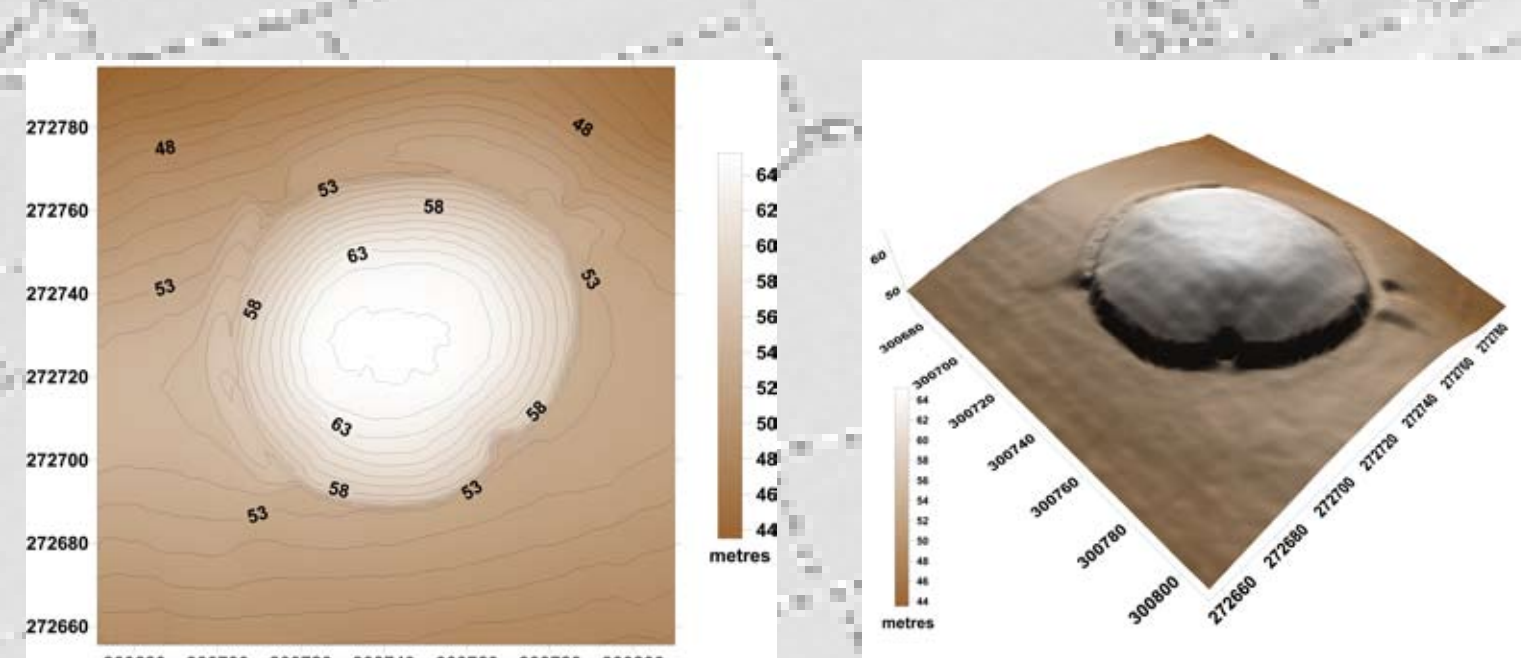
2. Newgrange Passage Tomb



Newgrange Passage Tomb viewed from the southeast with entrance to the passage and lightbox. The tomb is c. 85m in diameter and c. 11m in height at the summit. Excavation and subsequent reconstruction of the tomb in the 1960s and 1970s was limited to the area of passage and lightbox. The chamber area and its capstone were not excavated. There has been speculation that the tomb contains further passages with the first record of this being published in 1893. Can geophysical survey techniques find hidden chambers in Newgrange Passage Tomb?



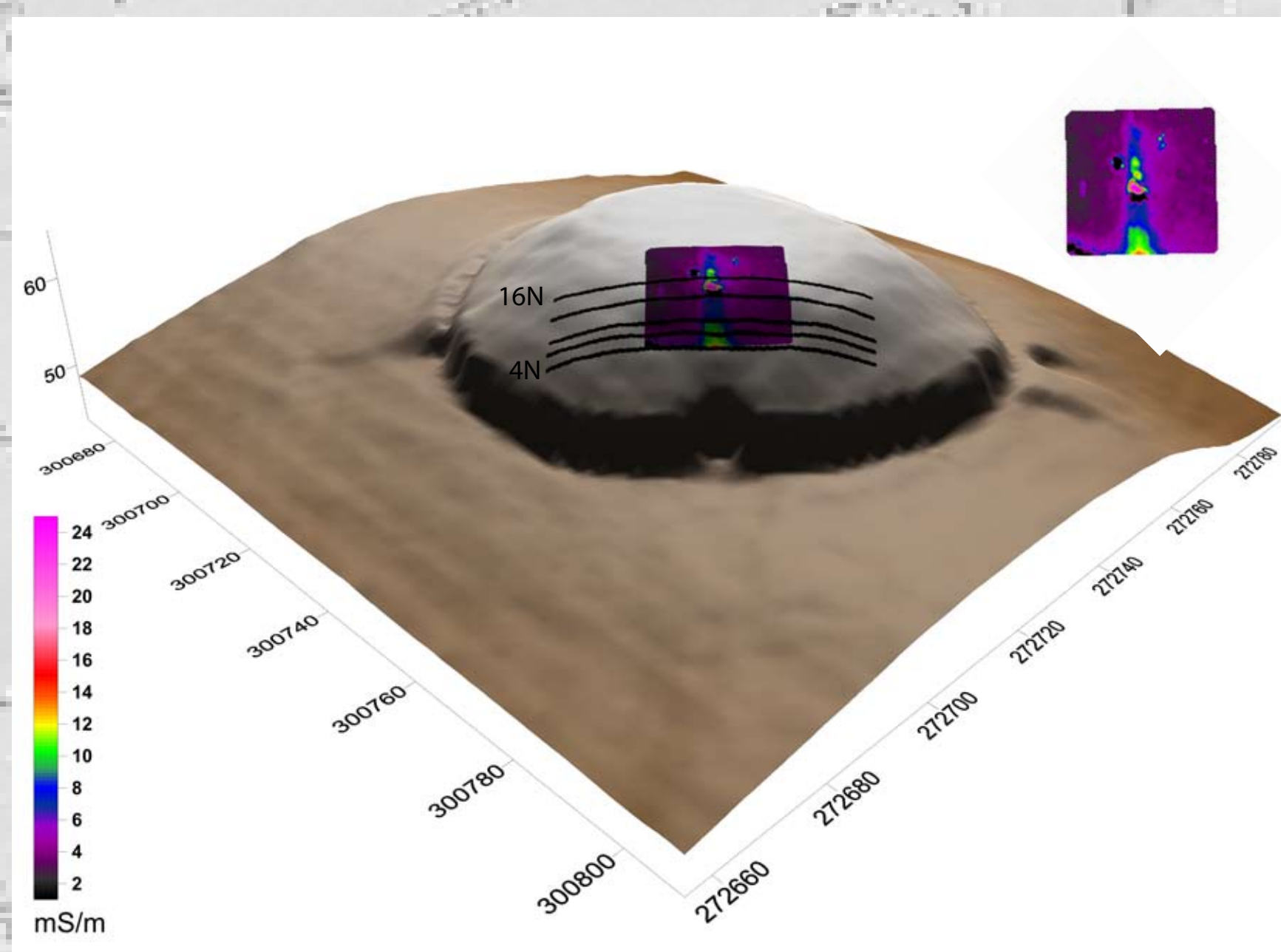
3. Airborne LIDAR data



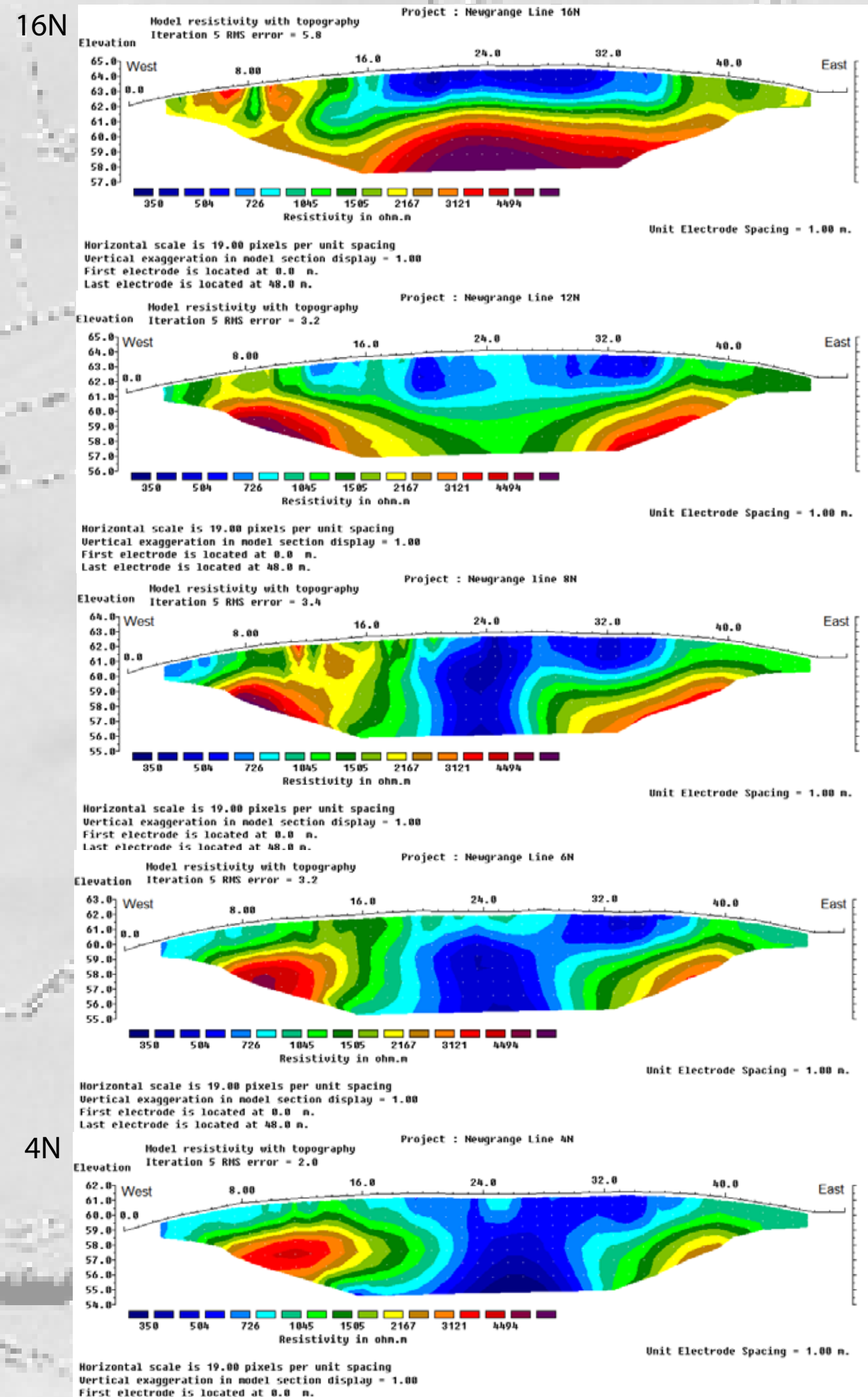
Available LIDAR data output on a 1 m x 1 m grid were used to construct contoured basemaps and 3-D models of the Passage Tomb in order to locate and position the geophysical surveys. The data were used in data reduction and modelling of the microgravity results.

4. Electromagnetic and Resistivity Surveys

Electromagnetic and electrical resistivity tomography (ERT) surveys were used to map the extent and sub-surface nature of the reconstructed passage to inform the interpretation of the microgravity survey.



The multi-frequency electromagnetic survey showed a significant linear apparent conductivity anomaly over the zone of the excavated and reconstructed passage. The depth of investigation was 1.8m. Five ERT transects were targeted to investigate zone of the reconstructed passage.

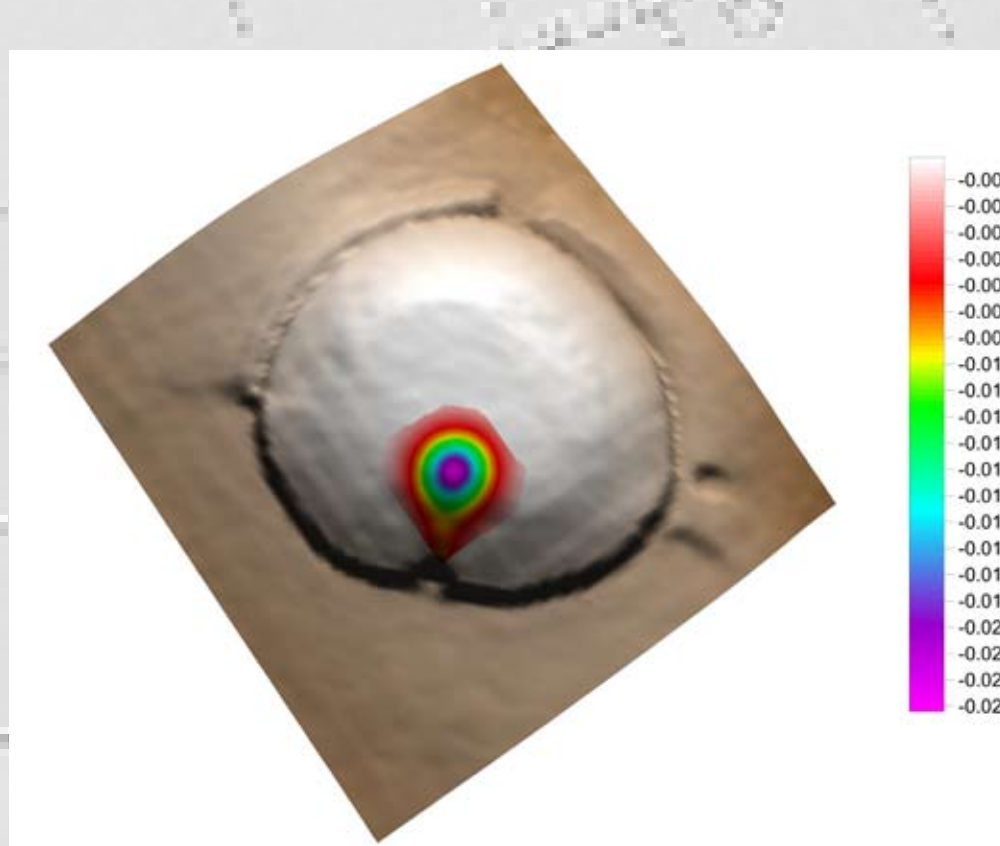


The low resistivity zone in the modelled 6m depth ERT pseudosections shown above maps the reconstructed passage, lightbox and viewing gallery seen in the photograph below. The high resistivity anomaly seen at the base of pseudosection 16N maps the area of the known chamber.



Newgrange Passage Tomb showing the reconstruction of the passage (lower), lightbox (middle) and viewing gallery (upper).

5. Microgravity - Predictive Modelling



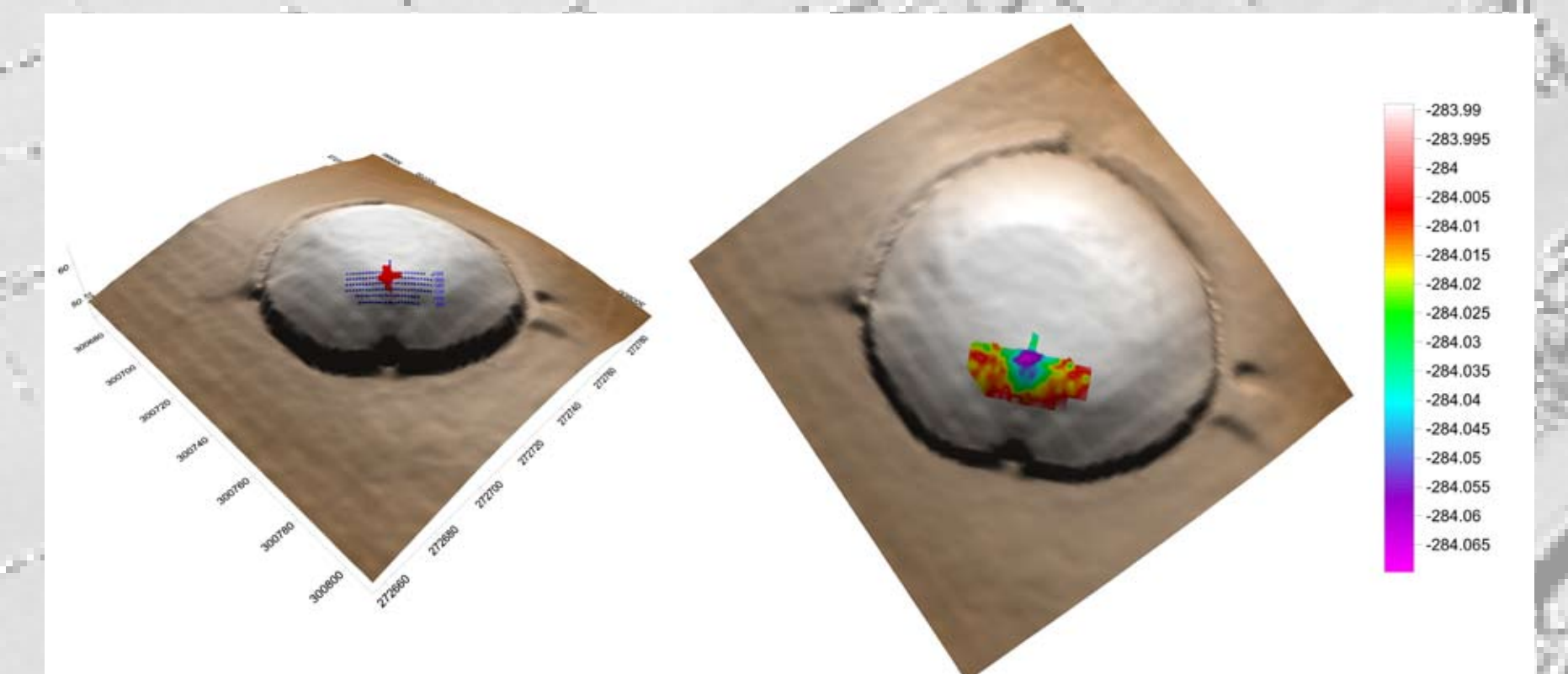
Using the known dimensions of the tomb, the passage and the chamber with an estimated density distribution a predictive gravity model was created. The model shows there would be a strong negative anomaly associated with the known chamber if gravity measurements were made on the surface of the mound.

6. Microgravity - Field Survey and Results

The microgravity survey was carried out as an international collaboration project in October 2011. The key objective of this survey was to investigate the potential of the microgravity method in the initial detection of the known chamber and subsequently in locating possible hidden chambers.

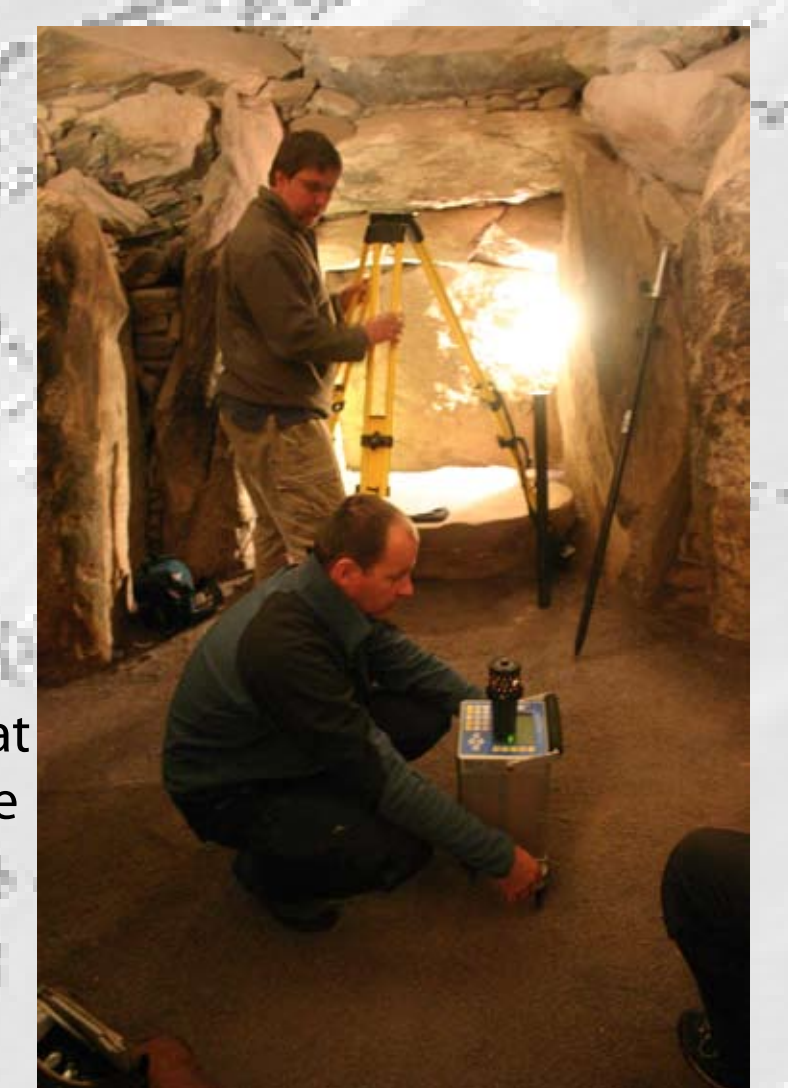


Initial field measurements were made over the known chamber along lines perpendicular to the passage axis. Lines were 2m apart and automated readings lasting 1 minute were taken at 1m intervals. The horizontal and vertical position of each of the 149 measurement points was precisely determined using differential GPS and laser tachymetry. The average error from repeated and independently controlled measurement points was ±15 microGals. This is relatively high but acceptable in the case of this survey.

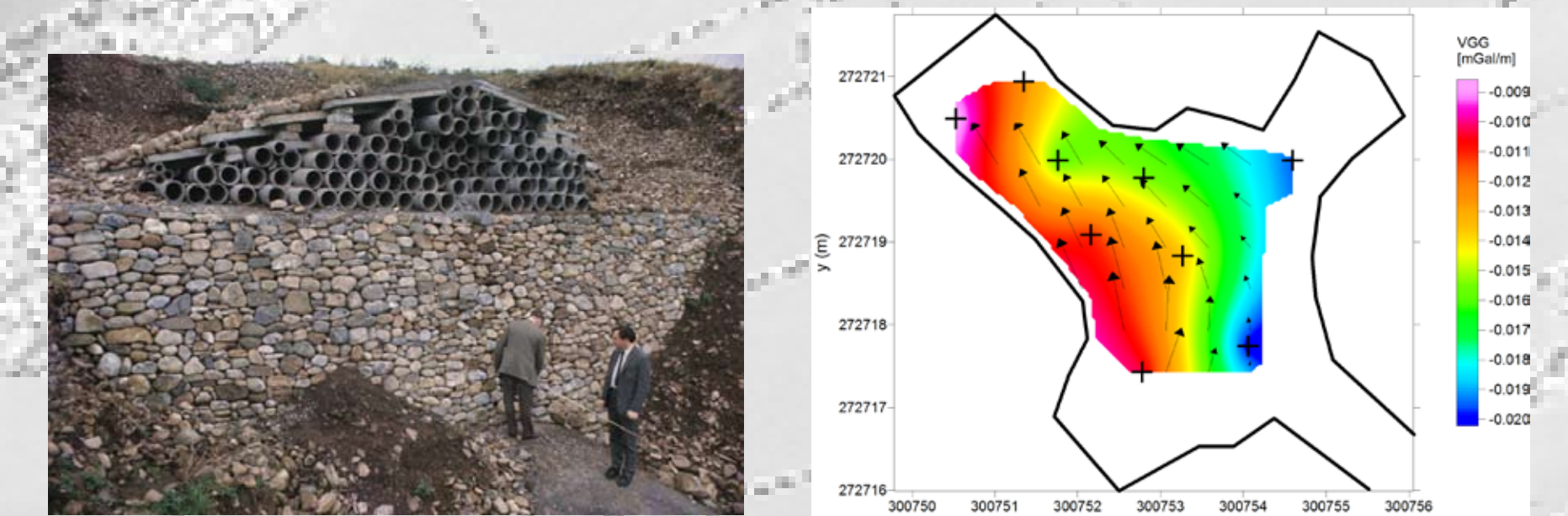


The data were processed to remove the effects of elevation, tidal variation, topography, latitude, and instrument drift. The output was a gravity anomaly map, draped on a 3-D model made from the LIDAR data shown above, which presents the properties and geometry of sub-surface inhomogeneities. This shows a well developed negative anomaly (a gravity low) over the centre of the known chamber. The size of the anomaly at its centre is several times larger than the precision of the instrument and also the average error of the instruments. The existence of the passageway cannot be detected. Its dimensions are too small and depth too large for the detection capability of the microgravity method.

Further microgravity measurements were made on the mound and in the chamber in order to seek further anomalies and refine the gravity model of the known chamber. Refinement of the gravity model indicated that the anomalies found could not be explained by the known structures and density distribution used in the model.



Subsequent archival research on the reconstruction of the tomb has revealed that there is a buried structure lying on top of the capstone of the chamber. This structure or cowl was used to reduce the weight loading on the chamber from overlying soils. The cowl is shown in the photograph below.



The existence of the cowl required a more detailed analysis of the horizontal and vertical gravity gradients. The area of and current analysis of the chamber area is shown above where the black crosses show the measurement locations in the chamber and the arrows show the direction of the general northwest trending horizontal gravity gradient. The vertical gradient of the anomaly, with only the effect of the known chamber removed, is shown in the coloured image. The lower vertical gradient values to the east may be due to the gravity effect of the passage. Taking all the measurements into account it appears that the measured effect of the known chamber is shifted to the west and northwest compared to the modelled effect. The gravity effects of the passage and cowl are being investigated to eliminate them from the gravity anomaly associated with the chamber.

Acknowledgements

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