Integration of Ground-Penetrating Radar, LiDAR, and Empirical Field Studies: A Multifaceted Analysis Comparing 1987 and 2019 field studies of the Durupinar Boat Formation known as "Noah's ark"

Abstract: This paper details a field expedition conducted by the ToPa 3D research team from the U.S.A. at the Durupinar Noah's ark site just south of Mt. Ararat, Türkiye near the village of Üzengili in Ağrı Province in October 2019. Motivated by the historical significance and legends associated with Noah's Ark, this expedition faced a myriad of challenges, from equipment acquisition complexities due to international customs to environmental variables inherent to the site. Despite these challenges, the field study yielded multifaceted data thereby underscoring the Mt. Ararat region's significance as a site of natural and potential archaeological importance.

Ground-Penetrating Radar (GPR) is an indispensable tool in today's geophysical research, facilitating detailed insights into subsurface structures and potential archaeological sites. This paper presents a rigorous analysis of GPR data processed using the advanced GPR-Slice v.7 software. Methodological approaches encompassed noise filtration, amplitude adjustment, and enhanced signal clarity, leading to the identification of distinct geometric patterns at a depth of 3 to 7 meters. These patterns, indicative of a unique subsurface structure, are critically examined in the context of both geological formations and potential archaeological remnants.

In addition to GPR, the expedition employed Light Detection and Ranging (LiDAR) technology, a pivotal advancement in geospatial mapping. LiDAR was instrumental in creating a detailed 3D topographical map of the Durupinar Noah's Ark site. This high-resolution map, capturing minute surface details, provided invaluable context to the GPR findings, allowing for a more comprehensive spatial understanding of the site's topography and potential structural remnants.

Lastly, the 2019 expedition results are compared with the 1987 geophysical survey. Similarities in the GPR data are shown at specific locations on the boat formation.

The synthesis of GPR technology, LiDAR mapping, and empirical field research offers a holistic and interdisciplinary approach to geophysical exploration. This paper underscores the synergistic potential of these methodologies in advancing geophysical research, contributing novel findings to the academic discourse in geology and archaeology.

Keywords: Ground-Penetrating Radar (GPR), LiDAR, Noah's Ark, Durupinar, Mount Ararat, geophysical survey

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Yere Nüfuz Eden Radar, LiDAR ve Ampirik Saha Çalışmalarının Entegrasyonu: "Nuh'un Gemisi" olarak bilinen Durupınar Gemisi Formasyonu'nun 1987 ve 2019 saha çalışmalarını karşılaştıran Çok Yönlü Bir Analiz

Özet: Bu makale, ABD'den ToPa 3D araştırma ekibi tarafından Ekim 2019'da Ağrı ilinin Üzengili köyü yakınlarındaki Durupınar Nuh'un gemisi alanında gerçekleştirilen bir saha keşif

gezisini detaylandırmaktadır. Nuh'un Gemisi ile ilgili tarihi önem ve efsanelerden ilham alan bu keşif gezisi, uluslararası gümrüklerden kaynaklanan ekipman edinme karmaşıklıklarından sahaya özgü çevresel değişkenlere kadar sayısız zorlukla karşılaştı. Bu zorluklara rağmen, saha çalışması çok yönlü veriler sağlayarak Ağrı Dağı bölgesinin doğal ve potansiyel arkeolojik öneme sahip bir alan olarak öneminin altını çizmiştir.

Yere Nüfuz Eden Radar (GPR), günümüz jeofizik araştırmalarında vazgeçilmez bir araçtır ve yüzey altı yapıları ile potansiyel arkeolojik alanlara ilişkin ayrıntılı bilgiler sağlar. Bu makale, gelişmiş GPR-Slice v.7 yazılımı kullanılarak işlenen GPR verilerinin titiz bir analizini sunmaktadır. Metodolojik yaklaşımlar gürültü filtreleme, genlik ayarı ve gelişmiş sinyal netliğini kapsamış ve 3 ila 7 metre derinlikte farklı geometrik desenlerin tanımlanmasına yol açmıştır. Benzersiz bir yüzey altı yapısının göstergesi olan bu desenler, hem jeolojik oluşumlar hem de potansiyel arkeolojik kalıntılar bağlamında eleştirel bir şekilde incelenmiştir.

GPR'ye ek olarak, keşif gezisinde jeo-uzamsal haritalamada çok önemli bir gelişme olan Işık Algılama ve Mesafe Ölçme (LiDAR) teknolojisi de kullanılmıştır. LiDAR, Durupınar Nuh'un Gemisi alanının ayrıntılı bir 3D topografik haritasının oluşturulmasında etkili oldu. En küçük yüzey ayrıntılarını yakalayan bu yüksek çözünürlüklü harita, GPR bulgularına paha biçilmez bir bağlam sağlayarak alanın topografyası ve potansiyel yapısal kalıntıları hakkında daha kapsamlı bir mekânsal anlayışa olanak tanıdı.

Son olarak, 2019 keşif sonuçları 1987 jeofizik araştırması ile karşılaştırılmıştır. GPR verilerindeki benzerlikler, tekne formasyonu üzerindeki belirli konumlarda gösterilmiştir.

GPR teknolojisi, LiDAR haritalama ve ampirik saha araştırmasının sentezi, jeofizik keşif için bütünsel ve disiplinler arası bir yaklaşım sunmaktadır. Bu makale, bu metodolojilerin jeofizik araştırmaları ilerletmedeki sinerjik potansiyelinin altını çizmekte ve jeoloji ve arkeolojideki akademik söyleme yeni bulgular katmaktadır.

INTRODUCTION

This paper summarizes the ToPa 3D research team's challenging field expedition from October 14-17, 2019, at the Durupinar Noah's Ark site, located just south of Mount Ararat (Ağrı Dağı) near the village of Üzengili in Türkiye's Ağrı Province. Next a comparison between the 1985-1987 geophysical survey results and the geophysical data obtained during the 2019 survey is made. The comparison suggests there are similar subterranean reflections seen below the ground in both surveys and that new angular reflections suggesting possible man-made structure was discovered during the 2019 survey.

OCTOBER 2019 SURVEY EXPEDITION

In early October 2019, ToPa 3D, a provider of 3D mapping services for architecture, engineering & construction (AEC), geospatial mapping, and historic projects out of Bend, Oregon, USA[1] was contracted to survey the Durupinar Noah's Ark site with LiDAR, ground-penetrating radar (GPR) and thermography (Fig. 1). The Durupinar Noah's Ark site has elicited a lot of controversy between Noah's Ark researchers, religious leaders, and scientists. Its size and rugged terrain and regional geopolitics meant it was indeed a surveying challenge, but during this expedition Topa 3D successfully surveyed the site with the needed geophysical equipment and provided preliminary analysis.[2] Among a range of technologies used, it was ground-penetrating radar (GPR) that had the most successful results.

Figure 1 The Topa 3D survey team along with a Science Channel video crew, local military personnel, and Turkish citizens. Image source: Zafer Önay, October 16, 2019.

Over a period of 4 days between October 14 and 17, 2019, the ToPa 3D team collected the GPR data using both a 100 MHz and a 250 MHz antenna (Fig. 2).[3] These two frequencies meant the team could possibly obtain results up to 12 meters down in wet clay soil for example.[4] The survey covered the whole boat formation with both antennas along with a detailed z-pattern survey in three locations on the site using the 250 MHz antenna.

Figure 2 ToPa 3D GPR expert on the Durupinar Noah's Ark site being interviewed by the Science Channel. Image Source: Andrew Jones, October 16, 2019.

[1] *Topa 3D, accessed March 12, 2024, www.topa3d.com.*
[2] *Paul Tice, 'Capturing Noah's Ark - Mt. Ararat, Turkey,' LinkedIn, accessed March 12, 2024, www.linkedin.com/pulse/capturing-noahs-ark-mt-ararat-turkey-paul-tice/.*
[3] *Paul Tice, Noah's Ark Reality Capture Study,' LinkedIn, accessed March 12, 2024, www.linkedin.com/posts/topa3d_noahs-ark-reality-capture-study-activity-6848359745838026752-z-4E/.*
[4] *Matt Peace, 'What Is the Effective Depth of Ground Penetrating Radar?,' US Radar Inc. Subsurface Imaging Systems, February 28, 2022, www.usradar.com/blog/what-is-the-effective-depth-of-ground-penetrating-radar/.*

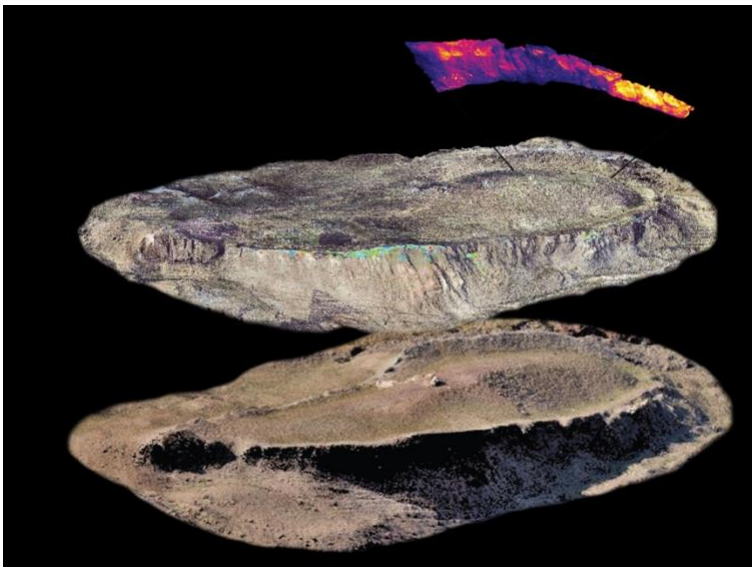

Figure 3 Photogrammetry model, LiDAR model with thermography section of the Durupinar Noah's Ark site. Image source: Topa 3D, February 2020.

The team, also, collected LiDAR data (Fig. 3) using "a FARO terrestrial laser scanner at ¼ resolution and x3 noise compression and processed in FARO Scene V2019.1 software. 111 scans were collected and registered (stitched) together creating a complete 3D model (point cloud) that is measurable within approximately 1". The point cloud data was aligned to survey control, established by a local Turkish surveying firm using a GPS unit (+/-1" precision) without base station. This ½ billion point cloud data will be used for archaeological grid layout for future analysis."[5]

For visualization purposes, a photogrammetry model was created of the Durupinar Noah's Ark site (Fig. 4). Using a DJI Mavic 2 Pro drone 1,835 aerial photographs were collect a month before the Topa 3D team arrived and during the expedition the imagery "was stitched photogrammetrically with Pix4D software depicting in detail, the rugged topography of the project site. Data was not aligned to control points. Geotagged images from the internal GPS unit provided. Typical precision expected with this internal unit without ground control points range from 1-2 meters horizonal, and 1-3 meters vertical."[6]

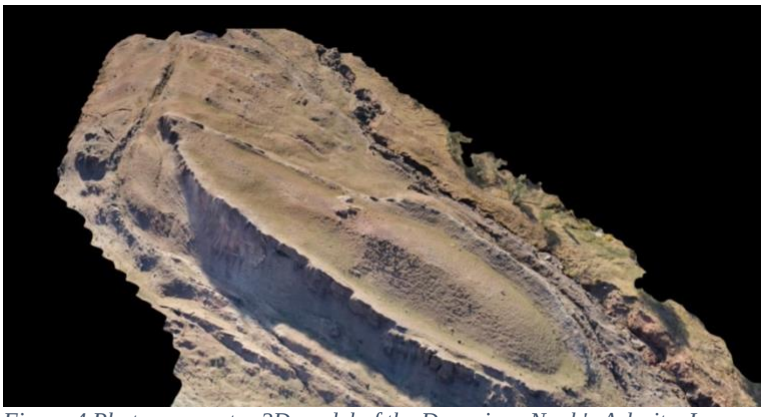

Figure 4 Photogrammetry 3D model of the Durupinar Noah's Ark site. Image source: Topa 3D, February 2020.

OCTOBER 2019 SURVEY RESULTS

Dr. Dan Bigman of Bigman Geophysical located in Norcross, Georgia, USA processed and interpreted the GPR data. "All data were processes using GPR-Slice v.7 software. A vertical

[5] *Topa 3D, "Noah's Ark - NUH_UN GEMİSI: Project Noah – Utilizing LiDAR, Photogrammetry, Ground Penetrating Radar and Thermography Reality Capture Mapping technologies for subsurface geospatial investigation in archaeological applications," slide 9, February 2020, www.noahsarkscans.com/articles/Noah%E2%80%99s%20Ark%20-%20NUH_UN%20GEM%C4%B0-v2.pdf.*
[6] *Topa 3D, "Noah's Ark - NUH_UN GEMİSI," slide 5.*

correction for data drift was first applied to all wiggle traces using a batch-wobble minus gain function. Then a time-zero correction was applied to data to adjust data lines to correspond with the ground surface reflection. Next a bandpass and background filter were applied to remove high and low frequency noise and remove horizontal banding from data profiles. Amplitudes were adjusted using an AGC automated gain function. A hyperbola fit was conducted, and data were migrated to account for signal distortion during data acquisition. Finally, a Hilbert transform was applied to generate absolute amplitudes for reflection responses."[7]

Several areas of interests were identified in the GPR data. First at approximately 7 meters down on the northwest interior of the boat formation's lower end a pattern of rectangular shaped reflections was seen in the 100 MHz data (Fig. 5 & 6).[8] While an excavation or core samples

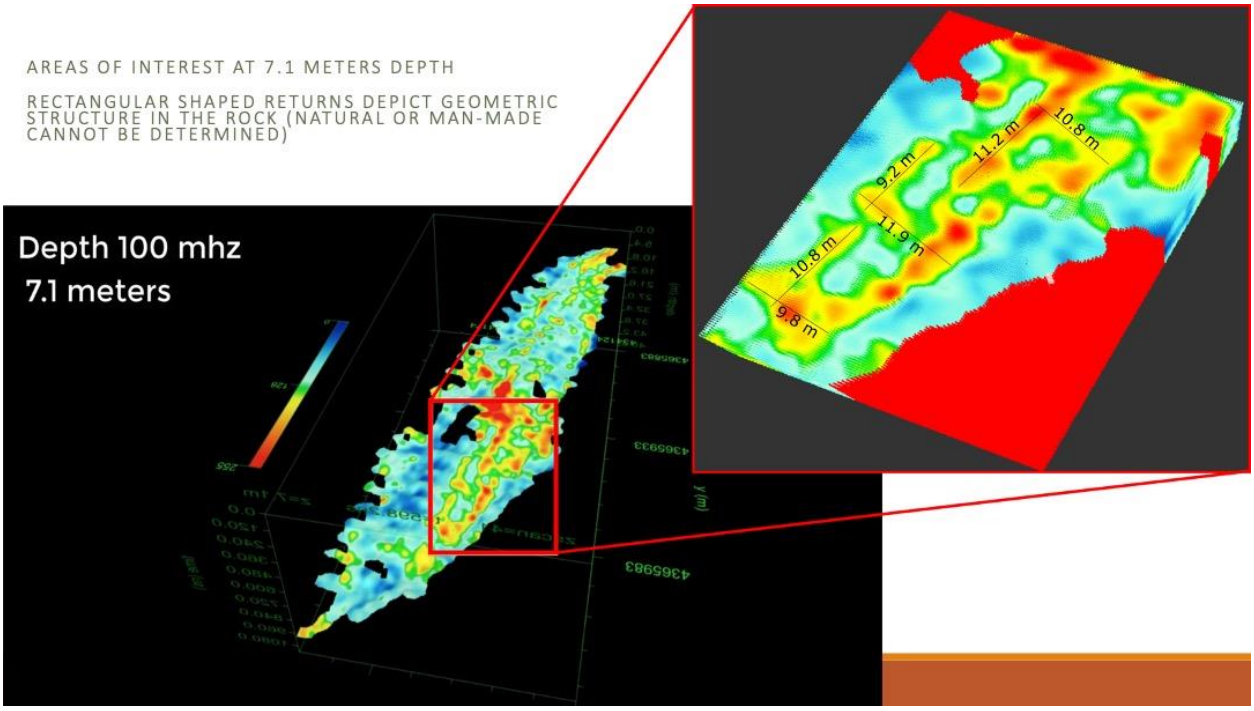

Figure 5 Geometric rectangular pattern of reflections seen at 7.1 meters down. Image source: Topa 3D, February 2020.

would be needed to determine the true nature of the reflections the 100 MHz data was nonetheless interesting. An analysis of the geometric structure's point cloud data revealed the structure had depth to it and was not a shallow feature (Fig. 7).

[7] *Topa 3D, "Noah's Ark - NUH_UN GEMİSI," slide 12.*
[8] *Topa 3D, "Noah's Ark - NUH_UN GEMİSI," slide 14.*

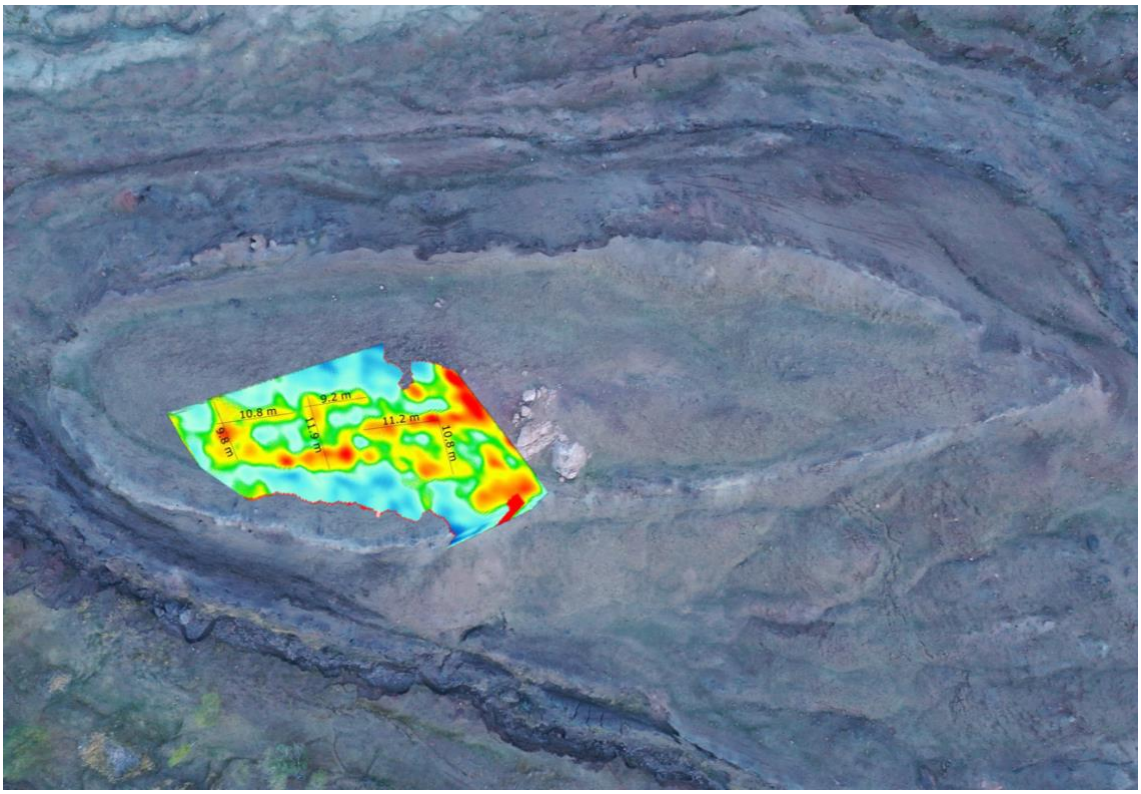

Figure 6 Location of the rectangular reflections on the Durupinar Noah's Ark site. Image source: Topa 3D & Andrew Jones, 2020.

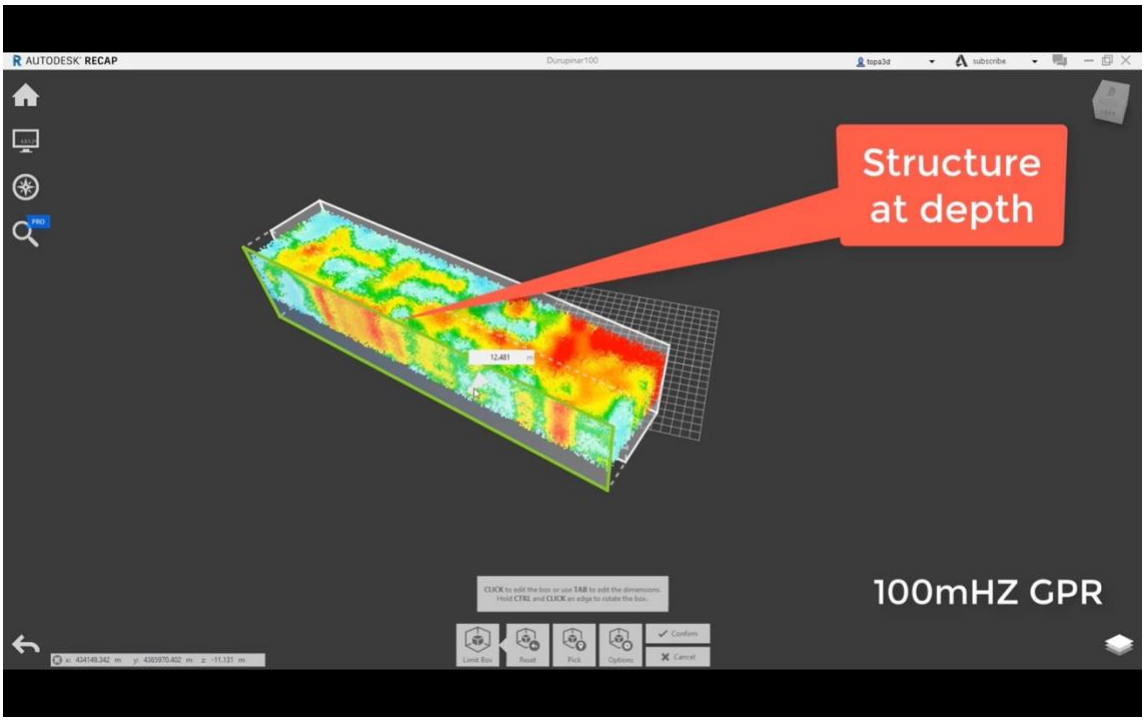

Figure 7 Rectangular geometric structure at depth. Image source: Topa 3D, February 2020.

In addition, linear features were detected at approximately 3 meters down on the eastern side of the Durupinar Noah's Ark site with the 250 MHz antenna (Fig. 8 & 9).

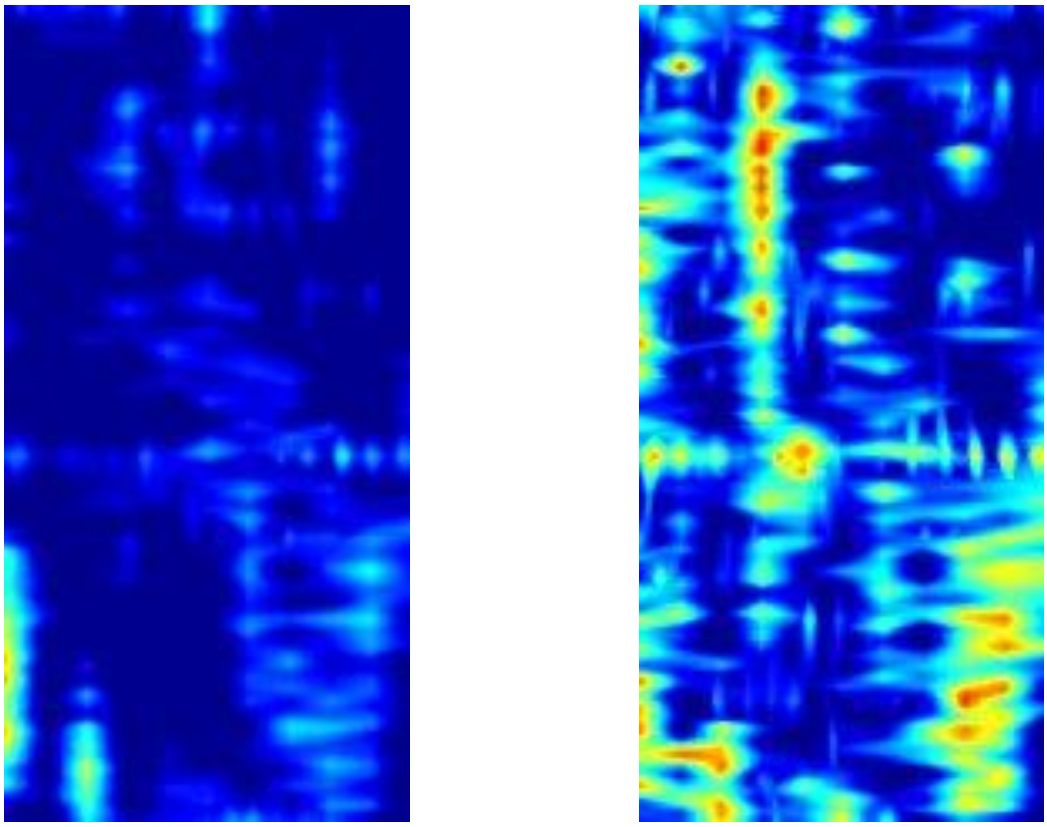

Figure 8 Linear reflections in the 250 MHz data approx. 3 meters below the surface. Image source: Topa 3D, February 2020.

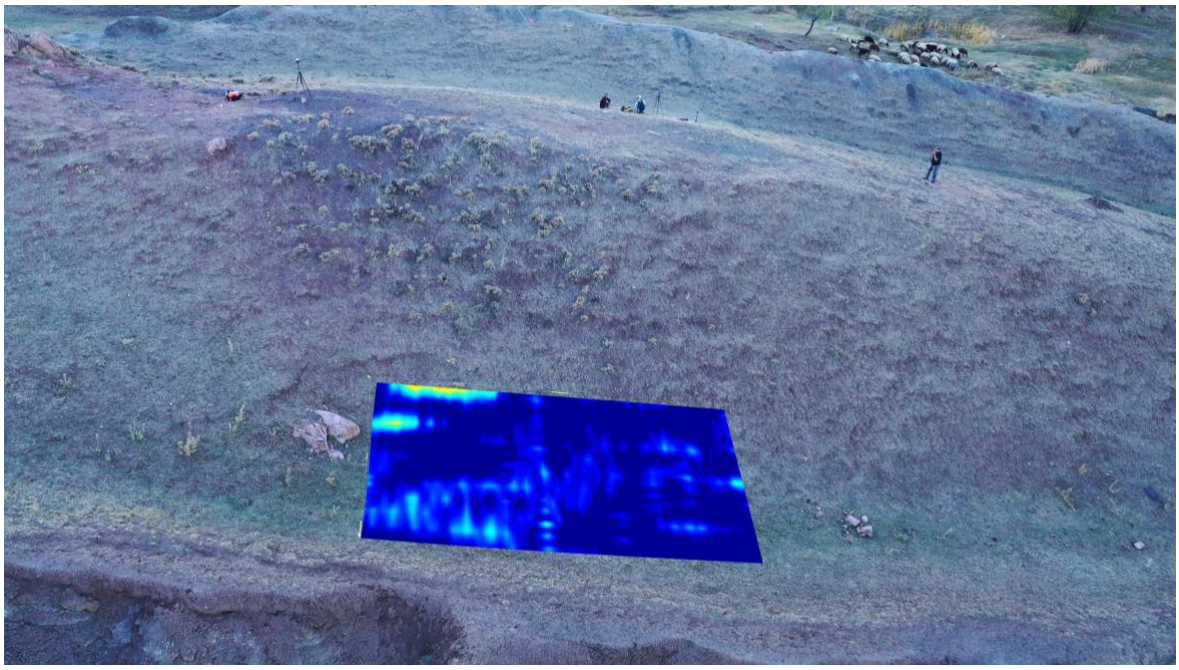

Figure 9 Location of linear reflections on the eastern side below the middle hump. Image source: Topa 3D, February 2020.

JULY 1987 SURVEY EXPEDITION

Between 1985 and 1987 a number of geophysical studies were done by Turkish and American scientists on the Durupinar Noah's Ark site. In July 1987 Assist. Prof. Dr. M. Salih Bayraktutan with Atatürk University in Erzurum, Turkey along with Dr. John Baumgardner with Los Alamos National Laboratory in the USA co-sponsored a number of geophysical surveys of the Durupinar Noah's Ark site (Fig. 10). In addition to ground penetrating radar the team did a magnetometer survey and seismograph investigations. The results were released in an unpublished report in November 1987. [9]

Figure 10 July 1987 Research Team. Image Source: Dr. John Baumgardner, 1987.

JULY 1987 GPR SURVEY RESULTS

Seventy-one GPR scans were completed across the site from July 19-23 and were spaced every 2 meters along east/west profiles (Fig. 11). A 120 MHz antenna was used to "achieve the maximum possible penetration."[10]

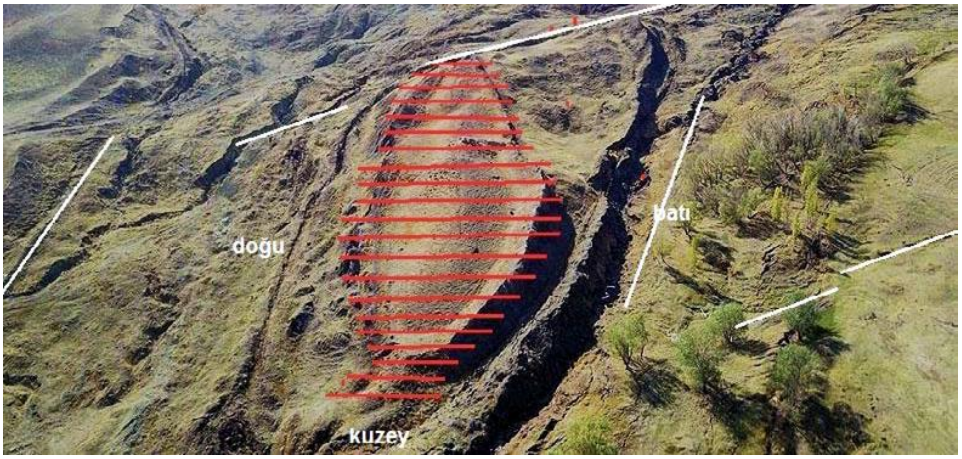

Figure 11 The July 1987 GPR survey pattern. Image source: Dr. M. Salih. Bayraktutan, 2019.

[9] *John R. Baumgardner and M. Salih Bayraktutan, "July 1987 Geophysical Investigation of Noah's Ark (Durupinar Site) Mahşer Village, Doğubayazıt, Ağrı," unpublished research report, Atatürk University, Erzurum, Turkey, 1987.*
[10] Baumgardner and Bayraktutan, "*July 1987 Geophysical Investigation of Noah's Ark (Durupinar Site)," 8.*

The GPR survey picked up an "almost planar" feature 4-8 meters below the surface across the lower end of the boat formation between 18 meters and 62 meters downhill from the exposed rock outcrop (Fig. 12).[11] An additional radar reflection was seen almost across the whole site around 1-1.5 meters below the surface.[12] [13]

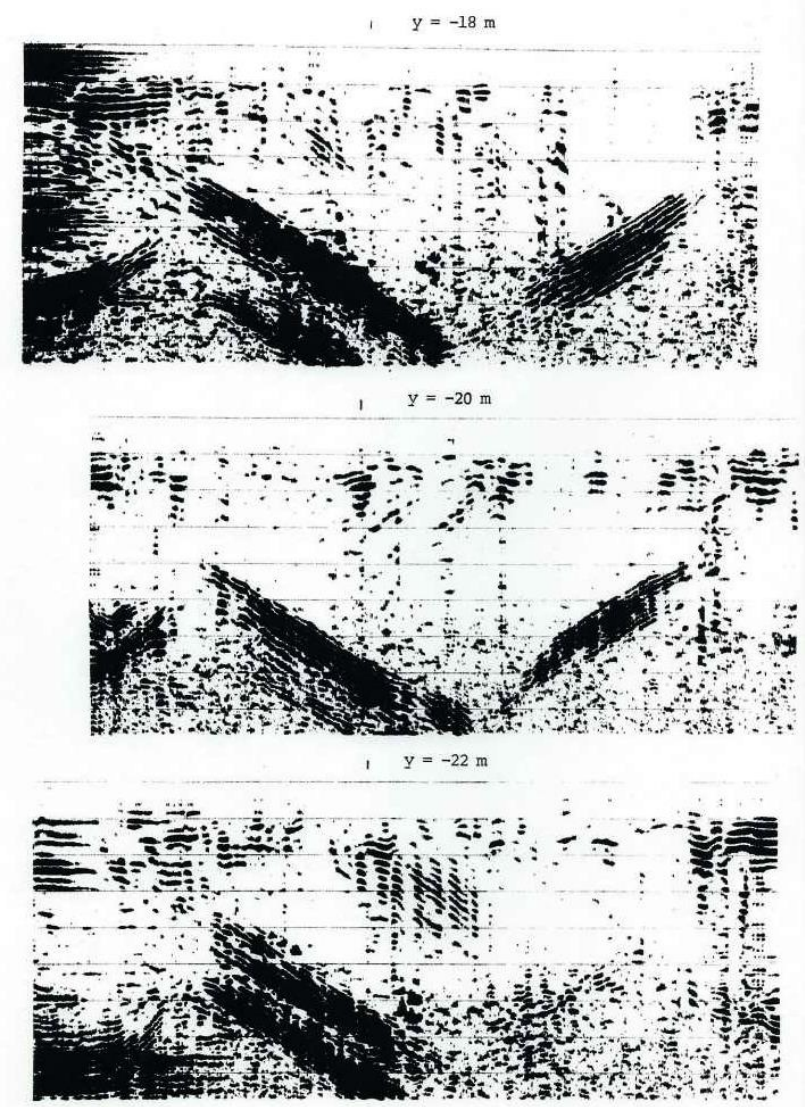

Figure 12 An example of the double V-shaped reflection in the GPR data. Topographical correction of the data creates a planar feature that is 4-8 meters below the surface. Image Source: Baumgardner and Bayraktutan, 1987, 26.

[11] Baumgardner and Bayraktutan, "*July 1987 Geophysical Investigation of Noah's Ark (Durupinar Site),*" *8, 45.*
[12] Baumgardner and Bayraktutan, "*July 1987 Geophysical Investigation of Noah's Ark (Durupinar Site),*" *10.*
[13] M. Salih Bayraktutan, "TELCEKER LANDSLIDE, GEOPHYSICAL EXPLORATION OF DURUPINAR SITE DOGUBAYAZIT (NOAHS ARK PROJECT 1985-87. AGRI)," in *The Fifth International Mount Ararat and Noah's Ark Symposium,* eds. Oktay Belli, Abdulhalik Karabulut, Faruk Kaya, Ibrahim Özgül, Vedat Evren Belli, (Ağrı, Türkiye, October 16-18, 2019), 129, https://ismana.agri.edu.tr/userfiles/5.%20A%C4%9Fr%C4%B1%20Da%C4%9F%C4%B1%20ve%20Nuh'un%20Gemisi%20Se%C3%B6pozyumu%20Tam%20Metin%20Bildiri%20E%20Kitap.pdf

COMPARISON OF THE 1987 AND 2019 GPR SURVEY RESULTS

Although varying radar technologies (analog versus digital) and frequencies (120 MHz in 1987 and 100 MHz as well as 250 MHz in 2019) were employed for the antennas, several features were consistently detected at nearly identical depths in the radar data from the two surveys that were 32 years apart.

The 120 MHz GPR data obtained in the 1987 survey detected a planar reflection 4-8 meters down in the lower northern half of the Durupinar Noah's Ark site (Fig. 13). In this same lower end of the boat formation the 2019 geophysical survey detected in the 100 MHz dataset a pattern of rectangular geometric reflections around 7 meters below the surface (Fig. 14). Without obtaining samples of the material via core drilling one could speculate as to how the angular features integrate with the planar layer.

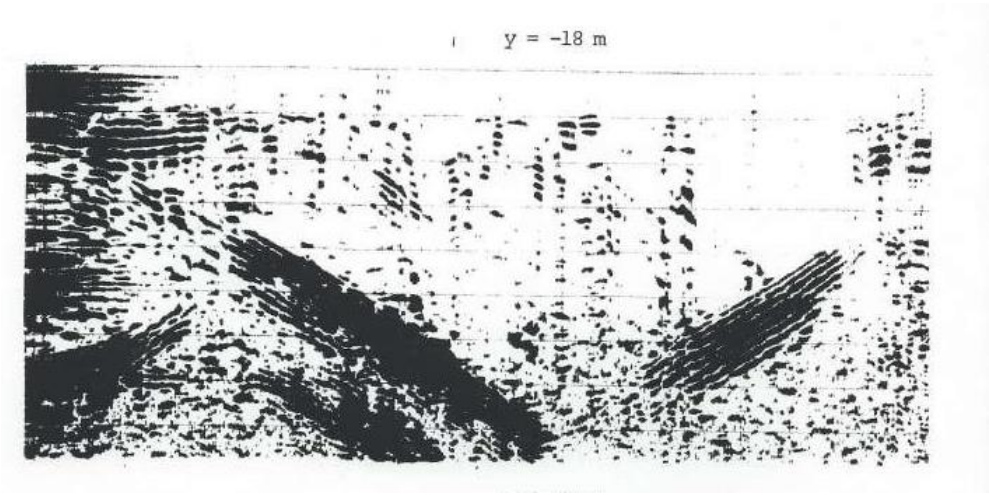

Figure 13 V-shaped double reflection between 4-8 meters below the surface and approximately 24 meters downhill from the rock outcrop. Image Source: Baumgardner and Bayraktutan, 1987.

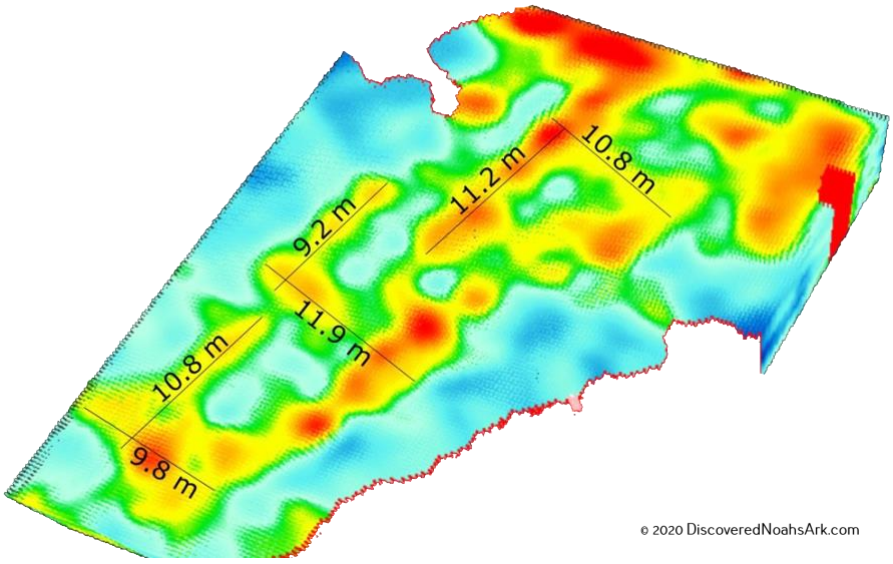

Figure 14 Angular patterns around 7 meters below the surface in the northwest depression inside the Durupinar site. Image source: Topa 3D, 2020.

Finally, both the 1987 and 2019 GPR surveys showed a consistent pattern of reflections at a uniform depth over almost the entire site around 1-2 meters below. The 2019 survey's 250 MHz dataset had a strong reflection across the site between 1.6-1.9 meters in depth (Fig. 15).[14] While the 1987 report mentioned a slightly shallower reflection at 1-1.5 meter in depth across the ship-shape formation.[15] Several layers in the soil can be seen on the exposed eastern side of the boat formation (Fig. 16). Are any of these visible layers producing the radar reflections seen in the GPR survey? More research is needed.

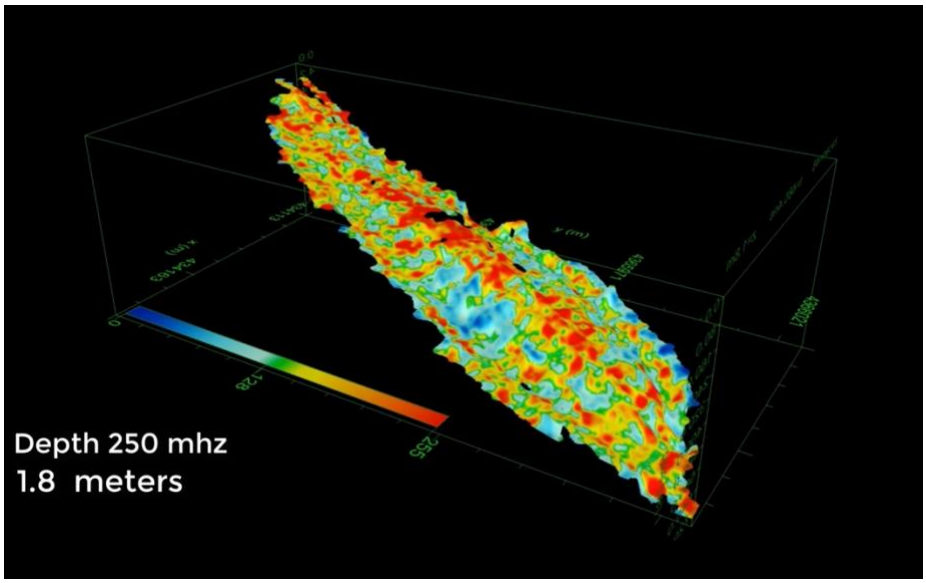

Figure 15 A consistent pattern of reflection seen across the site in the 2019 250 MHz GPR data at around 1.8 meters down. Image source: Topa 3D, 2020.

Figure 16 Below the highlighted lines are seen a number of layers of soil exposed on the eastern "wall" of the ship formation. Image source: Andrew Jones, 2023.

[14] *Topa 3D, "Noah's Ark - NUH_UN GEMİSI," 29.*
[15] Baumgardner and Bayraktutan, "*July 1987 Geophysical Investigation of Noah's Ark (Durupinar Site)," 10.*

SUMMARY

The different geophysical surveys done at the Durupinar Noah's Ark site only furthers the mystery as to what is below the surface in the ship shape and what is holding the site together since its first discovery in 1959. The 2019 expedition produced interesting angular and linear reflections deep in the structure. When compared to the previous geophysical work done in the 1980s more questions are raised as to how these features relate to each other and if they're man-made or natural. More scientific research is needed at the site. As the "father of Turkish archaeology", Professor Dr. Ekrem Akurgal, once stated on camera after reviewing the preliminary data about the Durupinar site in March 1985, "At any rate, it is a ship, an ancient ship, and it must be preserved."[16] Nearly four decades on, this assertion not only remains valid but has gained increased urgency.

Figure 17 The Durupinar Noah's Ark site. Image source: Andrew Jones, June 5, 2020.

[16] Mary Nell Wyatt, *The Boat-Shaped Object on Doomsday Mountain* (Cornersville: Wyatt Archaeological Research, 2004), 90.