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Geoheritage mapping: The case of Lesvos UNESCO Geopark

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Abstract:

The aim of this study focuses on the development and implementation of an integrated methodology for mapping the geosites that constitute the Lesvos island UNESCO Global Geopark, aiming to support its comprehensive management. Geosites, as fundamental components of a Geopark, pose significant challenges due to their diversity in geographic scale, topography, and geomorphology. This complexity necessitates specialized approaches that combine modern technologies and innovative methods (Papadopoulou et al., 2022). The Lesvos UNESCO Global Geopark is a site of exceptional geological and natural heritage, internationally recognized for its uniqueness (Wang and Zouros, 2021). Located in the northern Aegean, Greece, it encompasses an area of 1.6Km2 with a rich geological history spanning over 20 million years. The Geopark features an impressive variety of geosites, including the Lesvos Petrified Forest, volcanic formations, tectonic structures, coastal landscapes, and distinctive geomorphological features shaped by geodynamic processes (Zouros et al., 2004). The Lesvos Geopark serves as a living laboratory for scientific research, education, and public awareness of geoheritage. Moreover, it strengthens the local economy through geotourism, offering a unique experience for visitors interested in geology, nature, and culture. However, the effective management and promotion of such a geopark require the development of specialized mapping methodologies and tools that consider the unique geographic and geomorphological parameters of each geosite (Kubalíková and Kirchner, 2016; Zafeiropoulos et al., 2021). This necessity renders the mapping of geosites an exceptionally demanding process, requiring advanced technological solutions and innovative methodologies (Cayla et al., 2014; Pál and Albert, 2019; Sang et al., 2022).

The methodology followed in the present study is based on the use of advanced techniques for data acquisition and processing, such as Unmanned Aerial Vehicles (UAVs) equipped with various recording sensors (RGB cameras, LiDAR, thermal cameras, multispectral sensors, multi-cameras), web-mapping techniques, and state-of-the-art geovisualization methods. High-resolution data were collected using UAVs to capture the topographic - geomorphological characteristics of the geosites. The data collection was determined by: i. the specific characteristics of each geosite, taking into account their geomorphology, topography, and extent and ii. the appropriate cartographic scale of the results. The diverse nature of geosites, ranging from small-area features (e.g. petrified tree-trunks) to large-area geological structures (e.g. calderas, tectonic landforms etc.), introduced significant challenges. These challenges included the need to adapt data acquisition techniques, difficulties in accessing certain areas, and the diversity of topographies that impact both data analysis and geovisualization. Depending on the geographic scale of the geosites, the appropriate cartographic scale was determined. Small-area geosites required detailed mapping, whereas larger ones focused on a general representation of key features. Differentiating the cartographic scale was critical for accurate and efficient representation. Particularly for geosites characterized by complex geomorphology, advanced techniques were employed, combining multi angle (nadir and oblique) high-resolution UAV data. Advanced geovisualization techniques such as 3D models, 3D animations, 360° panoramas, virtual and augmented reality and interactive maps were developed to provide a multiscale and multidimensional approach to visualize the geosites. These geovisualization techniques were designed to meet the specific needs of each geosite, considering their stage of management (e.g. documentation, excavation, protection, promotion). Interactive online maps and cartographic web applications were developed to provide additional information concerning the geoheritage monuments of Lesvos Geopark. These maps and geovisualizations accessible through web-platforms (e.g. sketchfab for 3d models, youtube for animated maps, story-maps etc.), enhance user engagement and offer valuable tools for geopark management by enabling spatial - temporal monitoring and informed decision-making. Furthermore, a printed map was produced, consolidating all cartographic materials. This map incorporates modern symbols that activate augmented reality applications via mobile devices, allowing users to explore 3D models and other digital-content interactively. Emphasis was placed on the usability and visual appeal of the map, ensuring its effectiveness as a tool for promoting and managing the Lesvos geopark's geoheritage (map 1).

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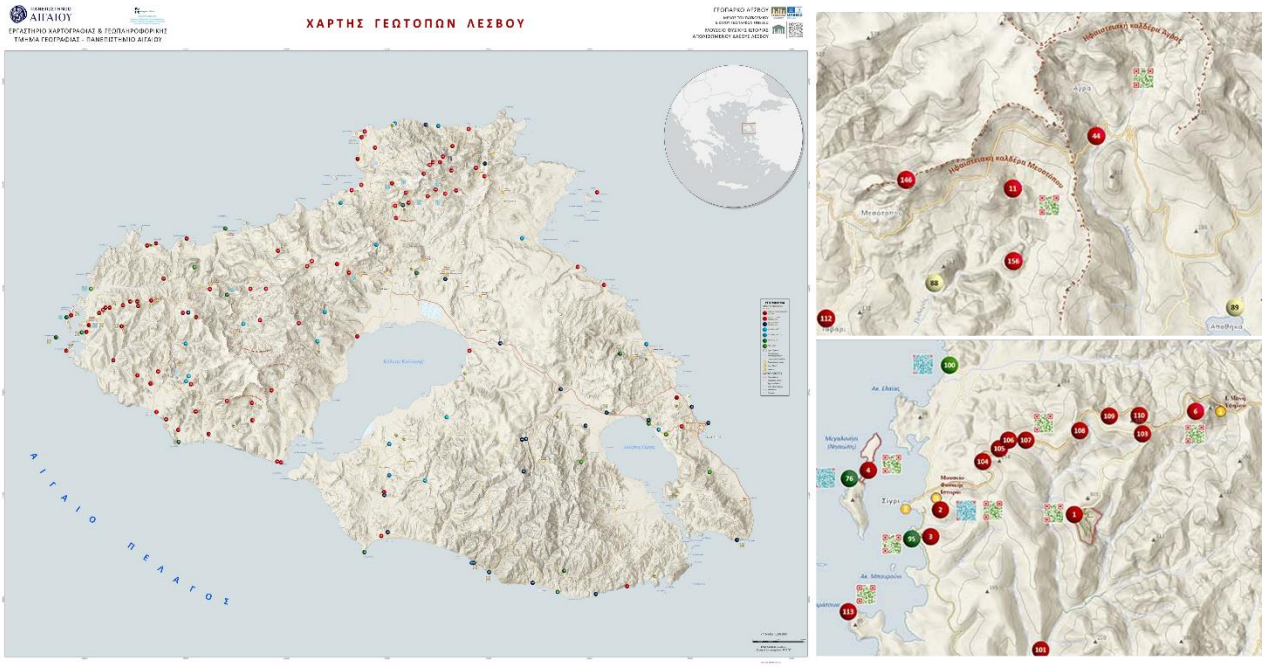

Map1. Lesvos UNESCO Geopark (scale: 1:50.000, dimensions 200cm X 160cm).

This study highlights the importance of integrating innovative mapping technologies with the protection and promotion of geoheritage sites. The diversity of geosites, combined with varying geographic scales, geomorphological parameters, and topographic challenges, makes this methodology particularly demanding. Nevertheless, it provides clear guidelines for applying specialized cartographic techniques, offering a framework adaptable to other Geoparks. The multidimensional approaches adopted improve the understanding, accessibility, and sustainable management of geoheritage while enhancing the experience of visitors and stakeholders.

The proposed methodology demonstrates that innovative mapping methodology which can significantly contribute to every stage of a geopark's integrated management. The collection of high-resolution UAS data, geographic analysis at multiple scales, and the use of advanced geovisualization techniques offer new opportunities for geoheritage promotion and sustainable management. The Lesvos UNESCO Global Geopark serves as an ideal area for applying these methods, providing valuable tools for preserving and showcasing its geoheritage. Additionally, this study can serve as a guide for utilizing similar technologies in other geoparks, advancing knowledge and innovation in the field of geoheritage. The significance of this methodology lies in its ability to adapt to the unique needs of each geosite, addressing challenges related to their geographic scale, geomorphology, and technological requirements. In this way, it provides a flexible tool that can be employed for geoheritage management on a global scale. Finally, future research will focus on creating geovisualizions aiming to support geo-education activities.

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