NEXUS ENGINEERING CHRONICLE
Volume 01 Number 01 SEPTEMBER-DECEMBER (2025)
DOI: 10.5281/zenodo.17952287
https://nexusjurnal.org/ojs/index.php/nec

Article

Active Coastal Tectonics and Uplifted Marine Terraces of Eastern Algiers: Geomatic Approaches for Plate Convergence and Sea-Level Reconstruction

Dinar Haythem[1], Rebouh Nouh[1], Mansouri Zineb[2], Nadji Housseyn[3], Boubguira Selwa[4], Batouche Toufik[5], Tabet Abdelhak[6] ,Abrar Ayoub[7],

1. Centre de Recherche en Aménagement de Territoire (CRAT), Campus Zouaghi Slimane, Route de Ain el Bey, 25000 Constantine, Algérie
2. Laboratoire de mobilisation et gestion des ressources en eau (LMGRE) Batna 2 university, Algeria
3. Laboratory of Sedimentary Environment, Mineral and Hydric Resources of Algeria Eastern,Department of Geology, University of Echahid Cheikh Larbi Tebessi, Tébessa, Algeria
4. Laboratory of Water Resource Mobilization and Management, Department of Geology, The Institute of Earth and Universe Science, University of Batna 2, Batna, Algeria
5. Department of Mining Engineering, Metallurgy and Materials. National Higher School of Technology and Engineering, 23005 Annaba, Algeria. Laboratory of Mines, Metallurgy and Materials (L3M), National Higher School of Technology and Engineering, 23005 Annaba, Algeria.
6. Mining Department, Faculty of Earth Sciences, Badji Mokhtar University Annaba, Algeria.
7. Department of Geoinformatics, University of Kashmir, India.

* Correspondence: haythem.dinar@crat.dz

Abstract: The eastern coast of Algiers represents a tectonically active margin within the African–Eurasian plate convergence zone, where the interplay of seismic deformation and sea-level fluctuations has shaped a series of uplifted marine terraces. These geomorphic markers preserve crucial information for quantifying long-term tectonic uplift, relative sea-level change, and seismic hazard.This study integrates geomatic approaches including high-resolution satellite imagery (SRTM 12.5), Geographic Information Systems (GIS), Global Positioning System (GPS) surveys, and field altimetry to map and analyze marine terraces along the eastern Algiers coastline. The research focuses particularly on the sector affected by the Mw 6.8 Zemmouri earthquake of May 21, 2003, which revealed the strong influence of active coastal tectonics in the region.A total of 81 measurements were conducted during our field investigations, and DEM analysis identified at least two distinct, well-preserved terrace levels. The first terrace, situated between 30.71 and 43 m above sea level, reflects long-term tectonic uplift linked to fault slip rates. The second terrace, preserved between 1 and 8.11 m, records more recent interactions between eustatic sea-level fluctuations and coseismic deformation. These elevations were validated through GPS and altimeter measurements, then cross-compared with regional sea-level curves.Preliminary interpretations suggest that terrace deformation is primarily controlled by active fault systems associated with the African–Eurasian convergence, while superimposed eustatic variations influence terrace morphology and preservation. The combined dataset provides new insights into uplift rates, neotectonic activity, and the spatial variability of deformation along this seismically active margin.By applying geomatic tools to coastal geomorphology, this study reconstructs the relationship between tectonic uplift and sea-level change, offering an improved understanding of long-term seismic hazard and coastal evolution in Algeria. These results contribute to regional geodynamic models, coastal risk assessment, and urban resilience strategies in the Western Mediterranean.

Keywords: Marine terraces, Coastal tectonics, Uplift, African–Eurasian plate convergence, Seismic hazard.

Citation: Dinar, H., Rebouh, N., Mansouri, Z., Nadji, H., Boubguira, S., Batouche, T., Tabet, A., & Ayoub, Abrar. (2025). Active coastal techtonics and uplifted marine terraces of eastern Algiers: Geomatic approaches for plate convergence and sea-level reconstruction. *Nexus Engineering Chronicle, 1*(1), 1-8.

Received: 10th Jan 2025
Revised: 11th Jun 2025
Accepted: 24th Jun 2025
Published: 27th Nov 2025

1. Introduction

Coastal geomorphological markers, such as marine terraces, provide essential archives for reconstructing the interplay between sea-level changes and tectonic deformation. These landforms, characterized by wave-cut platforms and stepped topography, preserve evidence of past sea-level positions and long-term crustal uplift. In convergent plate settings, their study offers critical insights into fault activity, earthquake recurrence, and seismic hazard [1,2 and 3].

Along the western Mediterranean, the Algerian coastline is highly vulnerable to active deformation due to the ongoing convergence between the African and Eurasian plates, estimated at 4–6 mm/yr [4,5 and 6]. Previous works have documented Quaternary folding, thrusting, and strike-slip faulting across the Tell Atlas and Mitidja Basin [7,8], as well as historical destructive earthquakes, including the 1716 Algiers and the Mw 6.8 Zemmouri event of May 2003 [7]. Despite these advances, significant uncertainties remain regarding uplift rates, terrace deformation, and their relationship to regional sea-level fluctuations.

The eastern coast of Algiers represents a key sector where well-preserved terraces record both tectonic uplift and eustatic influences. However, the spatial distribution, elevation, and deformation patterns of these terraces have not been comprehensively mapped using modern geomatic tools [9,10].

This study aims to generate high-resolution maps of deformed marine terraces in Eastern Algiers through remote sensing, GIS, and GPS analysis. The objective is to quantify uplift rates, identify active tectonic structures, and evaluate their implications for African–Eurasian plate convergence and regional seismic hazard, while also contributing to the reconstruction of sea-level curves and coastal resilience strategies.

2. Materials and Methods

The study was conducted in the Zemmouri coastal area (Figure 1), located within the Tell Atlas belt of northern Algeria, a tectonically active region marked by NE–SW trending folds and uplifted Quaternary terraces (Figure 2). This setting provides an ideal natural laboratory for investigating interactions between sea-level fluctuations and active tectonic deformation.

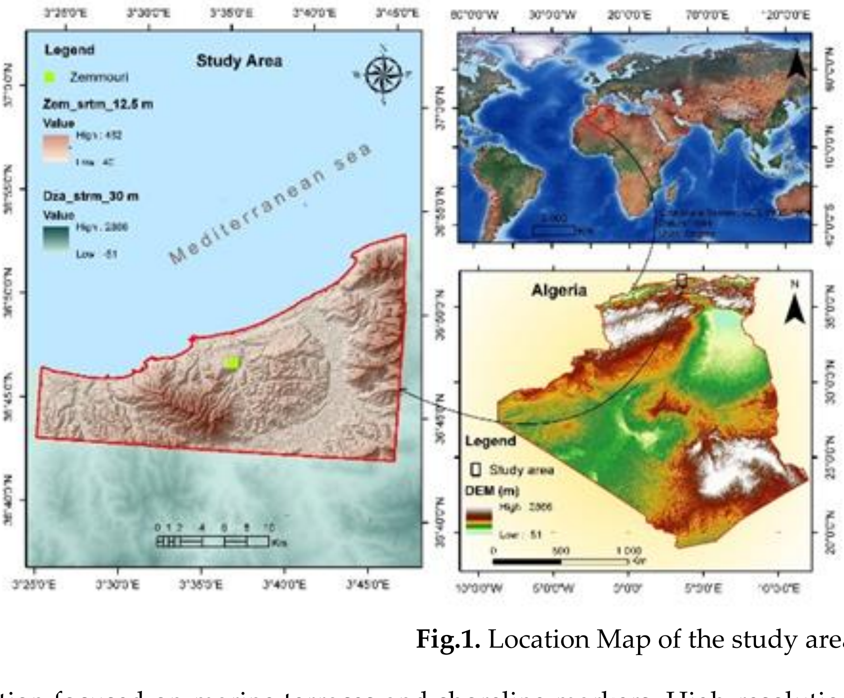

Fig.1. Location Map of the study area

Data collection focused on marine terraces and shoreline markers. High-resolution satellite imagery (ALOS, SRTM DEM, and 3-arc DEM) and aerial photographs were used to identify geomorphic features such as shoreline angles, wave notches, and terrace staircases. Digital Elevation Models (DEMs) provided slope indices, elongation ratios, and steepness indices, allowing distinction between marine terraces andalluvial or structural terraces. GPS surveys and elevation data were integrated to validate terrace heights and morphometric parameters.

Geospatial analysis was carried out using ArcGIS and MATLAB, enabling the extraction of hydrographic and topographic and geological maps (Figure 2) as well as terrace morphometry. These datasets facilitated mapping of scarps parallel to the coastline and quantification of terrace deformation [11,12 and 13], . The methodology combines geomorphological markers with quantitative morphometric indices to reconstruct relative sea-level changes and assess tectonic uplift. This multi-source approach ensures robust characterization of active coastal dynamics and supports broader interpretations of African–Eurasian plate convergence.

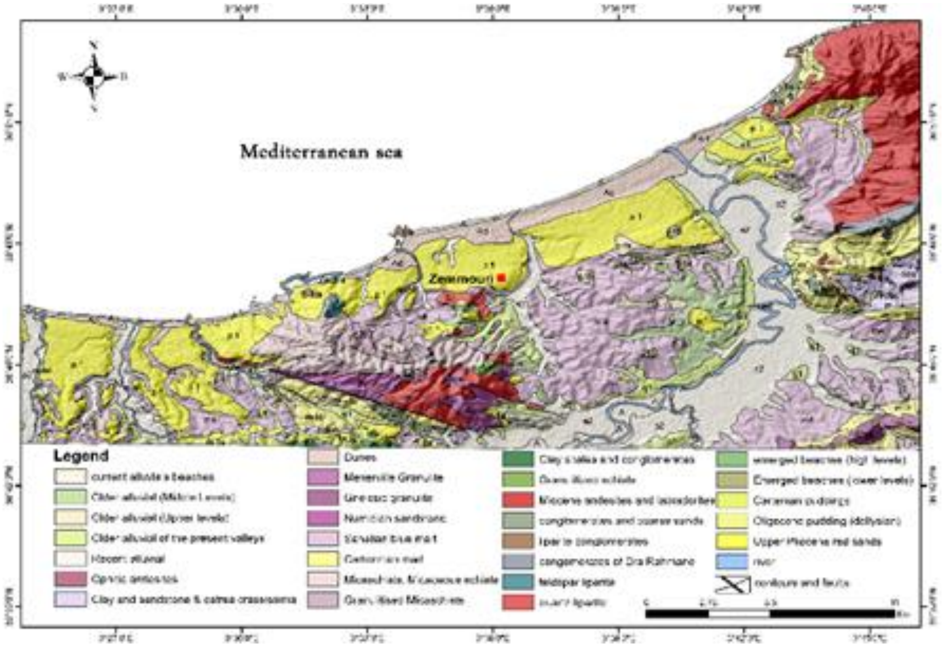

Fig. 2. Geological map of the Zemmouri region and surroundings

3. Results

3.1 Marine Terraces and Shoreline Angles

The geomorphological analysis of the Eastern Algiers coast identified two uplifted terrace levels (T1 and T2) and corresponding shoreline angles (ShA) (Table 1). Terrace T1 is preserved at elevations between 30.7 and 43 m, while T2 occurs at 1–8 m above present sea level. Shoreline angles were identified between 3 and 11 m, serving as reliable markers of former sea-level stands (Figure 3). These features are consistent with Quaternary uplift and glacio-eustatic sea-level oscillations.

Table 1. Summary statistics of marine terraces and shoreline angle elevations.

Feature	Minimum (m)	Maximum (m)	Mean (m)	Coordinates (Lat, Long)
T1	30.7	43.0	38.6	36.823°N, 3.350°E
T2	1.0	8.1	4.1	36.823°N, 3.350°E
ShA	0.9	11.4	7.0	36.823°N, 3.350°E

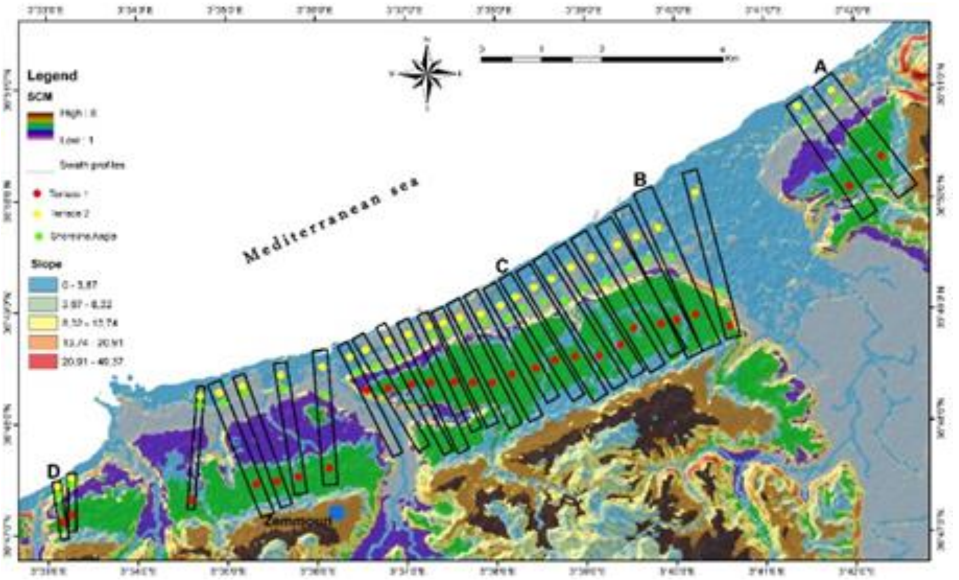

Fig. 3. The surface classification model shows Terrace 1, Terrace 2, and shoreline angles in the Zemmouri region

3.2 Seismic and Tectonic Influences

In the Zemmouri sector, terrace deformation correlates with active faulting. The Mw 6.8 earthquake of May 21, 2003 accentuated vertical uplift and generated new shoreline notches, confirming the strong link between seismic activity and terrace formation (Figure 4). Comparative elevation profiles (Figures 4) demonstrate differential uplift along the coast, with localized deformation zones marking fault-controlled subsidence and uplift [14].

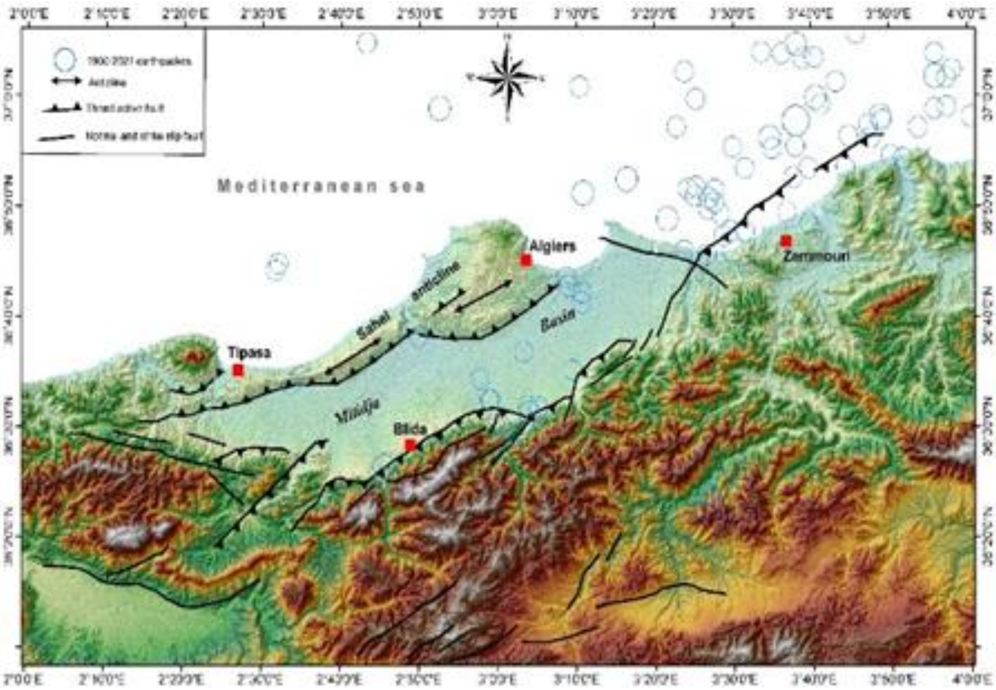

Fig. 4. NeoTectonic and seismicity map of the study area

3.3 Terrace Morphology and Deformation

Digital elevation models (ALOS, SRTM, 3-arc DEM) and field data revealed well-developed staircase morphologies, formed by alternating phases of uplift and marine abrasion (Figure 5). The terraces display horizontal platforms bounded by fossil sea cliffs, highlighting cycles of erosion and abandonment.

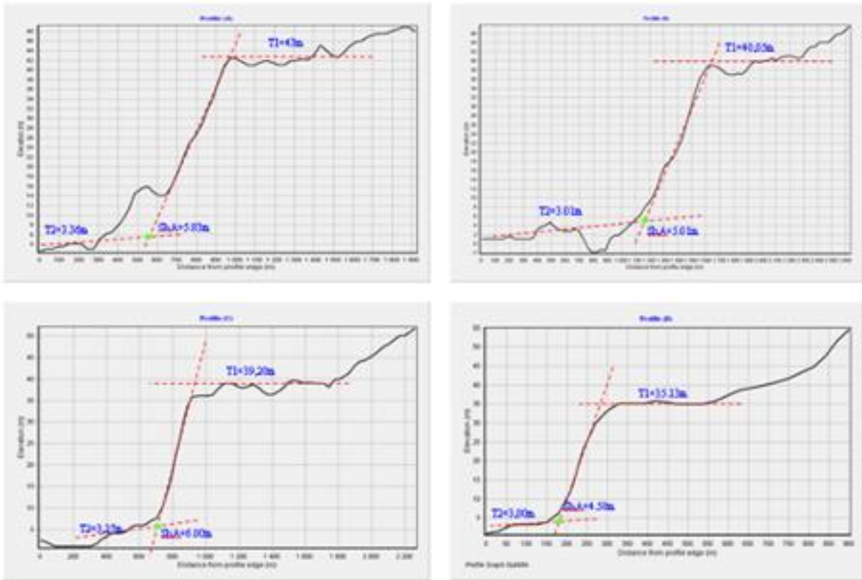

Fig. 5. Profiles A, B, C, and D shows the difference in elevation between T1 and T2

4. Discussion

The analysis of marine terraces in the eastern Algiers region (Zemmouri) highlights two distinct terrace levels. The higher and older terrace (T1) is situated between 30.71 and 43 m above sea level, while the lower and younger terrace (T2) ranges from 1 to 8.11 m (Figure 6; Table 1).

Fieldwork involved 81 measurement points where GPS provided geographic coordinates and altimetry defined elevations. These data were synthesized into four coastal profiles (A–D), positioned perpendicular to the shoreline. The profiles clearly display two flat, well-preserved terrace surfaces, separated by a shoreline angle (ShA) marking their transition.

A comparative diagram of terrace elevations confirmed differential uplift between T1 and T2, supported by field photographs that validated theoretical interpretations. The correlation between geomatic analysis and field evidence underscores the reliability of the results.

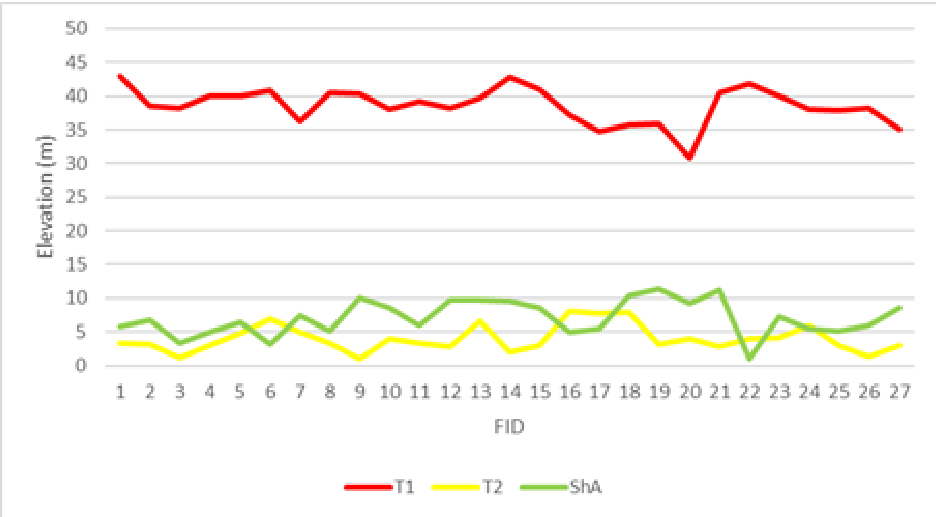

Fig. 6. Comparison of elevation between T1, T2, and ShA

Furthermore, sea-level curve analysis (Figure 7) indicates that successive shoreline formations correspond to global eustatic fluctuations. As emphasized by [15 and 16] selecting the most appropriate sea-level curve requires careful consideration of spatial variability and chronological resolution. Well-documented highstands such as MIS 11c and MIS 5e provide useful benchmarks [17]. Overall, the results demonstrate that marine terrace development in Zemmouri reflects the combined effects of tectonic uplift and eustatic sea-level changes.

To examine terrace geometry, four profiles (A–D) were established perpendicular to the coast (Figure 7, Photo 1). These profiles reveal two flat terrace levels, consistent with repeated uplift and marine abrasion.

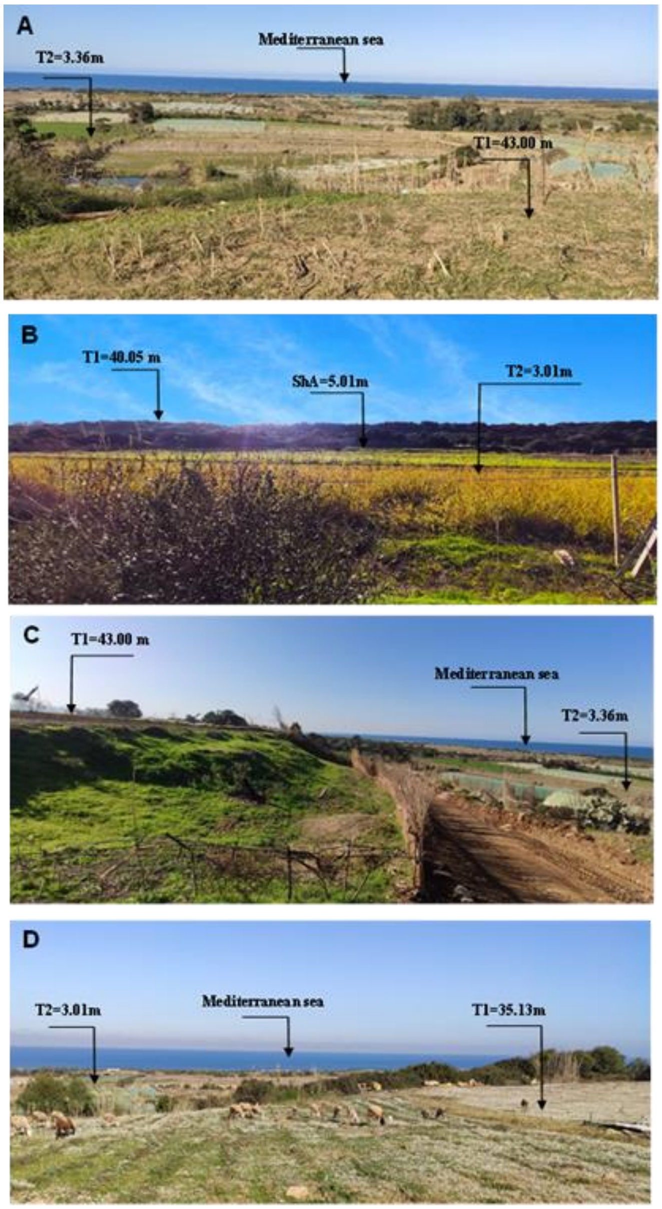

Fig. 7. Field photos presented the study area and the four profiles A, B, C, and D formed by T1 and T2

An elevation diagram illustrates the relative uplift between T1 and T2, while field photographs confirm the geomorphic interpretation (Photo 1).

Sea-level fluctuations played a central role in shaping these terraces. According to [7], the choice of sea-level curves must consider spatial variability, resolution, and original data quality. Well-studied highstands such as MIS 11c and MIS 5e provide robust benchmarks.

Overall, results indicate that marine terrace development in Eastern Algiers reflects the combined influence of eustatic sea-level change and regional tectonic uplift

5. Conclusion

This study demonstrates that the eastern Algiers coast, particularly the Zemmouri area, preserves two distinct levels of uplifted marine terraces shaped by tectonic uplift and sea-level fluctuations. Terrace elevations between 1–8 m (T2) and 30–43 m (T1), together with shoreline angles, provide robust geomorphic markers for reconstructing past coastal evolution. Field surveys, DEM analysis, and elevation profiles confirm that these terraces record repeated phases of uplift associated with the ongoing convergence of the African and Eurasian plates. The consistency of terrace morphologies across profiles suggests a regional tectonic control, reinforced by seismic events such as the 2003 Mw 6.8 earthquake [19-22].

The findings highlight the dual influence of plate convergence and sea-level variability on terrace development, offering valuable insights for seismic hazard assessment and coastal management. Future studies integrating high-resolution geophysical data and dating techniques would refine terrace chronology, improving our understanding of long-term landscape dynamics in the western Mediterranean.

REFERENCES

[1] Harris, P.T., Macmillan-Lawler, M., Rupp, J. and Baker, E.K., 2014. Geomorphology of the oceans. *Marine Geology, 352*, pp.4-24. https://doi.org/10.1016/j.soildyn.2006.10.002

[2] Whitehouse, P.L., Gomez, N., King, M.A. and Wiens, D.A., 2019. Solid Earth change and the evolution of the Antarctic Ice Sheet. *Nature communications, 10*(1), pp.1-14. https://doi.org/10.1038/s41467-018-08068-y

[3] Batouche, T., Dinar, H., Tabet, A., Hadji, R., Zedam, R., & Zerzour, O. (2025). Mitigating environmental impacts of phosphate blasting through optimized techniques in northeastern Algeria. *Euro-Mediterranean Journal for Environmental Integration,* 1-13.

[4] Nocquet, J. M., and Calais, E. 2004. Geodetic measurements of crustal deformation in the Western Mediterranean and Europe. *Pure and applied geophysics, 161*(3), pp.661-681. https://doi.org/10.1007/s00024-003-2468-z

[5] Selwa, B., Haythem, D., Nouh, R., & Badreddine, S. (2025). Groundwater vulnerability assessment of the Tamlouka Plain using a GIS-based DRASTIC model (Northeast Algeria). *Euro-Mediterranean Journal for Environmental Integration,* 1-17.

[6] Dinar, H., Rebouh, N., Tout, F., Batouche, T., & Mansouri, Z. (2025). Development of an erosion map using geographic information systems (GIS) and based on the hierarchical analytic process (AHP) case study of Boumerdes-Zemmouri, eastern of Algiers. *Analele Universității din Oradea, Seria Geografie, 35*(2), 97-110.

[7] Mansouri, Z., Dinar, H., Belkendil, A., Bakelli, O., Drias, T., Assadi, A. A., ... & Mouni, L. (2025). Integrated Groundwater Quality Assessment for Irrigation in the Ras El-Aioun District: Combining IWQI, GIS, and Machine Learning Approaches. *Water, 17*(11), 1698.

[8] Tout, F., Rebouh, N., Dinar, H., Benzid, Y., & Zouak, Z. (2025). Evaluating Algeria's Approach to Major Risk Prevention and Disaster Response. *Journal of Geography, Politics and Society, 15*(1), 50-56.

[9] Meghraoui, M., Maouche, S., Chemaa, B., Cakir, Z., Aoudia, A., Harbi, A., ... and Benhamouda, F. 2004. Coastal uplift and thrust faulting associated with the Mw= 6.8 Zemmouri (Algeria) earthquake of 21 May 2003. *Geophysical Research Letters, 31*(19). https://doi.org/10.1029/2004GL020466

[10] Rebouh, N., Tout, F., Dinar, H., Benzid, Y., Oudni, A., Khiari, A., & Özgür, N. (2025). Identification of potential groundwater zones using the analytical hierarchical process technique: Case study of the region of Constantine–Northeastern Algeria. *Geomatics, Landmanagement and Landscape*.

[11] Bougrine, A., Yelles-Chaouche, A.K. and Calais, E., 2019. Active deformation in Algeria from continuous GPS measurements. *Geophysical Journal International, 217*(1), pp.572-588. https://doi.org/10.1093/gji/ggz035

[12] Bounif, A., Bezzeghoud, M., Dorbath, L., Legrand, D., Deschamps, A., Rivera, L., & Benhallou, H. (2003). Seismic source study of the 1989, October 29, Chenoua (Algeria) earthquake from aftershocs, broad-band and strong ground motion records. *Annals of Geophysics,* 625-646.

[13] Batouche, T., Tabet, A., Zerzour, O., Hadji, R., Benyoucef, A. A., Moueri, A., & Dinar, H. (2024). Optimizing rock fragmentation in open pit mining: Blasting plan refinement using WipFrag and Kuz-Ram method. *Geomatics, Landmanagement and Landscape*.

[14] Ben, S. K., Ahmadi, R., Bustami, R. A., & Najar, I. A. (2023, March). Numerical investigation of seismic hazard and risk of Murum Hydro-Electric Dam (MHEP). In *International Conference on Dam Safety Management and Engineering* (pp. 855-869). Singapore: Springer Nature Singapore.

[15] Tout, F., Rebouh, N., Dinar, H., Zouak, Z., & Benzid, Y. (2024). The issue of using annual rainfall maps in multi-criteria analysis to identify flood-prone areas. *Geomatics, Landmanagement and Landscape,* (4), 267-278.

[16] Nouali, H., Bouroubi-Ouadfel, Y., Moulla, A. S., Mutlu, H., Vaselli, O., Dinar, H., & Khiari, A. (2025). Hydrogeochemical and isotopic characterization of the El-Tarf geothermal aquifer (Algerian− Tunisian border): Implications of the regional geodynamic structure and the water− rock interactions. *Journal of African Earth Sciences, 223*, 105523.

[17] Haythem, DINAR (2023). Characterization of Quaternary Deposits and Deformations in Eastern Algeria. Case of the Coastal Formations (Doctoral dissertation, University of Batna).

[18] Heaton, T. J., Köhler, P., Butzin, M., Bard, E., Reimer, R. W., Austin, W. E., ... & Skinner, L. C. (2020). Marine20—the marine radiocarbon age calibration curve (0–55,000 cal BP). *Radiocarbon, 62*(4), 779-820.

[19] Najar, I. A., Ahmadi, R., Mourad, R., Bendary, N. E., Tang, S., Ahmad, A., & Haris, M. N. F. (2025). Laboratory Investigation of Soil Suffusion Through Particle Size Distribution and Hydraulic Conductivity Analysis. *Iranian Journal of Science and Technology, Transactions of Civil Engineering, 49*(5), 1-19.

[20] Najar, I. A., Ahmadi, R., Bhawani, S. A., Namakka, M., & Ramli, N. H. (2025). Impacts of oil spill on geotechnical properties of soil. In *Biobased Materials and Their Composites for Oil Spill Treatment* (pp. 39-51). Singapore: Springer Nature Singapore.

[21] Najar, I. A., Bhawani, S. A., Bhat, A. H., Ahmadi, R., Tang, S., Khalik, Y. K. A., & Najar, N. A. (2025). Biodegradable Waste Sorbents for Oil Spill Treatment. In *Biobased Materials and Their Composites for Oil Spill Treatment* (pp. 77-90). Singapore: Springer Nature Singapore.

[22] Ahmadi, R., Ahmad, A., Abdullahi, A. F., Najar, I. A., & Muhamad Suhaili, M. H. A. (2019). A Framework on site-specific probabilistic seismic hazard assessment of Tabung Haji Hotel and convention centre in Kuching, Sarawak, Malaysia. In *4th World Congress on Disaster Management-IIT Bombay* (pp. 1-10).