

Earthquake Catalog Compilation and Filtering for Seismic Hazard Assessment in Egypt

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1. Introduction

The Arab Republic of Egypt, located in North Africa and bordered by the Mediterranean Sea, Sudan, Palestine, and Libya, is a nation with a deep historical legacy and critical modern infrastructure. Although generally considered a region of moderate seismic activity compared to high-hazard zones such as Japan or Indonesia, Egypt has experienced several significant earthquakes throughout its history. Notable events include the 1992 (M_w 5.8) Cairo earthquake, which caused considerable damage and loss of life [1], the 1995 M_w 7.2 Gulf of Aqaba earthquake, the largest in Egypt since 1900 [2], and the 1998 (M_w 5.5) El Dabaa earthquake [3]. More recently, the Gulf of Aqaba experienced earthquakes in 2015 (M_w 5.6) and 2016 (M_w 5.3), highlighting that seismic hazards remain a real and pressing concern [4]. The risks associated with these events are magnified by the presence of critical infrastructure such as the El Dabaa Nuclear Power Plant (NPP), currently under construction on the Mediterranean coast, and future nuclear and energy projects planned across the country. Ensuring the seismic safety of such facilities is of utmost importance for Egypt's long-term resilience and energy security. The location of the El Dabaa NPP and the epicenters of past significant earthquakes are shown in Fig. 1.

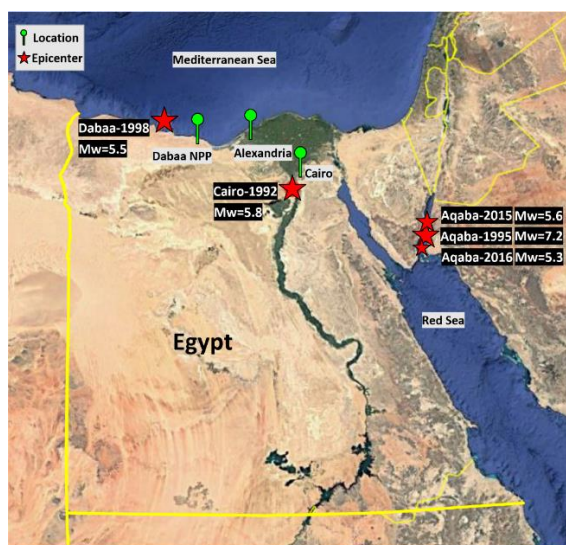


Fig. 1. The locations of El Dabaa NPP and the epicenters of past significant earthquakes.

Seismic Hazard Analysis (SHA) provides the scientific framework necessary to evaluate the potential ground shaking expected at a given site. For nuclear facilities, this is typically carried out through Probabilistic Seismic Hazard Analysis (PSHA), which incorporates uncertainties in earthquake sources, magnitudes, and ground motion prediction equations (GMPEs). PSHA plays a vital role in multiple aspects of nuclear safety, from site evaluation and safety reviews to seismic probabilistic risk assessment and the development of seismic design criteria. Through these applications, PSHA ensures that nuclear structures, systems, and components are designed to withstand earthquake-induced forces, thereby safeguarding critical infrastructure and public safety.

The work presented in this paper integrates two detailed research stages conducted on earthquake analysis across Egypt, each focusing on a key component of the PSHA process. The first stage involved the compilation of a preliminary earthquake catalog that brought together both historical and instrumental seismicity data, establishing the foundation for subsequent analyses. This dataset was then refined through filtering, which removed duplicate events to ensure that the catalog represented an accurate and reliable record of seismicity in the region.

This study provides critical datasets to support the seismic resilience of the essential infrastructure such as the El Dabaa NPP. Ultimately, this work lays the foundation for improved seismic risk management and disaster preparedness, contributing to the long-term safety and sustainability of Egypt's energy and development strategies.

2. Methods and Results

2.1 Earthquake Catalog Compiling

The geographical scope of the preliminary earthquake catalog is limited to within 400 km of mainland Egypt. This distance limitation is because the more famous GMPEs, specifically those from the Pacific Earthquake Engineering Research Center Next Generation Attenuation West 2 programs have a recommended site-to-source distance limit of about 400 km [5,6]. For Egypt, this zone is approximated by 21° E to 41° E and 18° N to 36° N. A map showing approximate distance limits from seismic stations is shown in Fig. 2.

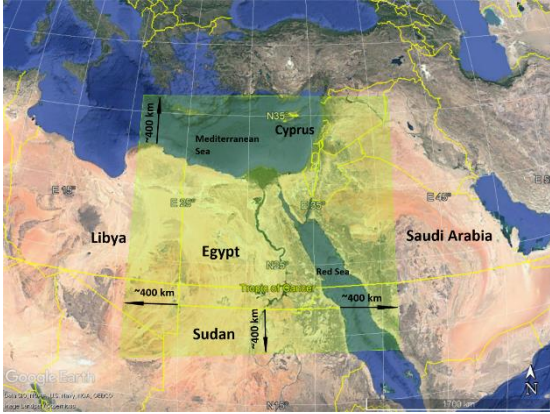


Fig. 2. Map of the study region. Geographical limits of about 400 km away from mainland Egypt as the search area for earthquake event data is shown in yellow.

In terms of temporal limitations, the investigation can only go as far back as the records allow. However, USNRC regulations stipulate only capable faults be considered for PSHA, outlining a limit of 500,000 years. Therefore, this investigation will use that time limit as a guideline. Investigations via paleoseismology will not be performed for this study. Earthquake data are sourced from various seismic monitoring agencies with a bias towards data derived from centroid moment tensor (CMT) inversion techniques [7,8,9]. The CMT method is based on the linear relationship between the six independent elements of a moment tensor describing the earthquake source and the elastic vibrations generated by the earthquake.

Given that most of the instrumented networks submit their data to the International Seismological Centre (ISC), the preliminary catalog compiles events listed in the ISC Reviewed Bulletin [10,11]. This includes results from GCMT, ISC-EHB, and ISC-GEM [12]. For completeness, Egypt historical catalog is also included [13,14,15]. The available local data by the Egyptian National Seismic Network (ENSN) is also be used.

At a minimum, the preliminary earthquake catalog includes information regarding time and location of the event, recorded magnitudes or intensities per event, sources of information, and identifiers for duplicate events. For this catalog, duplicate events are events whose recorded times were within 60 seconds of each other and estimated epicentral distances were within 110 km of each other.

The preliminary catalog contains a total of 43,266 events, including duplicates. Spatially, most earthquakes are concentrated offshore, particularly along the northern and eastern margins of Egypt, while the southern Sinai region also exhibits significant seismicity. These distributions are shown in Fig. 3.

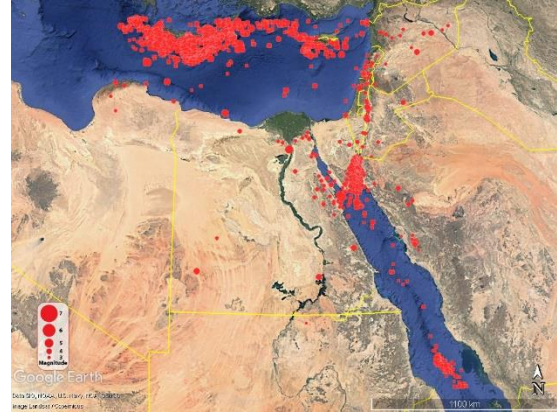


Fig. 3. Earthquake epicenters of the preliminary earthquake catalog shown in red.

2.2 Filtering the preliminary Earthquake Catalog

A key challenge in compiling catalogs from multiple agencies is the identification of duplicate entries. Such duplicates often arise when the same event is recorded by different networks, typically with slight variations in origin time, location, or magnitude. To avoid artificially inflating seismicity rates, a structured duplicate detection procedure was implemented, consistent with the methodologies described by [16]. In their study, events occurring within 60 seconds and 110 km of one another were considered duplicates, and additional issues such as magnitude homogenization and hierarchical criteria for event selection were also highlighted.

The preliminary catalog initially comprised 43,266 events. Following the application of filtering criteria, 4,118 events were removed. The resulting dataset consists of 39,148 unique events, providing a consistent and reliable basis for further analysis.

3. Conclusions

In this study, earthquake data from international and domestic sources were compiled to construct a comprehensive preliminary catalog for Egypt. The dataset integrates global catalogs such as GCMT, ISC, EHB, and GEM, alongside historical records documenting mainland events as early as 2200 BC. In total, the preliminary catalog contains 42,921 events spanning 2200 BC to 2024 and covering an area within 400 km of Egypt's borders.

Through the application of rigorous filtering criteria, the earthquake catalog was consolidated to 39,148 unique events, a reduction of approximately 10%. This refined dataset ensures a high level of consistency and reliability, thereby establishing a robust basis for site-specific evaluations, probabilistic and deterministic seismic hazard assessments, and the design of resilient infrastructure. Such advancements contribute to enhancing seismic safety in Egypt's moderate seismic environment.

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