The Moroccan Earthquake and Nature-Induced Disasters

By GGN Working Group for Geohazards

Introduction

The earthquake that struck Morocco on the night of September 8 2023 23:11 (local time) was the first experienced for many of the participants of the 10th International Conference of the Global Geoparks Network (GGN). Although the epicenter of the earthquake (the projection of the earthquake focus on the earth surface) was about 75 km away from Marrakech, the venue of the conference, the tremor was so strong that in many hotels where the participants were staying, cracked walls and pillars, while in the old city, some walls destroyed and few buildings totally collapsed. Several groups of participants had to change hotels due to the damages. It is fortunate, however, that none of the participants was injured. As of September 18, the total number of deaths exceeded 2,900, while more than 5600 were injured. Many of them are residents of the mountainous areas in the High Atlas Mountains near the epicenter of the earthquake. We pray for the souls of the victims.

The Global Geopark Network has formed a working group for Geohazards, in which representatives of regional networks are participating. We have been working on risk reduction of natural disasters that each Geopark region may face and exchanging the information. Last year, on the International Day for Disaster Risk Reduction, the activities of each regional network were introduced through the United Nations website. Regarding the Moroccan earthquake that we experienced, it is important to share our knowledge and experiences with the Geopark community. We would like to take this opportunity to suggest that all Geopark stakeholders understand the important link between natural hazards and Geoparks and that all stakeholders take action to mitigate disasters.

Under this view we have collected some information and data related with the M6.8 Morocco Earthquake and we would like to share it with all of you to better understand the specific hazard, its risk and the disaster that has caused.

The main features of M6.8 Earthquake in Morocco

The 8 September, Oukaïmedene Earthquake (named by the USGS), occurred within the African plate in the High Atlas Mountains (Fig. 1). This location is approximately 500 km south of the Eurasian-Africa (Nubian) plate boundary, where the African plate is slipping laterally against to the Eurasian plate at a rate of 3.6 mm/y towards the west to southwest. This lateral slipping and simultaneous convergence of the both plates create a large number of thrust faults in the east-west direction (Fig. 2). The earthquake had the epicenter approximately 75 km southwest of the city of Marrakech and occurred at 10 to 30 km depth. The earthquake was strongly felt throughout northern Morocco and also in Portugal and Spain (Fig. 3). The recorded intensity was very strong (8 on the Modified Mercalli Intensity, MMI) in the High Atlas Mountains and moderate (MMI 6 to 6.5) in the city of Marrakech. This earthquake was caused by the displacement of a large surface (fault plane) of about 60 km^2 that moved instantaneously during the earthquake development (Fig. 4). Studies of USGS and INGV (https://earthquake.usgs.gov/earthquakes/eventpage/us7000kufc/finite-fault; https://ingvterremoti.com/2023/09/13/marocco_insar/) indicate that vertical displacement of the upper part of the fault plane is at about 1.7 m, but the displacement is not expressed near the earth’s surface. Analyses using satellite images, which show how the earth's surface was displaced by the earthquake, and the distribution of aftershocks, which are smaller earthquakes following the main (largest) earthquake, indicate that this earthquake occurred along the northwest-trending Tizi’N’Test thrust with the fault plane gently dipping to northwest (TTF in Fig. 2). This thrust is very old and was active since the breakup of Pangaea, hundreds of millions of years ago, but most scientists believed it was not an active fault.

By 14 September, EMSC (Euro-Mediterranean Seismological Centre) had recorded about 200 aftershocks, but only four aftershocks of M3 or greater, including a M4.9 aftershock that occurred only 20 minutes after the main shock (https://earthquakeinsights.substack.com/p/tracking-updates-on-the-morocco-earthquake).

The earthquake had several side effects that magnified the impact of the disaster. The most serious are related to massive landslides and rockfalls in mountainous areas, which hampered access in many of the affected villages. The town of Adasir, with a population of 7,000, was reportedly actually swept away by a landslide.

The broader area around the High Atlas Mountain – Marrakech hasn't experienced such a big earthquake before. The USGS database show no earthquakes larger than M5.9 in an area of 500 km^2 around the epicenter since the 1900. The closest was the 1960 M5.9 Agadir Earthquake that killed 12000 to 15000 people in the coastal areas, while earthquakes of M6.4 happened further north. Thus, this earthquake appears to the strongest earthquake recorded in Morocco in centuries.

The impacts on buildings

The impact on the community differs based on the distance from the epicenter, the topography and local geology of the area, the engineering design of the buildings, the suitability of the sites, the integrity of old buildings or non-engineered buildings, and so on.

Marrakesh is located in the lowlands, and being about 75 km from the epicentre, buildings are still intact or lightly damaged, except for part of the old residential area in the old town (Fig. 5). Engineered buildings, only suffered minor, non-structural damage, and only cracks between buildings or between columns and walls. Relatively old houses, especially non-engineered buildings, suffered from partial wall collapse or collapse of towers or roofs to total destroy. The number of deaths and injuries was quite low.

On the other hand, in mountainous areas, especially villages close to the epicenter, houses and buildings were destroyed or badly damaged. Some of the factors that caused damages are the design of houses made of bricks without structural pillars, according to local standards, not considering earthquake shaking, and being very old. Many buildings that were built in sloping areas were destroyed or badly damaged due to landslides or rockfalls. A brief survey along the valleys of the High Atlas Mountains, from Ourika to Siti Fadma, about 70 km ENE from the epicenter, shows many rockfalls causing severe damage to buildings or blocking roads (Fig. 6).

Our solidarity and recent natural hazards

The GGN Executive Board issued on 11 September 2023a declaration for the 10th International Conference of Global Geoparks Network , expressing its condolences to the victims of the earthquake, thanking those involved in the management of this conference for their prompt and safe response immediately after the earthquake, and appealing for solidarity and unity of Global Geoparks, while staying close to the Moroccan people.

In recent years, global warming has led to the frequent occurrence of natural hazards such as frequent hurricanes, torrential rains, melting glaciers, and desertification due to extreme weather events. Natural hazards caused by the Earth's interior, such as earthquakes, tsunamis, and volcanic eruptions, also continue to occur. These natural hazards have caused disasters in many parts of the world, including UNESCO Global Geopark areas, such as frequent landslides, large-scale floods and forest fires, droughts, heat waves, and water shortages. In addition, there are more and more cases where these natural hazards are interrelated or cause compound or cascading disasters.

Geoparks are intended to enjoy, protect, and utilize the geomorphological and geological heritage that is the living proof of the Earth. For this purpose, it is necessary to understand the history of the Earth and the relationship between humans and nature and the environment in the past. Therefore, it is imperative to understand as much as possible about the mechanisms of nature induced disasters, of either geophysical or by global change origin and to prepare for them.

Our proposal from GGN working group on Geohazards

In addition to the International Geodiversity Day on October 6, International Day of Disaster Risk Reduction on October 13 is another important event for the Geopark community. The Day’s theme aligns with the Sendai Framework (2015-2030), which is the international agreement to prevent and reduce losses in lives, livelihoods, economies and basic infrastructure. The Sendai Framework is positioned in the SDGs as a key element to minimize human suffering from natural disasters and support sustainable development. The strategy of GGN is celebrating and promoting the related activities for the international days in cooperation with Geopark communities worldwide.

The GGN Working Group for Geohazards supports the international day on October 13 and will lead the Geoparks community to intensify its activities for disaster mitigation. Let's work with residents to understand the history and risks of natural hazards in each Geopark area and prepare for future disasters utilizing the Geoparks network through any possible means such as education and awareness activities for nature induced disaster mitigation, and possibly organize evacuation drills in the community and on tours.

(S. Nakada, C. Fassoulas and I. Komoo, 23 September 2023)

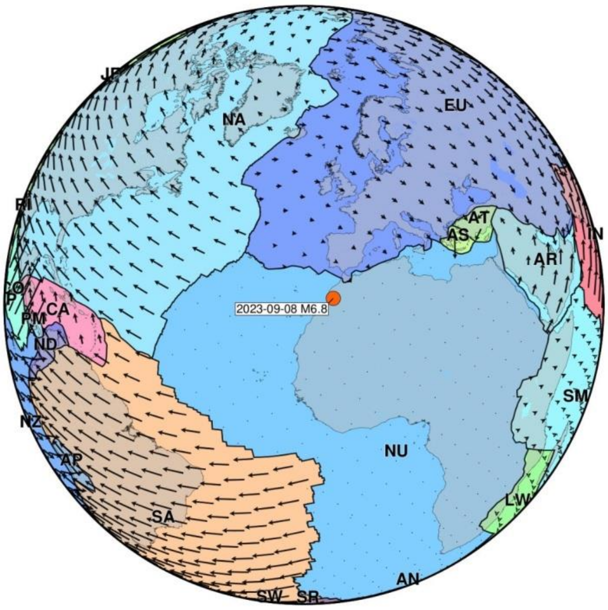

Fig. 1: The Earthquake epicenter and the plate boundaries on the globe. Relative motions to the African plate are shown as vectors (©USGS)

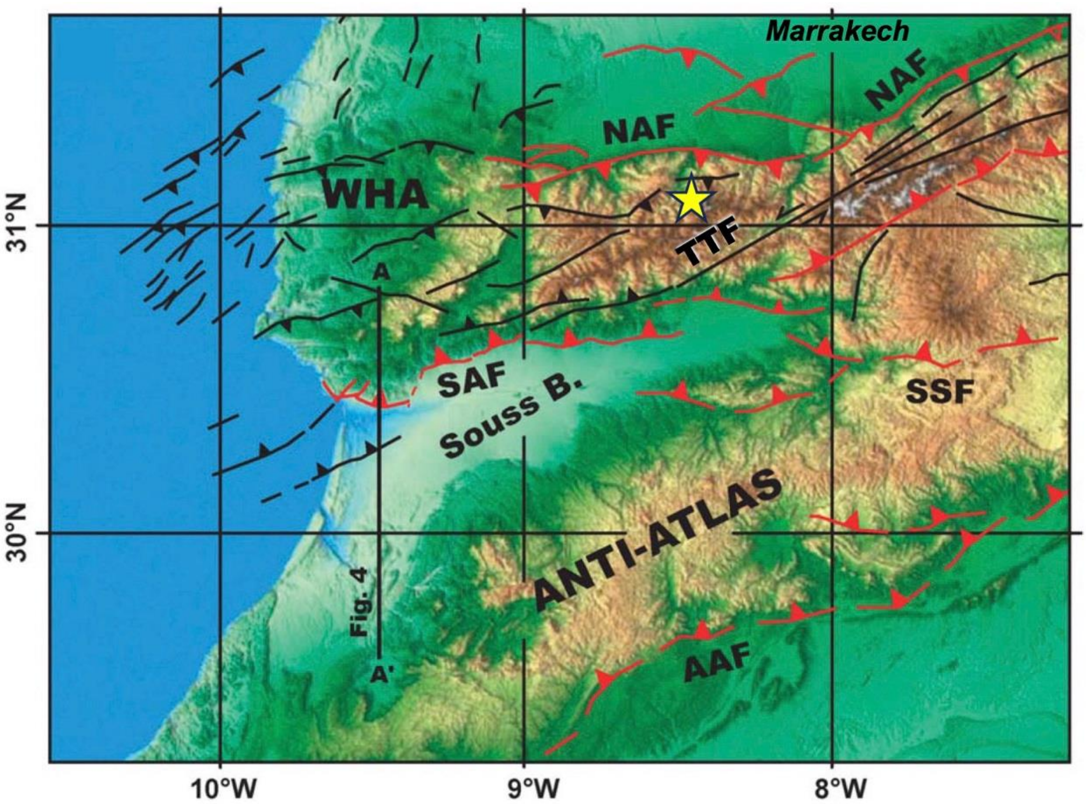

Fig. 2. The fault system in the western part of the High Atlas Mountains (WHA) and its southwestern branch (Anti-Atlas) and the epicenter of the 8 September Earthquake (yellow star). TTF: Tizi’N’Test Fault, NAF: North Atlas Fault, ASF: South Atlas Fault, SSF: South Siroua Fault, AAF: Anti-Atlas Fault. Lines with arrow-heads are thrust faults; red, active faults. Additions to Fig. 3a in Sébrier et al. (2006) C. R. Geoscience, 338(1-2), pp.65-79. https://doi.org/10.1016/j.crte.2005.12.001.

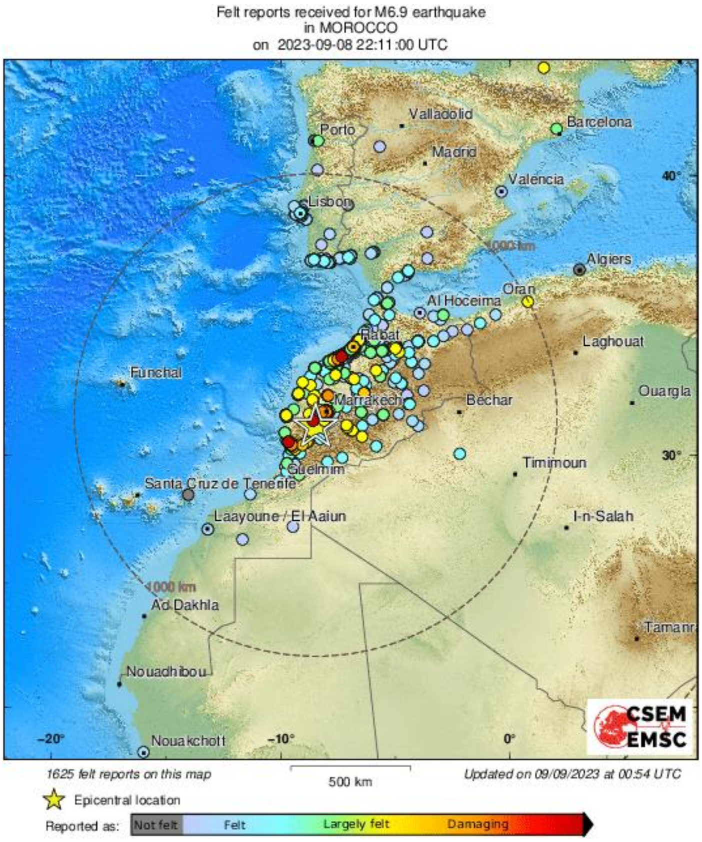

Fig. 3 Map showing felt reports from EMSC regarding the 8 September Earthquake.

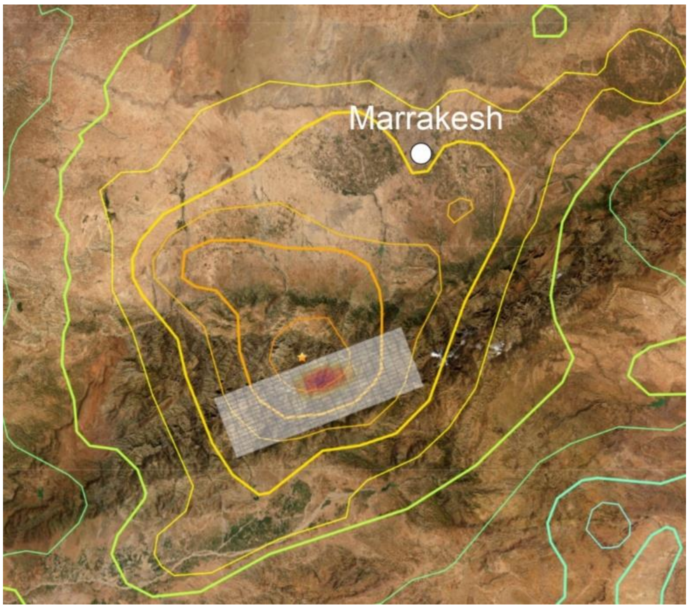

Fig. 4 The intensity contours and the displaced fault plane (white rectangle) projected on the Earth's surface of the 8 September Earthquake. The colored portion in the rectangle represents the displaced area. The model by USGS (https://earthquake.usgs.gov/earthquakes/eventpage/us7000kufc/finite-fault).

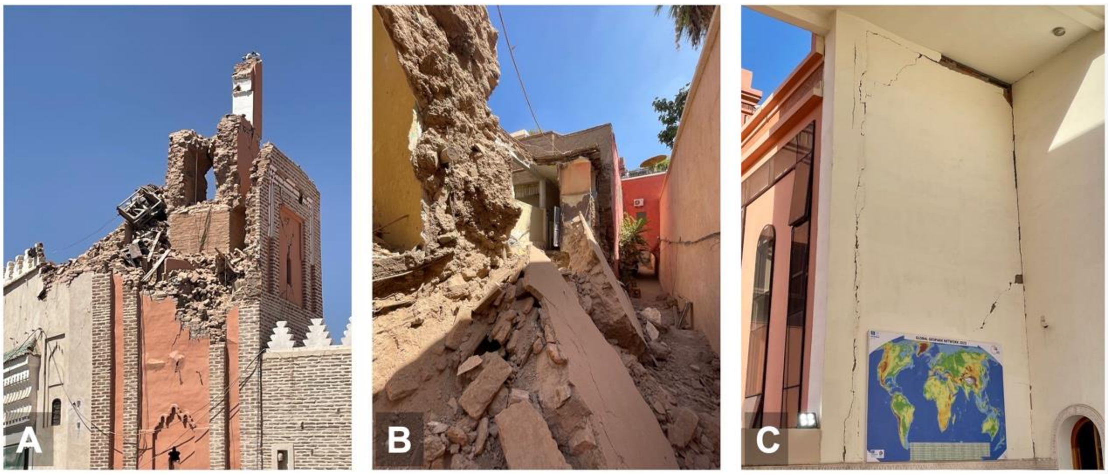

Fig. 5 Impacts of the 8 September Earthquake on buildings in Marrakech. A) Collapsed building top in the plaza, Djemaa el Fna, in the old town (11 September 2023). B) Collapsed house in the residential area (Rue de la Bahia) of the old town (11 September 2023), C) Cracked wall of the Geopark 2023 conference hall, Complexe Culturel et Administratif des Habous (10 September 2023).

Fig. 6. Impacts of the 8 September Earthquake in the High Atlas Mountains. A) Boulders blocking a road (probably near Okimden about 40 km S of Marrakech, 11 September 2023). Sorce: Maroc Defender (@Empirechrifien1). https://twitter.com/Empirechrifien1/status/1700845696864117238. B and C) Landslide deposit (aggregation of rock blocks) that destroyed buildings, photographed along the canyon from Ourika to Siti Fadma (11 September 2023).