Strong Algerian Earthquake Strikes Near Capital City

On 21 May 2003, a damaging earthquake of Mw 6.8 struck the region of Boumerdes 40 km east of Algiers in northern Algeria (Figure 1). The main shock, which lasted ~30–40 s, had devastating effects and claimed about 2300 victims, caused more than 11,450 injuries, and left about 200,000 people homeless. It destroyed and seriously damaged around 180,000 housing units and 6000 public buildings with losses estimated at $5 billion. The main shock was widely felt within a radius of ~ 400 km in Algeria. To the north, the earthquake was felt in southeastern Spain, including the Balearic Islands, and also in Sardinia and in southern France.

The main shock location, which was calculated at 36.91°N, 3.58°E (15 km offshore of Zemmouri; Figure 1), and the local magnitude (Ml 6.4) are from seismic records of local stations. International seismological centers obtained Mw 6.8 (NEIC) with a thrust focal mechanism solution and 1.83 x 10^4 dyne cm for the seismic moment. A sequence of aftershocks affected the epicentral area with two strong shocks reaching Ml 5.8 on 27 and 29 May 2003. Field investigations allowed us to assign a maximum intensity X (European Macroseismic Scale 98) and to report rockfalls, minor surface cracks, and liquefaction phenomena. The main shock was not associated with inland surface faulting, but one of the most striking coseismic effects is the coastal uplift and the backwash along the littoral of the Mitidja basin.

The Zemmouri earthquake is among the largest recorded events in North Africa. The heavy damage and death toll can be explained by the large magnitude, the poor quality of the constructions, and site amplification effects. The Zemmouri earthquake (21 May 2003) and its aftershocks caused extensive destruction in coastal cities and villages located along the coast, either by surface faulting and rockfalls, or by liquefaction of sand and sliding of river banks. The highest damage was in Boumerdes and Zemmouri El Bahri, where more than 100 buildings suffered “pancake” collapse, while in El Asnam and El Boulaouane, minor cracks, fissures, and small landslides were observed. The Zemmouri earthquake generated severe damage in areas and along the coast, with a maximum of 0.80 m between Boumerdes and Zemmouri El Bahri, suggesting a vertical deformation with possible fault emergence several kilometers offshore.

Surface and Macroseismic Effects

Horizontal ground deformations and rock falls, landslides, and liquefaction were observed between Bordj El Bahri and Delflys and mapped soon after the mainshock, the zone of maximum damage. Minor cracks, fissures, and small landslides were distributed parallel to the coastal cliff along a 10 km distance. Various geological and hydrological effects were also observed: altered flow of springs, modified water level in wells, liquefaction, and extrusion of sand and sliding of river banks between Algiers and Delflys. The uplift of individual rocks in the sea and emergence of algae level measured in different places along the coast, with a maximum of 0.80 m between Boumerdes and Zemmouri El Bahri, suggest a vertical deformation with possible fault emergence of a few kilometers offshore.

Macroseismic effects: The earthquake of 21 May generated severe damage in areas and cities and villages located along the coast between Algiers and Tizi-Ouzou, and further south to Bordj Menaiel (Figure 1). Many modern structures suffered “pancake” collapse in which hundreds of people perished. The Zemmouri village was almost completely razed, while other, nearby localities were severely damaged. We attributed an intensity X (European Macroseismic Scale 98) to the area between Delflys and Bordj El Bahri. Isoseismal of intensity X is localized (see Figure 1) and can be interpreted as probably due to the nature of the seismic source, wave path, and shallow depth, and the characteristics of the subsoil—which is generally clay and alluvial deposits—and to the poorly engineered recent building stock. The main shock of 21 May triggered a tsunami with damaging waves of 1–3 m amplitude along the southern coasts of the Balearic Islands.

The Mitidja basin is part of the Tell Atlas, an east-northeast-trending, fold-and-thrust belt along the plate boundary in North Africa. The Quaternary tectonics, reverse faulting, and related north-northwest-south-southeast compression movements are consistent with thrust focal mechanisms of recent earthquakes that result from the 5–6 mm/yr of convergence of Africa toward Eurasia [Argus et al., 1989]. The Tell Atlas may accommodate 2–3 mm/yr of shortening along the main thrust system of the plate boundary zone [Meghraoui and Doumaiz, 1996]. The Mitidja basin is bordered by the south by the Blida fold-and-thrust system, which corresponds to imbricated southeast-dipping thrust sheets. The northern side of the flat basin is limited by the Sahel active fold parallel to the coast. The fold scarp is probably related to a hidden reverse fault where the westernmost section produced the Mont Chenoua earthquake in 1989 [Meghraoui, 1991] (Figure 1).
the main shock,” a phenomenon probably related to the vertical uplift observed along the coastline. On the other hand, undersea telephone cables were cut at ~45 km offshore from the epicentral area and disturbed the telecommunications link between Europe and several other countries in Asia and the Middle East. This suggests the occurrence of major undersea landslides and turbidite deposits.

Seismological and Geodetic Surveys

A temporary network of 18 three-component, short-period seismic stations and 13 accelerometers was installed soon after the main shock in the epicentral area. In addition, four ocean bottom seismometer stations were installed offshore, and two of them are still in operation. Four stations from the permanent Algerian Telemetred Seismological Network (ATSN) were also used to monitor aftershocks (Figure 3). The aftershock distribution from 21 May to 10 June 2003 is oblique to the coastline and shows no significant surface ruptures were observed inland. Aftershocks are elongated in a northeast-southwest direction oblique to the coastline, and a coastal uplift was observed with an average 0.5 m of vertical movement between Boumerdes and Zemmouri El Bahri. The offshore continuation of the Blida reverse fault system may likely be at the origin of the 21 May earthquake.

The Zemmouri earthquake generated 0.58 g and 0.34 g of maximum acceleration recorded at ~20 and 60 km from the epicenter, respectively. The observed maximum acceleration was fairly well predicted by the seismic hazard evaluation in the Algiers region by Aoudia et al. [2000]. For structures with a 0.25 s (4 Hz) period of vibration in the epicentral area, constructions should have been designed for an acceleration of 0.6 g [Naili and Benouar, 2000]. Unfortunately, the Zemmouri earthquake had an average frequency of 4 Hz and caused the phenomena of resonance for all of the structures in the range of 2–4 stories.

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Fig. 2. Surface effects and damage in the epicentral area are shown. No surface faulting was visible inland. Photos: Upper left, coastal uplift (average 0.5 m) marked by the intertidal zone (white band); upper right, liquefaction features (sand blows); lower left, “pancake” building collapse; lower right, secondary surface cracks.

Fig. 3. Aftershock distribution (gray circles, M>2) from 21 May to 10 June 2003. Open squares show historical seismicity since 1365; open circles show instrumental seismicity since 1900. Stars are mainshock locations of the 21 May 2003 seismic event (Mww 6.8) based on information from seismological centers. Focal mechanism solutions are CMT (Harvard) showing thrust faulting consistent with field observations and uplifted coastline.