



**Research Note**

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# Pre-Seismic Assessing Hazard: Examples of Northern Algeria

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## ABSTRACT

*The study aims to describe the potential seismic tectonic structures and the seismic hazard mapping. The pre-seismic assessing is initiated for two regions belonging to Algerian Maghrebides chain, Constantine area in the East and Relizane area in the West. It is based on the inventory of mainly tectonic structures reported in the bibliography as being active within a radius of 50 kilometers of the both regions. For this purpose, a map of the principal neotectonic structures is established on basis of morphotectonic and structural interpretations of the zones which reveal indices of active tectonics. Then, seismotectonic analysis is carried out by correlation between tectonic structures and historical seismicity. A preliminary seismotectonic zonation is established. The seismic zonation map enlightens seismic source zones and seismic lines; the identified faults and suspected active faults affecting the both areas are modeled as source lines. And the areas marked by diffuse seismicity, are modeled as sources zones; therefore, three seismotectonic provinces have been defined. This preliminary seismotectonic zonation will direct the field work and also the management of data in GIS for quick response to any improvement in the assessment.*

**Keywords:**

Historical seismicity;  
Neotectonic structures;  
Seismotectonic zonation;  
Seismic hazard;  
Maghrebide domain,  
Northern Algeria

## 1. Introduction

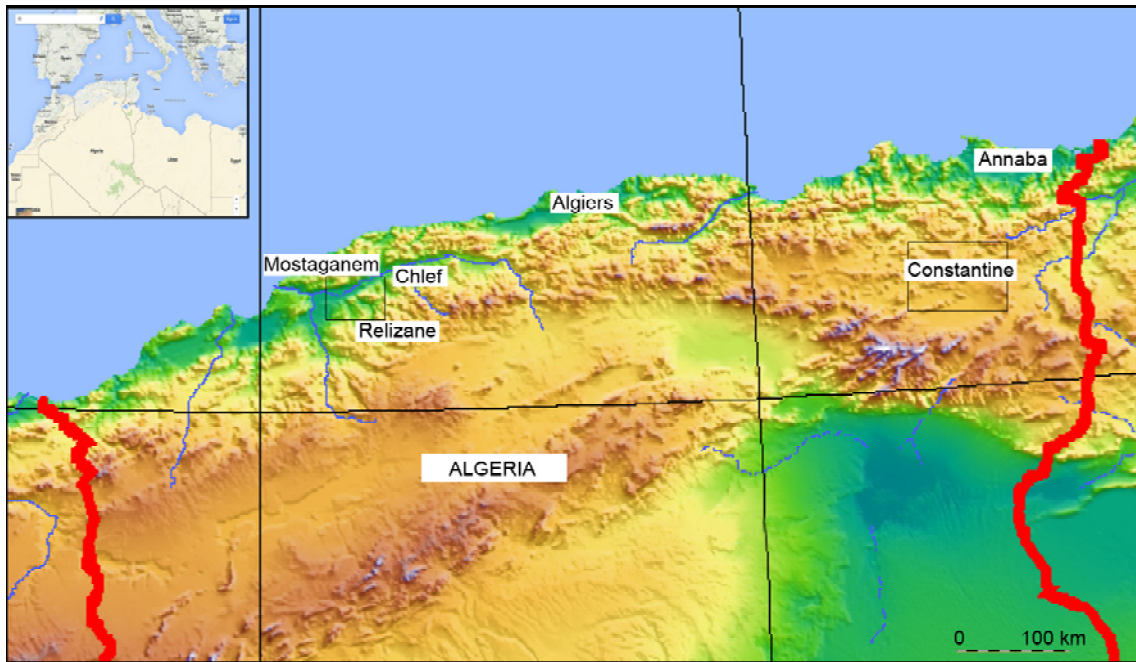
The pre-seismic assessment phase is initialized for two seismic regions of the Northern Algeria, Figure (1). It focuses on mapping of neotectonic structures, mainly faults affecting the Constantine region and Low Chellif Valley (Relizane area), around 50 km. These two regions are characterized by low to moderate seismicity and reveal neotectonic indications. The geometric parameters (direction length, dip) of faults are integrated subsequently in the calculation of the seismic hazard.

The Domain located near tectonic plates boundary, is subjected to seismicity in narrow relation with the tectonic activity affecting the

Western part of the Mediterranean basin. It has been marked by several destructive earthquakes. Except for strong earthquakes which have revealed tectonic evidences such as El Asnam earthquake (1980), Constantine earthquake (1985) and Chenoua earthquake (1989), Ain Temouchent quake (1999) and Boumerdes quake (2003), the majority of earthquakes shocking the northern regions are not associated with the known faults.

## 2. Seismicity Analysis

The active domain of Algeria includes the Tell Atlas characterized by high seismicity, the High Plateaus with low seismicity and the Sahara Atlas

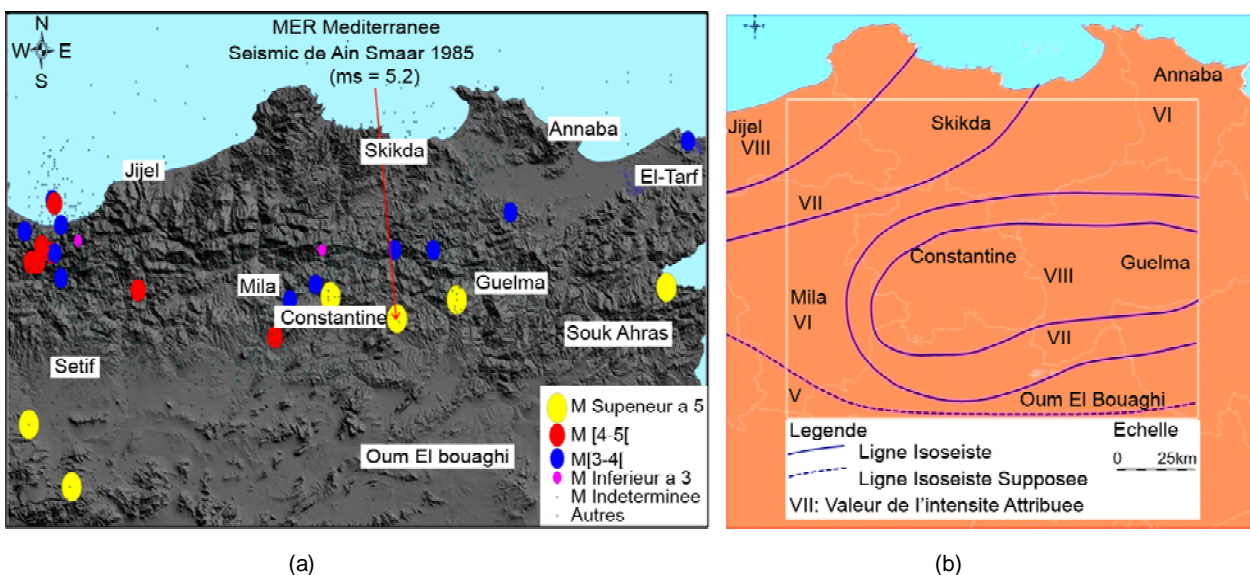


**Figure 1.** Localization of study regions: Low Chellif Valley [ $1^{\circ}$ - $2.5^{\circ}$ E,  $36.50$ - $35.5^{\circ}$ N] Constantine region [ $36.80^{\circ}$ -  $35.90^{\circ}$ N,  $6.12^{\circ}$ - $7.24^{\circ}$  E] (Source: Google Earth) area under square.

marked by seismicity. The two regions selected for this study belong to the first domain and are subjected to moderate seismicity:

Constantine area, during the 18<sup>th</sup> century, was marked by seven small historical earthquakes ( $I_0 \leq V$  MSK). From the 19<sup>th</sup> century to the present, it recorded three earthquakes with Ms 5 [event of the August 4, 1908 Ms 5.2, the event of the August 6, 1947  $M_s \geq 5.0$  and the event of October 27, 1985

with Ms 6.0, one earthquake with Ms 4-5, four earthquakes with Ms 3-4. The historical seismicity map established for Eastern Algeria [ $5^{\circ}$ -  $35.50^{\circ}$ N] on the basis of catalogue of Harbi [1] and on-line bulletins for the period 2010-2012. Indeed, the map reveals mainly three seismic zones in the surrounding area. These are: coastal of Skikda, Constantine-Mila area and Guelma area, Figure (2a). Besides, it is worth noting an important



**Figure 2.** a) Seismicity of Eastern Algeria [ $5^{\circ}$ -  $35.50^{\circ}$ N] on the basis of catalogue of Harbi [1] and on-line bulletin [2-3] for the period 2010-2012. Projection of epicenters /raster image SRTM data, b) Historical maximal intensities map.

concentration of epicenters at sea; more than 500 earthquakes with undetermined magnitudes are registered during the instrumental period. The maximum intensity map reveals E-W isoseismal lines extension with maximal intensity ( $I_0 = VIII$ ) can be attributed to Constantine-Guelma, Figure (2b).

Low valley of Chellif has recorded numerous earthquakes with magnitudes higher than 5. It is the case of Al Kalaâ earthquake, November 29, 1887 magnitude  $M_s = 5.5$  and  $I_0 = VIII$ . Earthquakes of magnitudes  $M_s [3-5]$  are recorded in the North-East of Relizane, it is the example of Inkerman quake in Oued Rhiou on August 24, 1928 with  $M_s = 5.4$ , the strongest earthquake recorded to date. Recently, in May 22, 2014, an earthquake shook Low Chellif valley and a magnitude  $M_s 5.1$  was recorded in Bouguirat area [4].

The historical seismicity map of Low Chellif valley is a compilation of catalogues [2-6], Figure (3a). It covers the period of 1819 to present and indexes 84 events. It reveals a pattern of epicenters in the West of Relizane with magnitudes  $3 < M < 5$ .

The maximum historical intensities map reveals an intensity  $I_0 = VI$  for Relizane. Its surroundings such as Oued Rhiou and Hamadena located in the North-East, El Bordj located in South-West (Mascara area) recorded the maximum of damage following significant earthquakes with a maximum historical intensity of  $I_0 = VIII$ , Figure (3b).

### 3. Neotectonic Setting

The study regions belong to the Algerian Maghrebides located in the South part of Western Mediterranean marge, Figure (4). The convergence

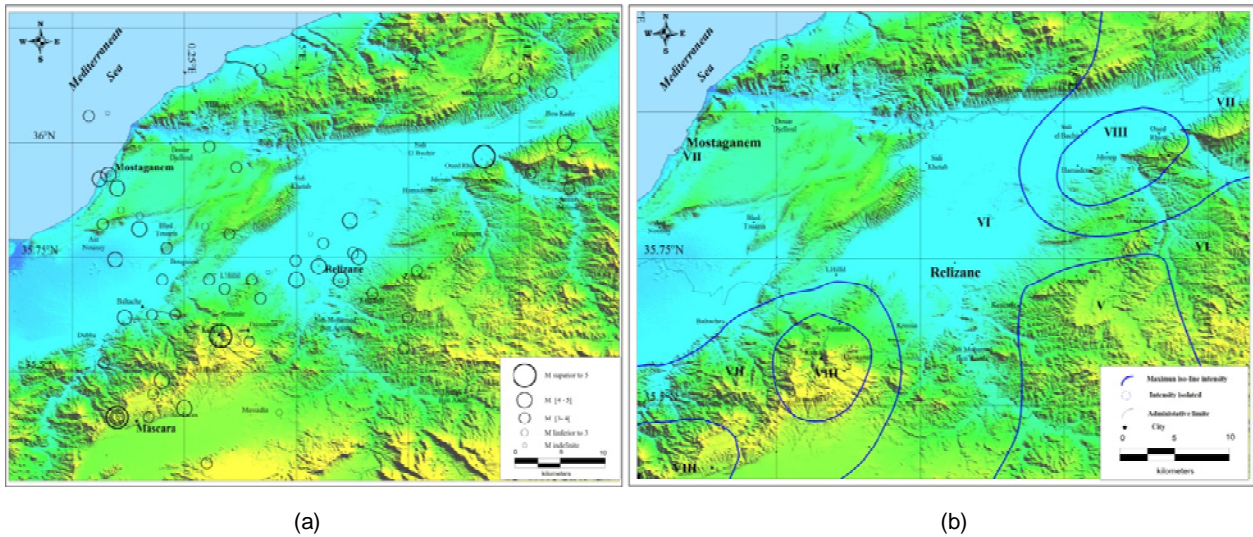


Figure 3. a) Seismicity of Lower Chellif valley based on Worldwide Elevation Data (SRTM) and the online catalog of the ISC and the USGS [2-3]. b) Maximum historical intensities.

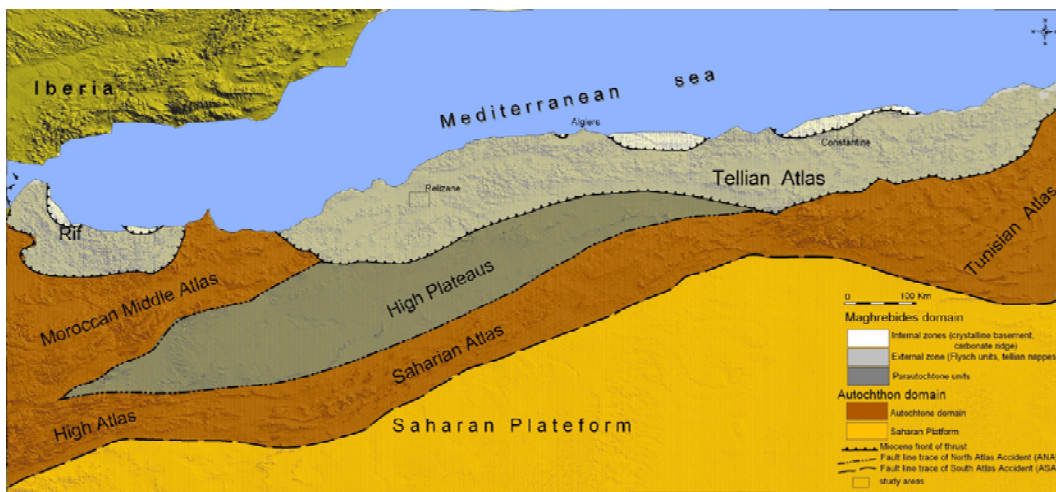


Figure 4. The main geological domains of North of Algeria redraw from [7-8].

has started in the domain since upper Miocene. And also, it registered before by Cretaceous, Eocenes and lower Miocene tectonic phases. The study regions reveal indications of a neotectonic activity and there are marked by NE-SW potentially seismic faults which are associated with NE-SW or E-W anticlines and synclines.

The neotectonics map of Constantine shows from north to south three geological units and their structures, Figure (5):

1. Quaternary deposits,
2. Neogene regroups Miocene post nappes (upper Miocene), volcanic calc-alkaline rocks and Pliocene deposits.
3. Ante-Neogene of internal and external zones of Maghrebides, brings together; allochthonous grounds represented by Socle Kabyle characterized by Paleoproterozoic foliated metamorphic rocks, Dorsale Kabyle or carbonate chain characterized by Jurassic to Eocene-Oligocene deposits, Flyschs Kabyle from Cretaceous to Tertiary, Tellian nappes from Jurassic-Cretaceous to Eocene, the Parautochthon terrains of the High Plateau composed essentially by Jurassic, Cretaceous and Miocene formations.

According to Vila [9], the Alpine tectonic structures correspond mainly to NE-SW, NW-SE system faults, E-W Thrust faults and NE-SW folds. The recent tectonics can be highlighted by

reactivation of certain NE-SW reverse faults and E-W strike-slip faults. It is marked by deformation of Pliocene; near the South Kabyle fault in southern Skikda. This is a segment of a regional miocene fault "Chevauchement Sud Kabyle" separates the internal zones from external zones, and also, near Sigus fault in Oum El Bouaghi plain, Figure (5).

The Lower Chellif valley is limited by the plateau of Mostaganem in the North, the Higher Chellif valley in North-East, and Tell Mountains in the South. The valley is oriented N070 gathers Ante Neogene grounds, Miocene formations and Pliocene and Quaternary deposits. The Plateau of Mostaganem is folded to NE-SW anticlines and affected by a reverse fault about thirty km of length and dip toward NW, Figure (6). The obviousness related to the Quaternary activity in Lower valley is the level of wind gap of Chellif River, where recent clay (probably Holocene) occupies an elevation more than 20 m. Also, older fluviatiles terraces are located around 40 m of elevation relatively to the current level of Mina River in Bel Hacer area (in M2i, 2003). In addition, according to Thomas [10], the sedimentation process of the Neogene and quaternary deposits in Chellif Valley is controlled by major "East-West" dextral faults and by NE-SW reverse and sinistral strike-slip faults.

The plain of Lower Chellif is bordered in North and the South by two tectonic accidents NE-SW:

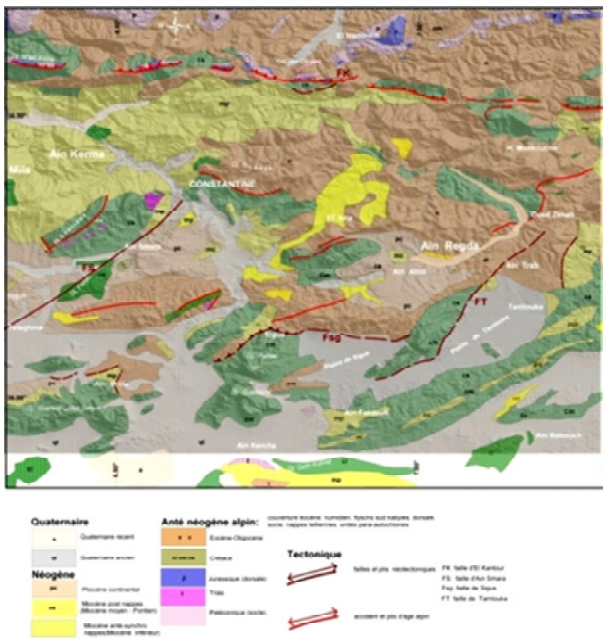


Figure 5. Neotectonic map of Constantine region (on basis: SRTM images and geological map: 1/500.000).

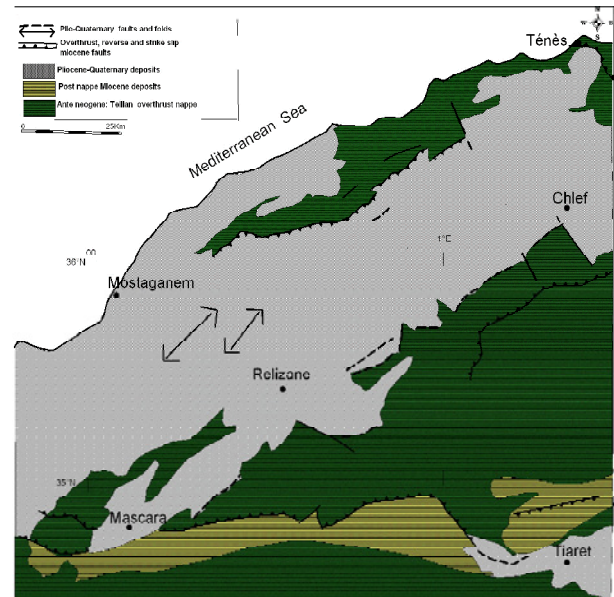


Figure 6. Structural scheme of the Lower Chellif Valley [Realized starting from the geological draft of André Caire [11]].

1. Northern belt composed by Mercier Lacombe-Mostaganem faults (AML), which are revealed on surface by some alignments of folds and saltworks in the plain.
2. Southern belt collected reverse faults; Beni Chougrane fault in western of study zone, Relizane Boukadir, Oued Fodda faults in Chellif valley. The existence of belt is marked by axial inflections of the recent deposits between Mostaganem and Mascara and by the faulting of the Miocene thrust nappe, Figure (7).

**4. Seismotectonic Zonation**

The seismotectonic map contains potentially active faults and seismic zones (Z1, Z2.Z3). The identified active faults and supposed active faults localized on a diameter of 100 kilometers around the study areas are modeled sources lines. The geological domains marked by seismicity and neotectonics deformation are modeled sources zones. Therefore, numerous seismotectonic provinces can be defined: Z1 includes all identified (observables) active faults; Z2 corresponds to the geological province characterized by seismicity and its Neogene is deformed; Z3 corresponds to the geological province characterized by low seismicity and uplift of its older terrains.

The Constantine region is marked by four seismic lines:

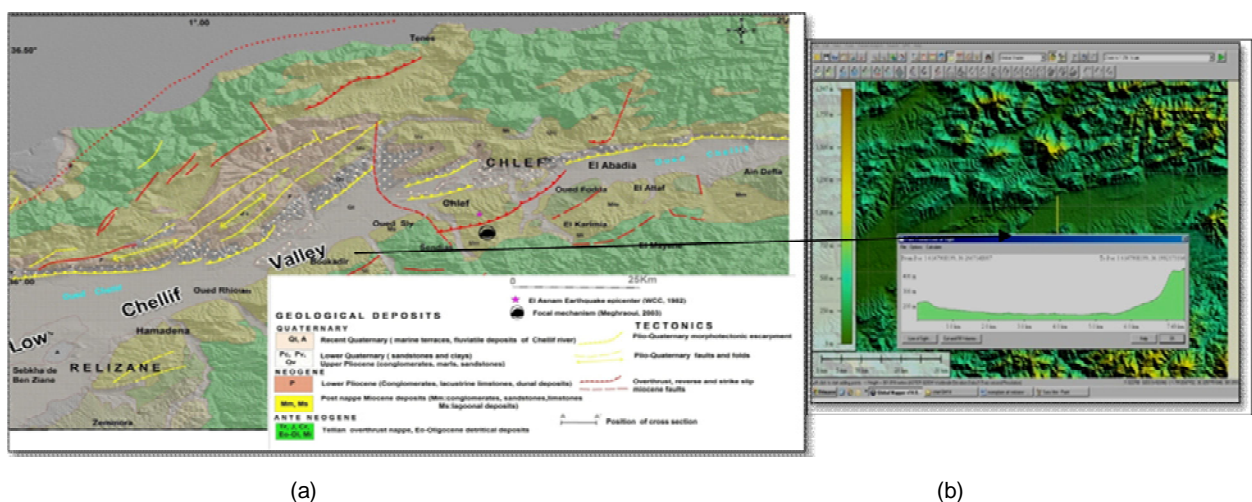
*Ain Smara source* is a NE-SW sinistral strike slip fault with a length more than 50 km. It juxtaposed Eocene-Oligocene flysch with Miocene in the

Northern part, the Quaternary, Miocene with Cretaceous of external zone in centre and southern parts, Figure (8a). The epicenter of the earthquake of October 27<sup>th</sup> 1985 has been localized in Kef tassenga [12], the reactivate segment about 36 Km oriented N060 85°, corresponds to the northern of the Ain Smara fault zone;

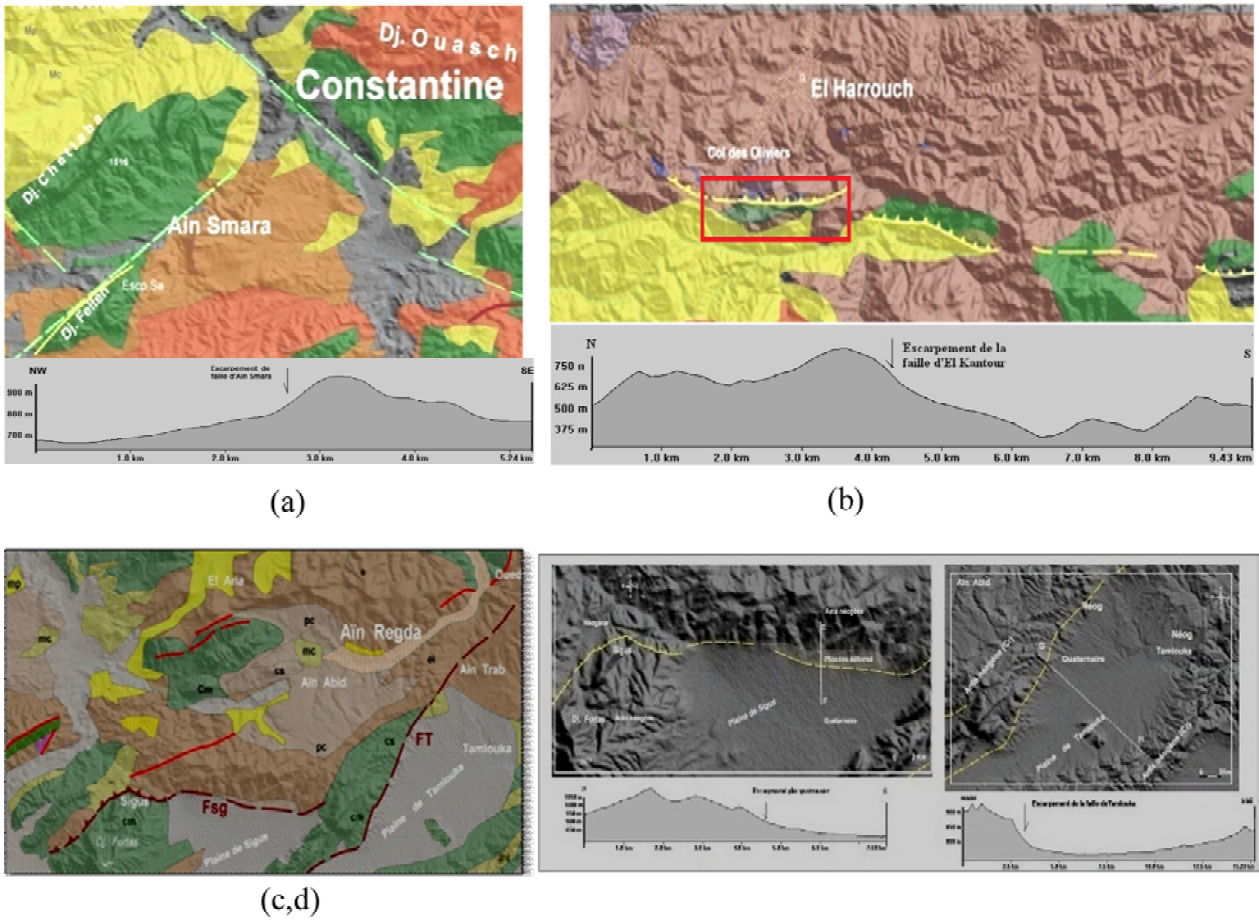
*South Skikda source* is a reverse fault oriented N090 40°N, having a length of 15 km, the fault is connected to E-W regional abnormal contact dipping north where several historical earthquakes with low magnitudes can be associated, Figure (8b);

Tamlouka source is a sinistral strike slip oriented N050 25 NW, Sigus source reverse fault N080 30E; these two supposed active faults border faults separate the Cretaceous massive from underlying Plio-Quaternary plains. Some epicenters can be associated to these faults, Figures (8c) and (8d).

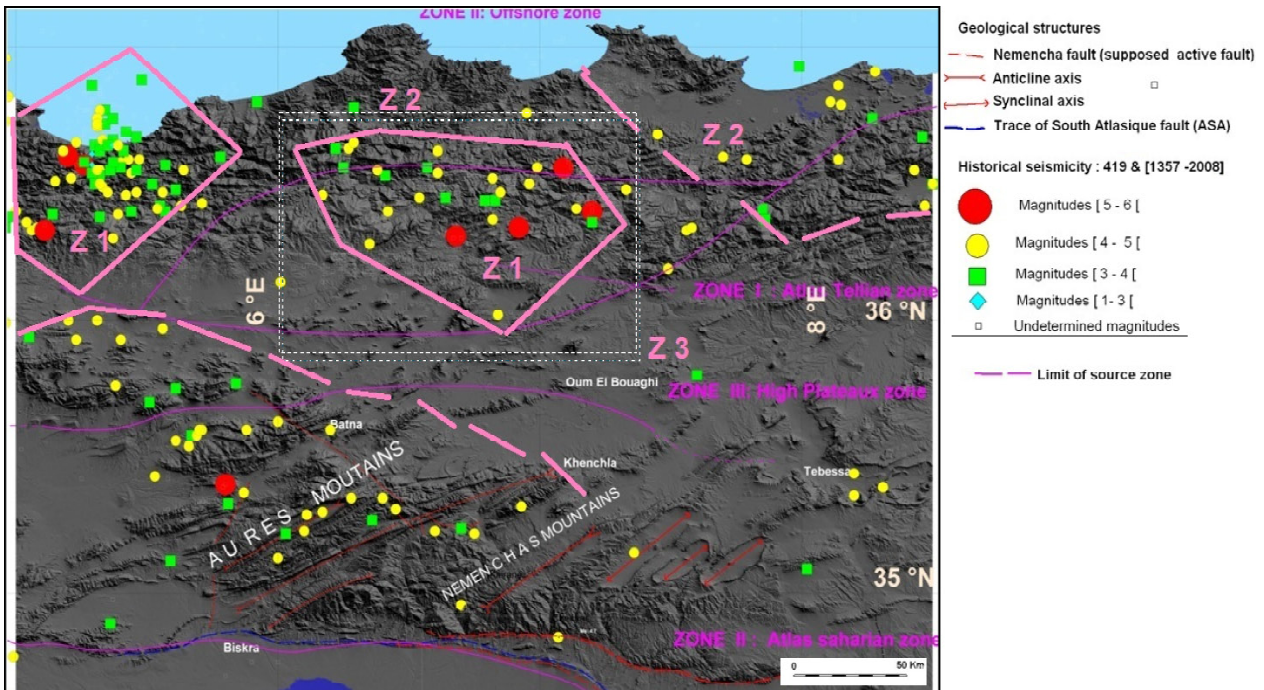
The region is divided into three seismic sources zones; the mainly zone presents a high seismic hazard and corresponds to South Constantine zone, Figure (9). This province (Z1) includes the external Tell of Maghrebides, is oriented globally E-W, encircled in the north by front de nappes and in the south by geomorphological limit of Tamlouka and Sigus basins. The province has registered seismic events with magnitude  $M_s \leq 4.5$ . The north Constantine province (Z2) includes the margin and coastlines massives of Skikda. The province limited in the north by offshore fault and in the south by front de nappes, has registered seismic events with magnitudes  $M_s$  2-4. The High plains province (Z3)



**Figure 7.** Neotectonic map of Chellif region (on the basis of geological map and active fault map) [13]. (b): NS section line (in yellow) shows the scarp of fault Oued Rhiou (Source: SRTM data /Global Mapper-14).



**Figure 8.** The scarps of active faults and supposed active faults in Constantine region: (a) Ain Smara fault visible at the Jebel Felten, (b) South Skikda fault, (c, d) Sigus fault (Fsg) and Tamlouka fault (FT).



**Figure 9.** Sources zones delineating of Eastern Algeria including Babors region [Zone source (Z1): Babors region, South Constantine Zone source (Z2): Offshore-North Constantine region, Zone source (Z3) des High Plateaus and Sahara Atlas]. Under square study region.

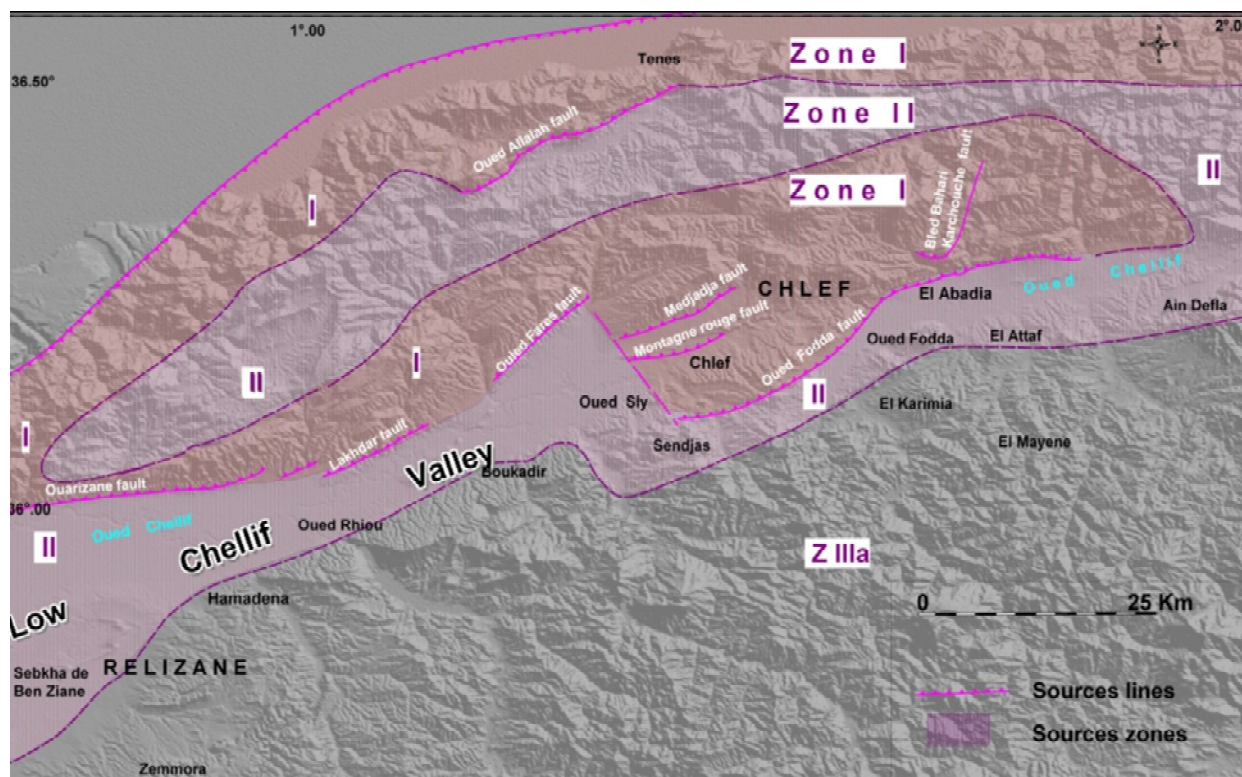


Figure 10. Sources zones delineating of Chellif Valley (redraw from [13]).

characterized by low seismicity collects the high plains and southern post sheets basins (avant-fosse miocène) and limited toward the south by the North Atlantic Accident (ANA).

The Low Valley is marked by two sources lines: Oued Rhiou fault oriented NE-SW and lengthens transversely the plain, Figure (7b). The Boukadir line source corresponds to the faulted fold oriented N050 and it has 30 km of length. These two faults correspond to the central segment of the southern belt. This one belongs to a group of NE-SW reverse faults dip towards North-West. While in the North, this is the northern belt located in sea, very close to the coast, which belongs to reverse faults zone with the same direction dip towards south.

The Valley classed in Zone source II and surrounded by three seismic zones, Figure (10): the Mostaganem source (ZI) localized between the continental plateau and the littoral shows a notable elevation of Calabrien terrace at more than 130 m; moreover, the recent deposits are folded. The zone is characterized by significant seismicity with epicenters in offshore and in Mostaganem littoral. Relizane-Oued Rhiou source (ZII) bordered in North and South by masked faults, gathers the

zone between plain and tellian thrust nappe, and it is characterized by some epicenters with low intensity.

## 5. Conclusion

For assessing seismic hazard of two cases of northern Algeria, we mapped mainly the tectonic structures reported in the bibliography as being active, and we realized historical seismicity map and seismotectonic zoning. For Constantine region, there are four potential seismic sources: Ain Smara fault, which has generated an earthquake ( $M_s = 6.0$ ) in 1985, the South Skikda fault segment of the regional fault and the two border faults Tamlouka-Sigus supposed active faults.

In surrounding Relizane area, there are two potential seismic sources classed probably active faults: Oued Rhiou and Boukadir faults and within the same prolongation in the East, Oued Fodda fault, which has generated El Asnam earthquake ( $M_s = 7.3$ ) in 1980. The zone source of Mostaganem "masked fault" that is characterized by a diffuse seismicity can be coincides with the northern belt, border between the plain and the continental plateau in the sea.

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