INVESTIGATIONS OF EARTHQUAKE HAZARDS IN THE OULED FARES AREA

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SUMMARY

This paper is a preliminary report of geologic investigations in the Ouled Fares area to define the rate of activity of the Ouled Fares fault, an active reverse fault associated with an anticline and having an average slip rate of about 0.12 mm per year. The most recent displacement on the fault appears to have occurred more than 2,000 years ago. Seismic microzoning studies, now underway, suggest that the peak acceleration expected in the Ouled Fares area with a return period of 500 years is about 0.36 g.

GEOLOGIC AND TECTONIC SETTING

Algeria is situated in the African plate. To the north, the Eurasian plate is thought to be colliding with, and being thrust over the African plate. A wide belt of folded mountains (the Atlas Mountains) and a zone of crustal shortening up to 400 km (250 miles) wide is being produced along the collision zone. Reverse faults are the dominant structures in the region and trend east-west to east-northeast (Fig. 1), parallel to the plate boundary and normal to the direction of plate convergence.

A broad zone of shallow seismic activity extends along the north African part of the plate margin. In Algeria, the seismic activity is concentrated in coastal areas and associated with the structural features of the Atlas Mountains (Fig. 2). Three zones of destructive earthquakes in Algeria have been noted: 1) a zone delineated by the towns Oran-Mascara-Relizane, 2) a zone extending from the Massif de Dahra to the Mountains of Hadna and Aures, and 3) a zone corresponding to the line Kerrata-Constantine-Guelma. Destructive earthquakes have occurred in all three zones.

Ech Cheliff (formerly El Asnam) has experienced moderate to large earthquakes at least a dozen times in the past 250 years. The most notable recent earthquakes occurred in 1922, 1934, 1954, and 1980. The major earthquake ($M_s = 7.3$) of 10 October 1980, which struck the Ech Cheliff region, caused extensive damage to buildings and lifeline systems over an area of about 1,000 km^2 and affected to a lesser extent an area of about 10,000 km^2 (Refs. 1-2). About 2,700 people died in the earthquake and losses to buildings and facilities exceeded $1 billion. The epicenter of the El Asnam earthquake was about 10 km (6 miles) east of Ech Cheliff on the Oued Fodda fault system, an active reverse fault that has about 47 km of surface faulting. Although some controversy exists about the location of the 1954 earthquake, many experts believe that it may have also occurred on the Oued Fodda fault system.

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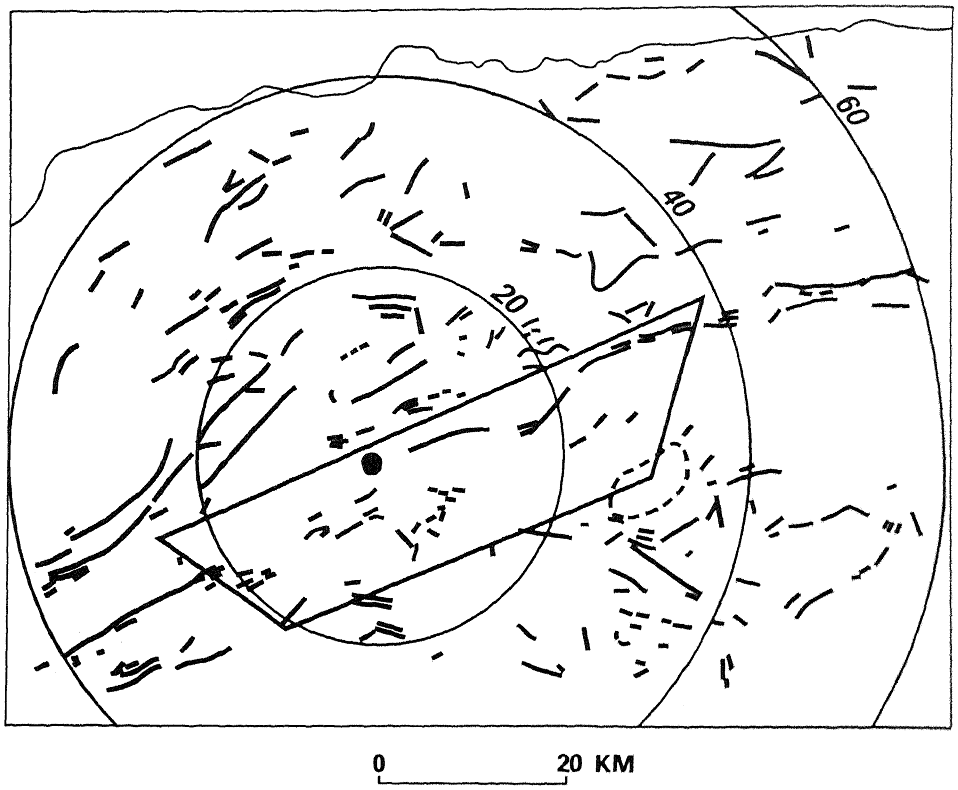

Figure 1.--Map of lineaments in the Ech Cheliff region. Many of the lineaments are active reverse faults. Ech Cheliff is shown by the dot; Ouled Fares is 10 km to the northwest.

SEISMIC MICROZONING STUDY

Seismic microzoning, the division of an urban area into zones expected to experience the same relative severity of ground shaking (or alternately surface fault rupture, tectonic deformation, or earthquake-induced ground failure), was initiated in May 1983 and is underway at this time. The research leading to a better definition of the earthquake hazards in the Ech Cheliff region has preceeded on two scales: 1) a regional scale focusing on the 100 km x 100 km area surrounding the Ech Cheliff region, and 2) an urban scale focusing on the 20 km x 50 km region containing Ech Cheliff, and other urban areas. The seismic microzoning study is scheduled for completion in July 1984. Delineation of individual seismic sources, an important part of seismic microzoning, is being done on the basis of identification of the most important faults (see Fig. 1) and characterization of their seismic potential through geologic mapping, trenching, and age dating. The basic assumption used in delineation of the seismic sources is that most historic surface faulting and other tectonic deformation has occurred in the geologically recent past and has been of a similar nature to that of previous events in the area. The physical parameters of individual seismic sources are defined by integrating geologic studies and historical seismicity.

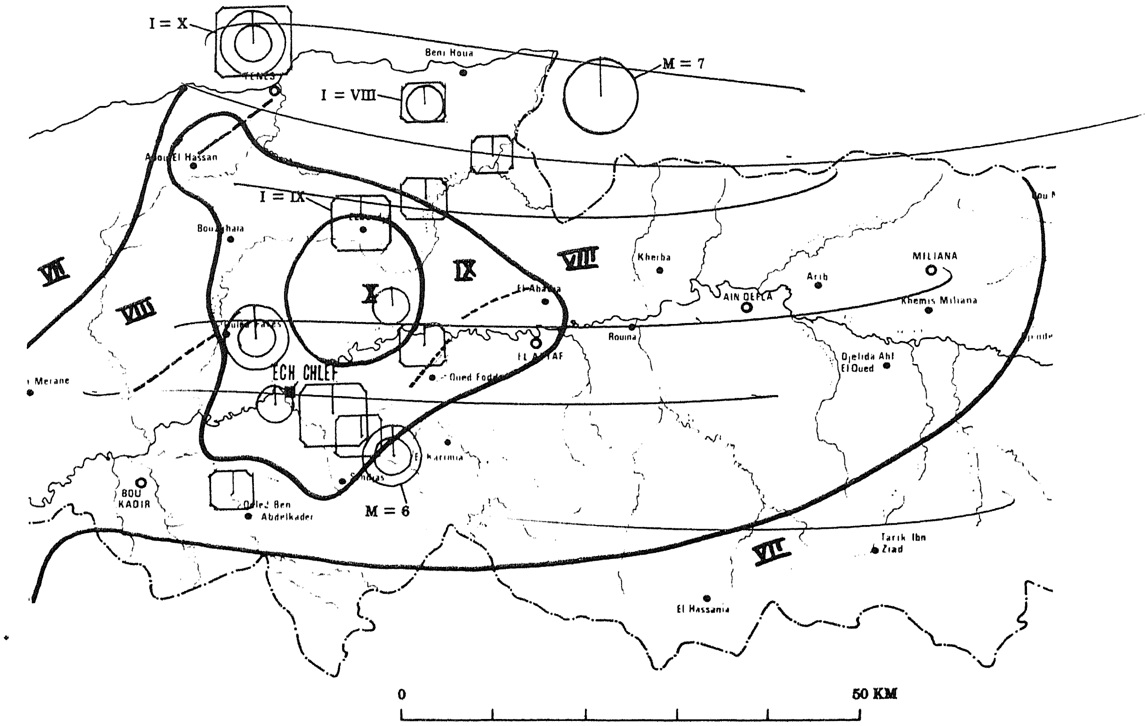

Figure 2.--The map showing Ech Cheliff region and Ouled Fares area. The maximum values of historic intensity are shown as contours. Epicenters of past earthquakes determined instrumentally are shown as circles along with the value of the magnitude. Epicenters shown as squares are preinstrumental and the value of I_0 is shown next to them. Active faults are shown as dashed lines.

CHARACTERIZATION OF ACTIVE FAULTS

Knowing the long-term rate of activity of a fault enables one to make comparisons with other faults, to estimate recurrence intervals for use in constructing probabilistic ground-shaking hazard maps, and to estimate the size of potential future earthquakes. The activity of faults may be classified in terms of the chart below (Ref. 3).

CLASSIFICATION OF FAULT ACTIVITY

CLASS	DESCRIPTION	LONG TERM RATE OF SLIP (S) (MM/YR)
AAA	Extremely high	s greater than 100 mm/yr
AA	Very high	s between 10 and 100 mm/yr
A	High	s between 1 and 10 mm/yr
B	Moderate	s between 0.1 and 1 mm/yr
C	Low	s between 0.01 and 0.1 mm/yr
D	Extremely low	s less than 0.01 mm/yr

The long-term average rate of slip is determined geologically and is based on the total displacement of the unit divided by the age of the unit.

TRENCHING

Recognition of active faults and classification of their activity is a difficult task. When carried out properly, trenching is one of the subsurface methods that can provide the most complete and accurate information on near-surface faulting. As a general minimum, trenches should be excavated to a depth of 4 m and widths of about 1 m. Lengths of trenches vary with local conditions, but should be at least 30 m long in most locations in order to detect tilting or drag, normal irregularities in contacts, variations in thickness of units, and to intersect subsidiary faults.

Trenching has advantages as well as disadvantages. The reliance on trenching for providing accurate information on earthquake recurrence intervals and the identification of significant fault movements involves several implicit assumptions, including:

1. A significant part of the crustal strain involved in generating major earthquakes can be isolated at discrete surface locations.

2. Significant earthquake-generating fault movements duplicate the near-surface pattern of deformation.

3. Near-surface materials around a fault have the potential to be dated and to be preserved for longer periods of time than the recurrence interval of major fault movements.

Greater care is needed when trenching thrust faults, the primary mode of faulting for the modern tectonics of Northern Algeria, than when trenching strike-slip faults. For a given size of fault movement, thrust faults have a reduced chance of causing surface rupture than normal or strike-slip faults. Also some or all of the fault movement at depth may be converted into plastic deformation (folding) of near-surface sediments. For thrust faulting, the movement of rock over the fault creates a dynamically changing near-surface stress system that can divert the course of the fault as it approaches the surface.

PRELIMINARY RESULTS IN THE OULED FARES AREA

The objective of the geologic investigations in the Ouled Fares area was to locate the faults and to obtain information on their ages, types, dimensions, and rates of activity. The investigations ranged from a broad regional examination for increasing understanding of the general tectonic setting to detailed investigations along sections of a fault for attaining site-specific data. Instead of just classifying the faults as active or inactive, an effort was made to estimate the rate of activity, using trenching and other geologic studies.

Trenches excavated in the Ouled Fares area indicated that the Ouled Fares fault is active with a average slip rate of approximately 0.12 mm/yr. The fault is associated with an anticline and is partially buried by Quaternary flood plain deposits. The most recent displacement occurred more than 2,000 years ago. This rate of activity is representative of that determined for other faults in the Ech Cheliff region. These rates can be compared with the rates determined for faults in other regions of the World (Fig. 3). From this chart (Ref. 3), a rate

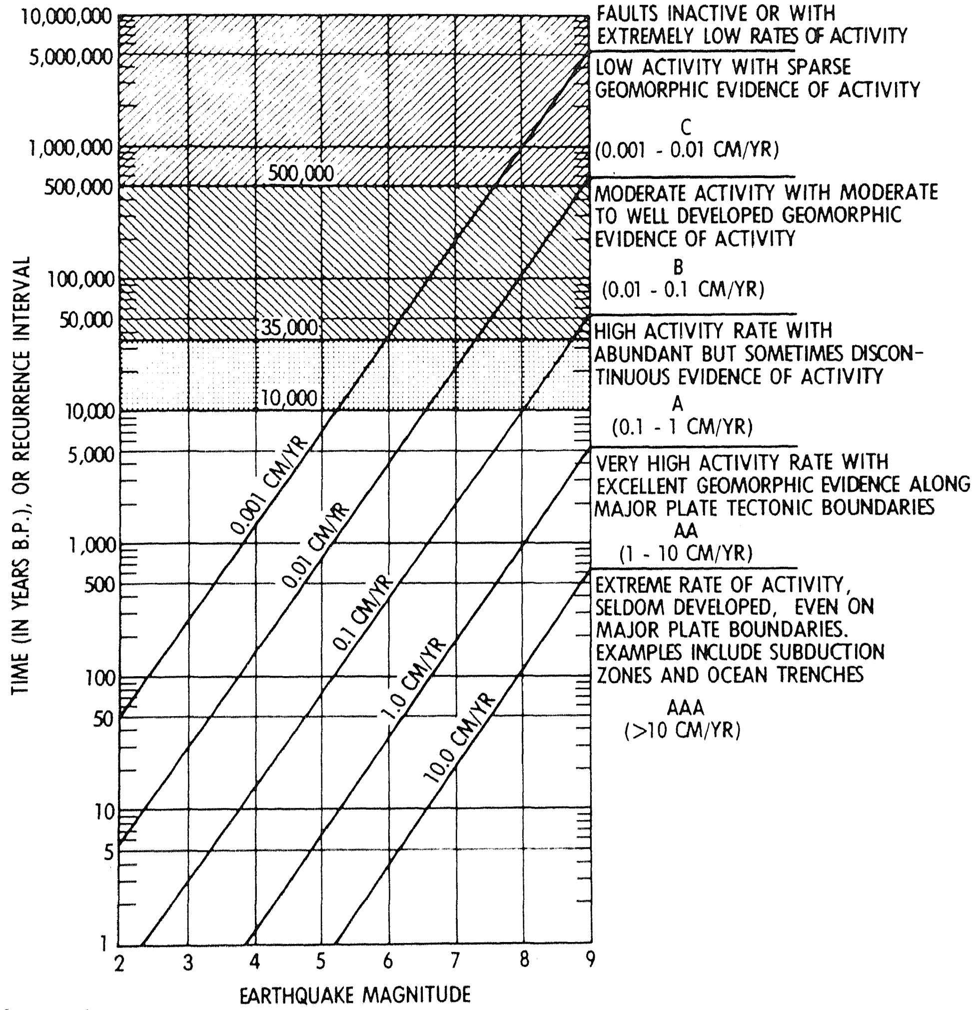

Figure 3.--Graph showing earthquake magnitude, strain rate, and recurrence interval of active fault zones throughout the World (Ref. 3).

of 0.12 mm/yr corresponds to faults having moderate activity with moderate to well developed geomorphic evidence of activity. An earthquake of magnitude 7.3 would be expected to have an average recurrence interval of a few tens of thousands of years.

This result illustrates the classic problem encountered when defining the ground shaking hazard for a region; namely, the recurrence intervals provided by historical seismicity data and geologic data can be considerably different. The seismicity data reflects the activity of all the faults in a region and typically encompasses only a few hundred years; whereas, the geologic data obtained from trenching an individual fault typically encompasses several tens of thousands of years. Considerable controversy exists over whether to give more weight to the historical seismicity data or to the tectonic data. It seems inappropriate to disregard the historic record of earthquake occurrence in estimating the ground shaking hazard. In many cases historic record is the only real evidence one has for defining the earthquake potential in a region. Tectonic hypotheses, on the other hand, are intellectually stimulating, but are not always easy to prove or disprove. Tectonic hypotheses are more attractive than historical seismicity data when one is trying to estimate the ground-shaking hazard for return periods that are an order of magnitude longer than the existing historic record.

Probabilistic Peak Acceleration

Historical seismicity was given the greatest weight in deriving a preliminary estimate of the ground-shaking hazard in the Ouled Fares area. On the basis of the geologic and seismological investigations, a value of peak acceleration of 0.36 g is estimated for the Ouled Fares area. This value corresponds to a 500 year return period, the return period that is typically used for the seismic design provisions of building codes. This estimate is for sites underlain by stiff soil and has a 90 percent probability of nonexceedance.

Additional data needed to answer the many technical questions that still remain will be forthcoming from the seismic microzoning study. In addition, as future earthquakes occur in Algeria, instruments in the Algerian strong motion network should provide information on: 1) the seismic attenuation relation, 2) near-field ground motion values, and 3) the effect of soil and rock on ground motion attenuation and site response. This information will serve to refine the preliminary estimates of the ground shaking hazard in the Ouled Fares area.

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REFERENCES

Cited in the Text

1. Tebbal, F., Chaker, A., Rebzani, B., Ameur, B., and Sendjani, A., 1983, "General report on the earthquake of October 1980 at Chlef", Ministere de L'Habitat et de L'Urbanisme, Organisme de Conrtole Technique de la Construction, 139 p.

2. Earthquake Engineering Research Institute and National Academy of Sciences, 1983, "El-Asnam, Algeria, Earthquake, October 10, 1980--A Reconnisance and Engineering Report," Earthquake Engineering Research Institute, Berkeley, California, 110 p.

3. Bonilla, M. G., 1982, "Evaluation of Potential Surface Faulting and Other Tectonic Deformation", U.S. Geological Survey Open-File Report 82-732, 88 p.

Not Cited in the Text

Benblidia, M., 1983, "L'amenagement Regional et les Aleas Sismiques". Conference Proceedings, Octobre 1983.

Allen, C. R., 1975, Geological criteria for evaluating seismicity: Geol. Soc. America Bull., v. 86, p. 1041-1057.

Allen, C. R., and Smith, S. W., 1966, Pre-earthquake and post-earthquake surficial displacements, in Parkfield earthquakes of June 27-29, 1966, Monterey and San Luis Obispo Counties, California -- preliminary report: Seismological Society of America Bulletin, v. 56, no. 4, p. 966-967.

Ambraseys, N. N., 1960, On the seismic behavior of earth dams: World Conf. Earthquake Eng., 2d, Tokyo and Kyoto Japan, 1960, Proc., v. 1, p. 331-358.

ANAT, 1982, "Schema d'amenagement Regional de la Wilaya de Chlef". Report. Octobre 1982.

Commission Interministerielle pour la Reconstruction de Chlef, 1981, Report.

Chaker, A., 1984, "A preliminary model of the earthquake ground-shaking hazard in the Ech Cheliff region", World Conference on Earthquake Engineering, 8th, Proceedings (in press).

Ferritto, J. M., 1982, "Evaluation of Earthquake-Induced Ground Failure", U.S. Geological Survey Open-File Report 82-880, 109 p.

Hays, W. W., 1980, "Procedures for Estimating Earthquake Ground Motion, U.S. Geological Survey Professional Paper 1114, 77 p.

Hays, W. W. and Algermissen, S. T., 1982, "Problems in Constructing a Map of the Earthquake Ground-Shaking Hazard", International Conference on Seismic Microzonation, Proceedings, Vol. 1, p. 145-156.

Krinitzsky, E. L., and Marcuson, W. F., 1983, "Considerations in Selecting Earthquake Motions for the Engineering Design of Large Dams", U.S. Geological Survey Open File Report 83-636, 57 p.

Petrovski, J., and D'Albe, F., 1983, "Evaluation of Seismic Hazard and Risk Elements in the Extended Urban Area of Ech Cheliff for the Needs of Physical and General Urban Planning", UNESCO Report, April 1983.

Slimani, M., 1984, "A Scenario for Acquiring Strong Ground Motion Data in Northern Algeria," World Conference on Earthquake Engineering, 8th, San Francisco, California, Proceedings (in press).

Slimmons, D. B., 1977, "Faults and Earthquake Magnitude", U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss., Miscellaneous Paper S-73-1, Report 6.

Tebbal, F., 1984, "Recommendatins for Regional Planning of the Province of Chlef (El Asnam) After Regional Risk Analysis," World Conference on Earthquake Engineering, 8th, San Francisco, California, Proceedings (in press).

Wood, R. M., 1983, "Evaluation of Trenches in the Ech Cheliff area", Report of CTC Control Board.

Woodward Clyde Consultants, 1983, "Map and Catalog of Historical Seismicity of Chlef Region". Report, October 1983.

Woodward Clyde Consultants, 1983, "Map of Historical Intensities" Report, October 1983.

Woodward Clyde Consultants, 1983, "Photogeological Lineament Map of Chlef Region", Report, October 1983.