Engineering Geology and Mapping Fractures For Earthquake Hazard
Azerbaijan area (Iran)

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Abstract

Major regional events then occure on the Tabriz -Marand salmas fault, when the energy of deformation is large enough to allow seismic instabilities to occur. Fractures propagating in perturbed stress fields will curve to follow the direction of the stress field trajectories. A progressive change in fracture direction is observed from unperturbed regions away from faults, to strongly perturbed zones abjacent to faults.

Digital fracture analysis techniques, which use topographic and seismic hypocenter data, provide geologists another structural analysis tool that will complement classic field mapping of Geoligic units and structural forms.

Seismic activity associated with these tectonic structures occurs dominamtly within these fracture Zones, but many events also occur on minor secondry structures during local deformation and dilation. In seismic fracture analysis, we assume that a significant number of these events will be located on the primary plane a dominant fracture zone.

This study of the brittle structures that are forming on a segment of the Tabriz fault, including its intersection with the Marand-Salmas and Zanjan fault, has provided a rigorous test of the research tools being used for structural analysis of fracture zones.

Introduction

The Azerbaijan plateau is characterized by active faulting recent volcanics and high surface elevation along the Alpine - Himalayan mountain belt.

The convergent movements between the Arabian and Eurasian plates, with an an estimated rate of about 4.7-5.1 Cm/year (X.Lepichon 1986, Mckenzie 1972, Jacob and Quittmeyer 1979) are principally taken up by folding and reverse faulting along inherited structures within the Iranian continental crust.

The drift of the Arabian plate towarod, the North-Northeast against Eurasia results in a collision zone in the region of Lake Van (Turkey) and Lake Urmiah (Azerbaijan), D.Mckenzie (1972), *noted that the other smaller plates of the region* the Black Sea, Tutkish, Iranian and South Caspian plates move symmetrically away *from the Lake Van and Lake Urmiah region* to the east and to the west, as if pushed a side by the advancing Arabian plate.

Geotectonic Evolution

From the Late Precambrian until the Late Paleozoic Southeastern Turkey, Iran, central Afghanistan and Arabia were part of one continent a fragment of Gondwanaland separeted from the Eurasian plate by the Hercynian phase.orogen<<paleotethys>> Ocean. (Fig 1)

The tectonic development, as in the Mediterranean, commenced in Late Permian-Triassic time, by rifting along the Main Zagros fault, an spreading of the continental plate along the Zagros-Oman zone resulting in the detachement of the Iran-Afghanistan microplates from Arabia, and opening of new ocean <<,neotethys>>.

The closing of Paleotethys by the Northward motion of the central Iranian Afghanistan microplates resulted in the latter becoming welded to the Eurasian plate a long a suture zone oceanic crust. It is not yet certain whether the closing of the of the Palaeotethys by Late triassic jurassic time was followed by subduction of these microplates beneath the Eurasian plate.

The mountains Azerbaijan are divided a *series of tectono- stratigraphic terranes* which are elongate parallel to the orogen. The major terranes are shown in (Fig 2). The North *most of these the high terrane, represents* the Northeast Talesh Alborz Moutains margin of Caspian Sea. The other terranes were accreted to it *during the* Paleozoic *and* Meso-Cenozoic, the inportant montains volcanics (Savalan-Sahand).accreted during Quaternary.

The boundaries of the terranes are coposite structures formed during along history of development and reactivation in which they were active both as shear zones and brittle faults. Sympathetic shear zones and faults are developed within the terranes, locally defining smaller terranes, and the region is characterrized by lenticular disposition of Rock units.

characteristics of active faults in Azerbaijan (Iran).

A fault that is active is likely to move again (Wallace 1986). If the fault moves

Tabriz Fault forms a well marked boundary between the rocks Miocene upper red formation of the Tabriz border folds an Quaternary alluvial deposits of the Tabriz piedmont zone, upthrusting the Miocene rocks againtst the alluvial deposits.

Northwest fault system

The general direction of the Tabriz fault is continued after Marand city by a system of little known NW-SE faults of probable Quaternary activity, referred to here as the Northwest fault system. Neogene-quaternary lava flows and alluvial recent cover make it difficult to trace faults in the Khoy-Salmas region, but nearer to the Turkish frontier, in the 39-40N,44 -45E sector.
other smallar faults are also seen in the ENE-WSW direction.

Historical earthquakes in the Azerbaijan

A-historical earthquakes of Tabriz city.
Study of the seismic history of Tabriz based on available data shows that the region has been seismically active since 634 A.D., although there are several recorded shocks for which there isno macroseismic information; however these earthquakes were strong enough to be reported by the early chroniclers.
The destruction Tabriz city by several catastrophic earthquakes during historical times needs critical study to establish whether they were associated the North Tabriz fault. One of the most likely cases of ground deformation which could be due to earthquakes faulting is mentioned by Brydges (1834) in his description of the region just North Basminj.
According to Eprikian (1903,P,580,581) five major destructive earthquakes are remembered as having occurred in Tabriz, four of which took place in 634,1441,1322 and 1780 and earthquakes of Tabriz 1900-1990.

B-Earthquakes of Salmas-Khoy region And Derik Fault

The Derik fault branches off from the Tabriz fault near Marand town and continues in a N 80. direction to die out between Derik and Deir at the Iran-Turk frontier (Fig 4), Near derik where it was studied in the field, it is a left-lateral structure which was reactivated during the Salmas earthquakes 1930 May 6, The earthquakes displacement was probably left-lateral and the Northern compartment subsided by about 1m by strike-slip produces earthquakes, then it is important to society to be able to forecast when the next displacement will.occur. Forecasting future activity depends on depends on developing and using information on the past behavior of the fault. One way to be this is to learn the slip rate V, from offsets of geologic markers of known age. (Roberts.yeats and.D.P. Schwarts 1990).

The surface displacement,d is estimated for an earthquake charateristic of the fault. The recurrence interval,r,between successive earthquakes the same faultis:

$r= d/v$

This method assumes that the fault will rupture the same amount in the next earthqake as it did in the last, and the method implies a uniform recurrence rate, a constant value of (r). In nature, however recurrence intervals can be variable.

discontinuities (bends or breaks, steps) along crustal strike-slip faults are potential initiation and arrest zones of earthquake ruptures. earthquake commonly intiate at the base of the seismically active zones, were conditions are thought to be close to the brittle ductile transition of crustal rocks (Sibson 1984). There fore the study of fault stepover that were active at transition conditions may offer insight into the initiation of fault ruptures and the mechanics of slip transfer across discontinuities.

Deformation alon faults (Tabriz-fault, Derik fault, Salmas fault...) is concentrated at their peripheries and around discontinuities over a wide range of length scales and geologic settings.

Where faults temminate or deviate from their trace, strain from fault slip must distributed in the surrounding rock by elastic straining, fracture, and/or flow. The characteristics of the deformation change with scale, depend on material properties and pressure temperature conditions, and are influenced by heterogeneity in the wall rock, the seismic or aseismic nature of faulting and the cumulative slip magnitude on the adjoining fault segments.(R.Burgmann and.D.pollard 1994).

Over 150 destructive earthquakes, have been described in the last 1100 years in the history of Azerbaijan and more than 50 active faults have been recongnized by studies on land. The town of Tabriz and Salmas has been devastated by a number of earthquakes during its history, but a critical study is required to establish wether they were actually associated with the Tabriz and Salmas fault.(fig 3)

The Tabriz fault starts in the souteast near Bostanabad, follows a N300 direction passing along the Northern of the town of Tabriz and divides, near marand in to the Derik fault (fig 34). and the Northwest fault system. The fault trace is approximately N 115 E (M.Berberian and Arshadi 1975) and its dip is vertical, over its central part, between Soufian town and Northe of Tabriz , the North

A Norther fault, The Salmas fault, was also reactivated during the earthquakes: its direction is NW-SE (approximately parallel to the Tabriz fault) and its displacement in 1930 was about 4m right-lateral and 5 M Northeast side down.

The Salmas earthquakes of 1930 is one eight earthquakes of magnitude equal, to or greater than 7, which have occurred in Iran since 1900, and one of the few which was accompanied by surface faulting.

The salmas plain, the epicentral region of the earthquake, is located to the North west of Lake Urmiah, and has an area of about 300km^2. (Fig 3) it lies between about 1500m (N.W and 1280m, the latter being The average level of the Lake Urmiah which forms its eastern border.

Recent earthquakes in the Northwest of Iran

Northwest of Iran eas hit by the most deadly earthquake since the 1976 Chinese earthquake: On June 21 at 30 minutes after midnight local time, a magnitude 7.7 earthquake struck about 230Km northwest of Tehran, an estimated 40 to 50 thousand people were killed 60000 were injured, 50000 homeless, and extensive Damage and landslides occurred in the Rasht - Zanjan - Qazvin area. Nearly all buildings were destroyed in the Rudbar - Manjil area.

Considerable damage occurred as far away as KhalKhal and Nowshar and slight damage was experienced at Tehran. The quake was felt in most of Nortwestern. Iran including Arak, Kermanshah, and Tabriz, Sligh damage also occurred in southern Azerbaijan and the quake was felt at Baku city.

Both faulting and folding associated with the earthquake were observed in the epicentral area coseismic surface faulting was associated with at least three main discontinuous, complex fault segments with a total length of more than 80 Km.

These three main fault segments are earthquake are arranged in a right-stepping - EN -echelon pattern, and are separated by gaps in the observed surface ruptures (M.Berberian and M. Goreish 1991) each segment has a strike of 095-120° with oblique left - lateral and reverrse montion on faults that are sub-vertical or have steep pip to the S or SSW. Maximum surface displacements were 60 Cm Horizontal (left-lateral) and 95 Cm vertical (South side.up).(Fig 4).

Conclusion and discussion

The reactivations of old and younger faults and planes of weakness appears to be an important process on in continental deformation and is illustrated by the examples shown here.

On the continents for example Azerbaijan area it is the refore inportant to understrand the deformation which occurs at the ends of the long linear *strike-slip-faults which commonly join regions of compression of extension.*

It appears that, at the ends of these strike-slip-faults,older faults of the most favourable orientation are reactivated, there by approximately maintaining the direction of motion in the region but causing some internal deformation in the blocks involved. This internal deformation is manifest as the diffuse distribution of minor aftershocks in the blocks defined by the larger earthquakes faults.

No overall conclusions are attempted here as the data presented is primarily of a *reconnaissance nature* nevertheless, it seems use ful to point out at this stage that the data is agreement with the plate tectonics model proposed by Mckenzie fot the Middle East(1972). In his model the Arabian plate moves north with respect to Eurasia (D.Mckenzie 1972).

In front of this plate is a zone of shortening or compression which extens Northwards to encompass the Caucasus, and in which earthquake Mechanisms show approximately equal amounts of thrusting and right-lateral strike-slip. To the west and east 4 smaller plates (microplates: Turkish,Black Sea, Iranian an South Caspian) move symetrically away from a North-South line passing through the Azerbaijan-Caucasus and in so doing "move continental crust away from Asia Minor towards either the Mediterranean or the Arabian Sea". In the east, the two major faults, the Main Recent fault and the Tabriz fault, do not intersect,but ground displacements associated with the Salmas earthquake (1930). were interpreted interms of a regional extension and an eastward motion of crustal material. the PiranShahr earthquakes (1970) which occurred near the termination of the mainrecent fault provided the first known extensional earthquake mecanism of the region. The Rudbar-Zandjan earthquake (7.7 magnitude) which occurred of the SouthCaspian Sea near the Aborz fault.

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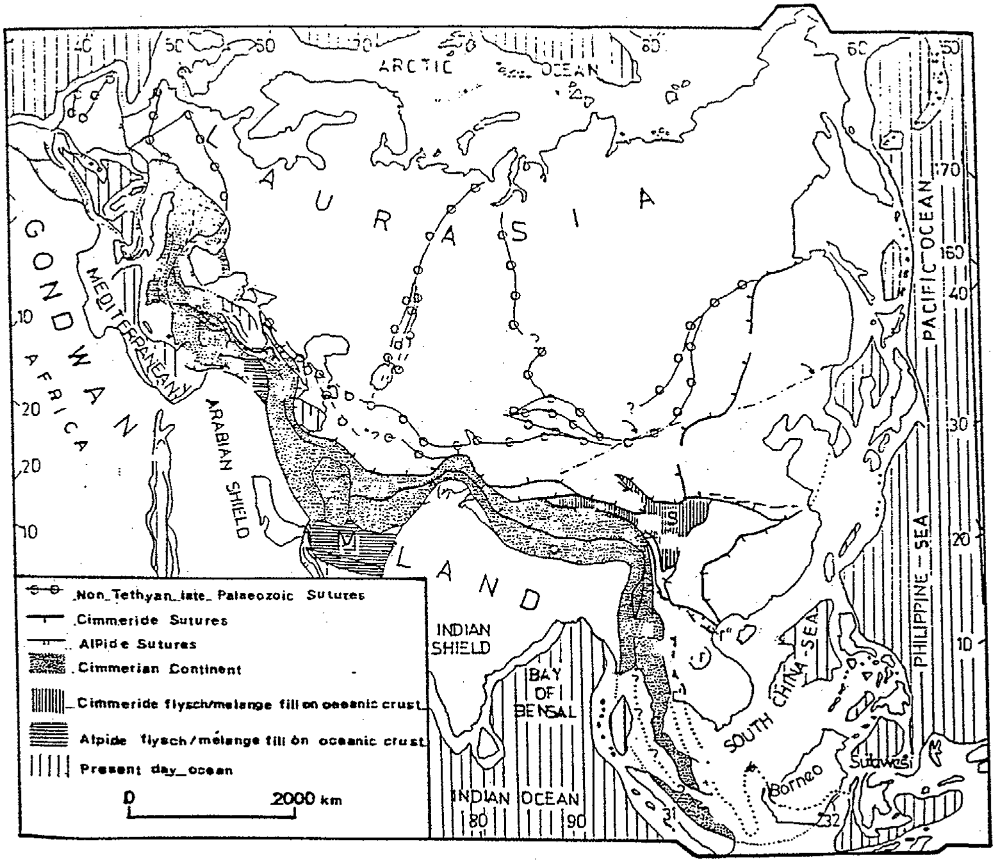

ARCTIC OCEAN
AURASIA
GONDWANALAND
AFRICA
MEDITERRANEAN
ARABIAN SHIELD
INDIAN SHIELD
BAY OF BENGAL
INDIAN OCEAN
SOUTH CHINA SEA
PHILIPPINE SEA
PACIFIC OCEAN
Borneo
Sulawesi
Non_Tethyan_late_Palaeozoic Sutures
Cimmeride Sutures
AlPide Sutures
Cimmerian Continent
Cimmeride flysch/melange fill on oceanic crust
Alpide flysch/melange fill on oceanic crust
Present day_ocean
0
2000 km

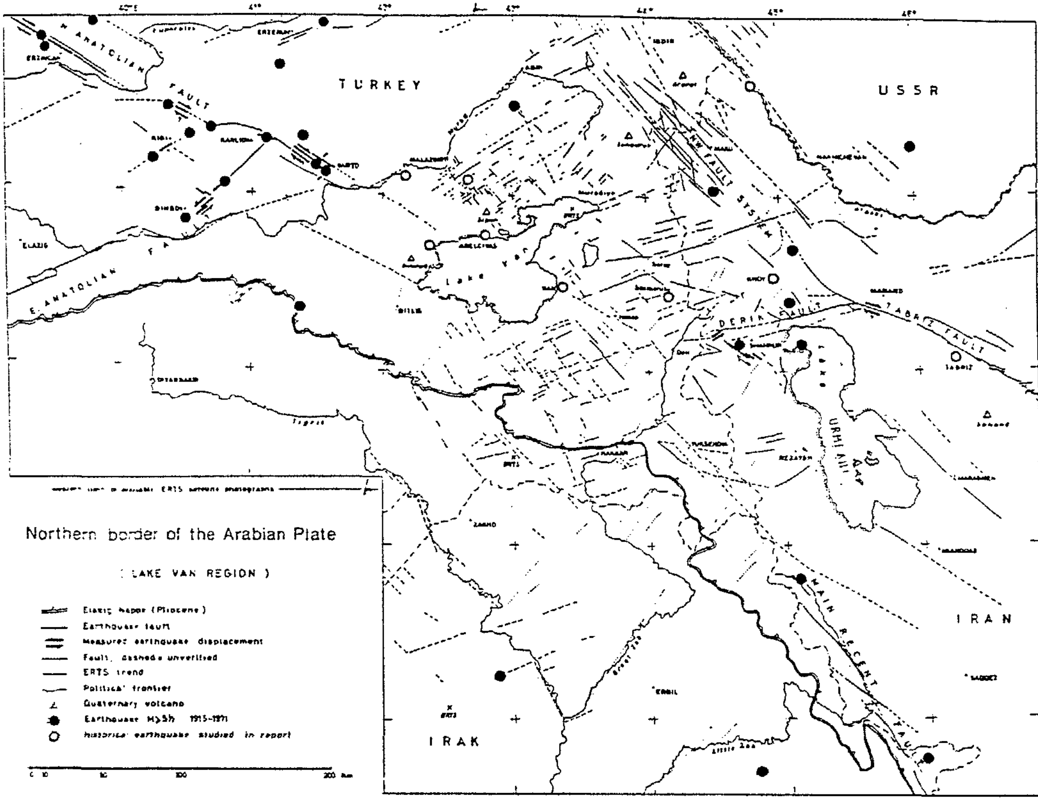

FIGURE 2

Northern border of the Arabian Plate (Lake Van region).

Tectonic information is from published 1:500,000 geological maps of Turkey and 1:2,500,000 geological maps of Iran (1959), as well as from the following: E. Altinli (1966), E. Arpat and F. Saroglu (1975), H. Bobek (1938), J. Stöcklin and M.H. Nabavi (1968), A. Verdier (1961). Centres of satellite photographs for westernmost strip are marked ERTS

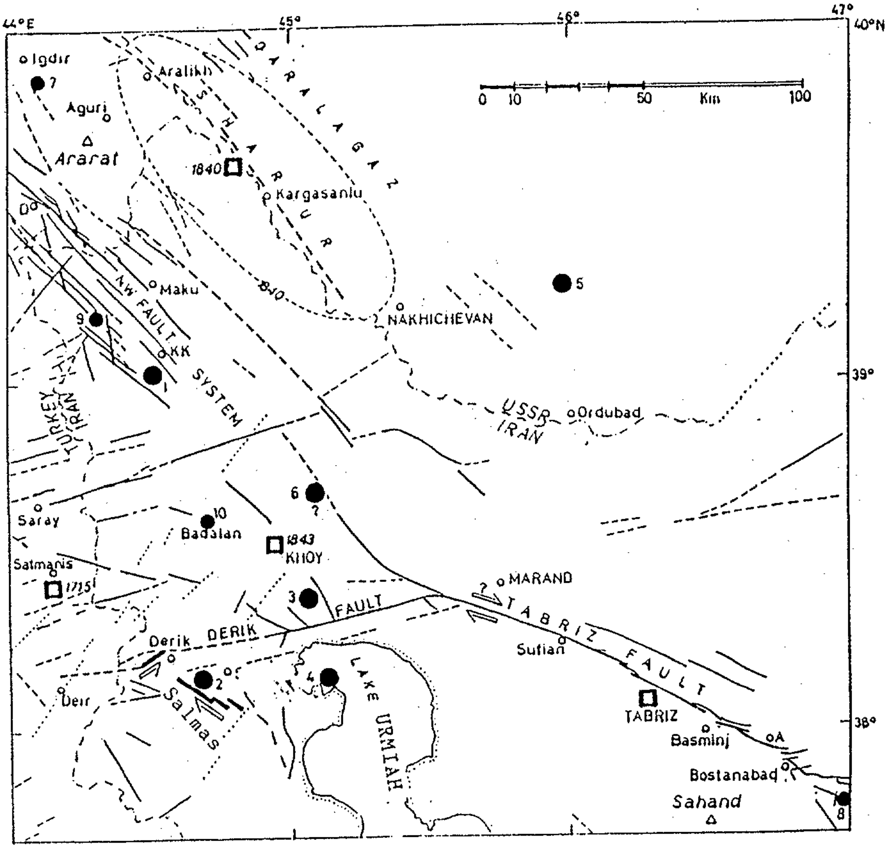

Figure 3

Tabriz Fault : western termination.

Large circles : Earthquake M ≥ 5 ½.
Small circles : Earthquake 5 ≤ M < 5 ½.
Squares : Historical earthquake mentioned in text.

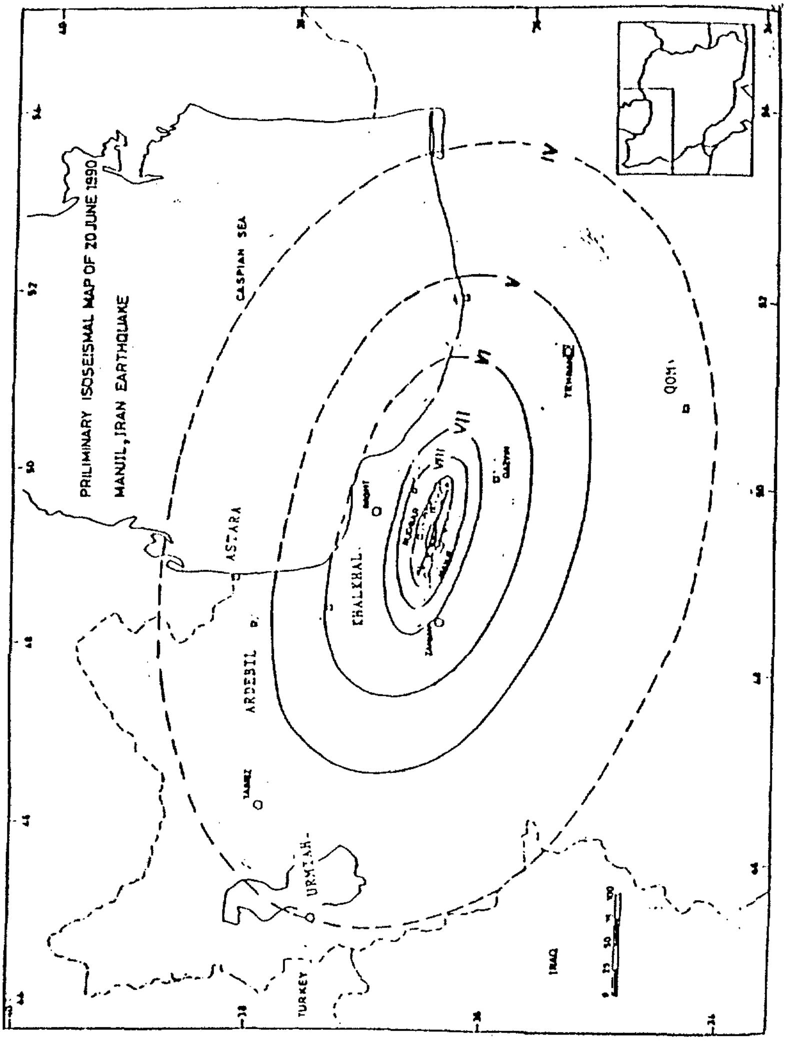
PRILIMINARY ISOSEISMAL MAP OF 20 JUNE 1990
MANJIL, IRAN EARTHQUAKE
CASPIAN SEA
ASTARA
KHALKHAL
ARDEBIL
QOM
URMIAH
TURKEY
IRAQ
IV
V
VI
VII
VIII

Fig4