DEVELOPMENT OF GIS-BASED DATABASE OF ACTIVE FAULTS IN THE MIDDLE EAST AREA

Mohammad R ZOLFAGHARI
Associate Professor, Civil Eng. Dept., K.N.Toosi University of Technology, Tehran, Iran
mzolfaghari@catrisks.com

Atefe DARZI
PhD Candidate, Civil Eng. Dept., K.N.Toosi University of Technology, Tehran, Iran
adarzi@mail.kntu.ac.ir

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ABSTRACT

The Middle Eastern region is located at the junction of major tectonic plates, namely the African, Arabian and Eurasian plates with relatively high tectonic and seismic activity. Some of the most fatal earthquakes in human history such as Aleppo-Syria, Rudbar-Manjil-Iran and Beirut-Lebanon earthquakes have occurred in this region (Table 1). Earthquake activity in this region is concentrated along active faults or plate boundaries. This study attempts to develop a GIS-based database representing active faults zones for the Middle East area by performing an elaborated investigation on researches and published material on active faults. For that purpose, a digital database has been conducted which provides facility to update and compile information from latest researches. It facilitates efficient organization of faults characteristics such as strike angle, dip angle, fault mechanism, horizontal and vertical slip rates and also covers all publically available researches on seismotectonic and active faults for the Middle East. This integrated database also contains information on historical earthquakes, field observations and photographic images, geo-referenced images and published articles for all known faults within the region under consideration. SRTM digital topographic map layers with 3 second resolution in conjunction with other published seismotectonic data have been used to adjust geographical locations of some of the known faults in this region.

INTRODUCTION

Population in several developing countries in the Middle East such as Lebanon, Jordan, Syria, Yemen and Iran are exposed to sources of seismic activity. Seismic hazard in these countries in conjunction with insufficient construction codes and rapid unplanned urban extension highlights the importance of seismic risk management in these countries. Essential to any efforts for seismic risk management is reliable assessment of seismic hazard, for which identification of seismotectonic sources are required. In order to define seismic sources to reliably evaluate regional seismic hazard, a comprehensive knowledge of active tectonics and characteristics of active faults are required. Tectonic deformation, fault location, geometry and seismic activity are fundamental information for defining seismic sources and to assess seismic hazard. In this study, an effort is made to compile a GIS-based database of active faults for all Middle Eastern countries. This integrated GIS-based database provides facilities for collecting and updating information from latest researches on active fauls. It facilitates efficient organization of faults characteristics such as strike, dip angle, fault mechanism, horizontal and vertical slip rates. This databasae consists of all publically available researches on seismotectonic and active faults of the Middle. The database also contains information on historical earthquakes, field observations and photographic images, geo-referenced images and published articles for all known faults within the region under consideration. Where possible the location and shape of fault lines were adjusted using SRTM digital topographic map in 3 second resolution.

TECTONIC SETTING of THE MIDDLE EAST

Separation of Arabian plate from Africa along the Gulf of Aden and Red sea (Courtillot et al., 1987; McKenzie et al., 1970) and subsequently oceanic expanding deformation in between resulted in Arabia-Eurasia continental collision such as eastern Turkey, the Zagros, and the Caucasus Mountains (McQuarrie et al., 2003). Along the Levantine coast of the eastern Mediterranean, this motion is taken up by a 1000-km-long transform fault, Dead Sea transform or the Levant fault system, which connects the Red Sea ridge to the southwest segment of the East Anatolian fault system (Figure 1). The Dead Sea Fault System (DSFS) consists of three main sections: A ~400 km long southern section from the Gulf of Aqaba through the Araba, Dead Sea, and Jordan River Valleys; a ~200 km long northeast–southwest striking restraining bend through the Mt. Lebanon and Anti Lebanon ranges, and a ~250 km long, north–south striking section in northwestern Syria and southern Turkey.

Figure 1 shows GPS velocities in the Arabian plate, Iran and adjacent area in a Eurasia-fixed reference frame. Except for elastic strains near plate boundaries and possible shortening across the Palmyride fold-thrust belt, based on the Euler vectors the Arabian plate is not deforming internally at the present level of GPS uncertainties (i.e., < 1.5 mm/yr., or < 10% of Arabia plate motion rate relative to Eurasia) (ArRajehi et al. , 2010). ArRajehi et al. (2010) believe that the kinematics of Arabia plate motion are most consistent with plate motion being driven by subduction processes along the Makran subduction zone and beneath the Zagros fold-thrust belt, and that the Afar plume served mainly to weaken the African continental lithosphere allowing deformation to concentrate along the future Red Sea and Gulf of Aden rifts.

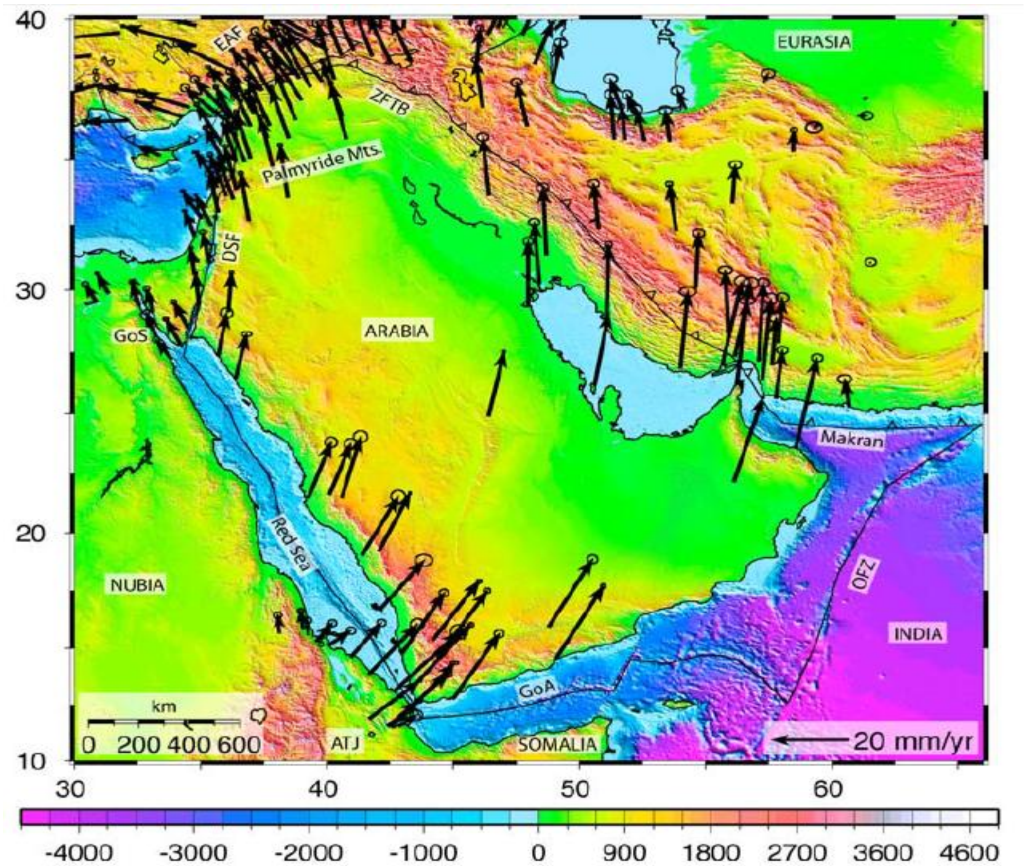

Figure 1. GPS velocities in the Arabian plate, Iran and adjacent area in a Eurasia-fixed reference frame. Abbreviations: EAF, East Anatolian fault; ZFTB, Zagros fold thrust belt; GoA, Gulf of Aden (ArRajehi et al., 2010)

Based on geodetic data, convergence between the Arabian and the Eurasian plates is estimated at around 21mm/yr at a longitude of 52°E (e.g., McClusky et al. 2003; Vernant et al. 2004a). In the Eastern part of the Middle East, Iran is also deforming actively as part of the Alpine Himalayan orogenic belt that extends over more than 10,000 km from west Europe to Southeast Asia (e.g. McKenzie, 1978; Stِcklin et al., 1968). Consequently, Iran is one of the most seismically active regions covered by many of active faults. The Arabia-Eurasia convergence is accommodated differently in eastern and western Iran. East of 58°E, most of shortening is accommodated by Makran subduction zone (19.5±2mm/yr) and less by the Kopet-Dag (6.5±2mm/yr). West of 58°E, the deformation is distributed in separate fold and thrust belts. At the longitude of Tehran, Zagros and the Alborz mountain ranges accommodate 6.5±2mm/yr and 8±2mm/yr respectively. The Central Iranian Block is characterized by coherent plate motion (internal deformation < 2mm/yr). East of 61°E sites show very low displacement relative to Eurasia. The kinematic contrast between eastern and western Iran is accommodated by strike-slip motion along the Lut Block. To the south, the transition zone between Zagros and Makran is under transpression with right-lateral displacement of 11±2mm/yr.

SEISMICITY of THE MIDDLE EAST

Most active tectonic features are located along plate boundaries in this region and characterized by large deformations. Due to this continental collision, some part of Middle East such as Syria, Lebanon, Iran and Turkey are among the most active tectonic regions and have been affected by several major historical and instrumental earthquakes. As shown in Figure 2 the majority of earthquakes in the Arabian Peninsula, Iran and adjacent regions are concentrated along fourth major belts.

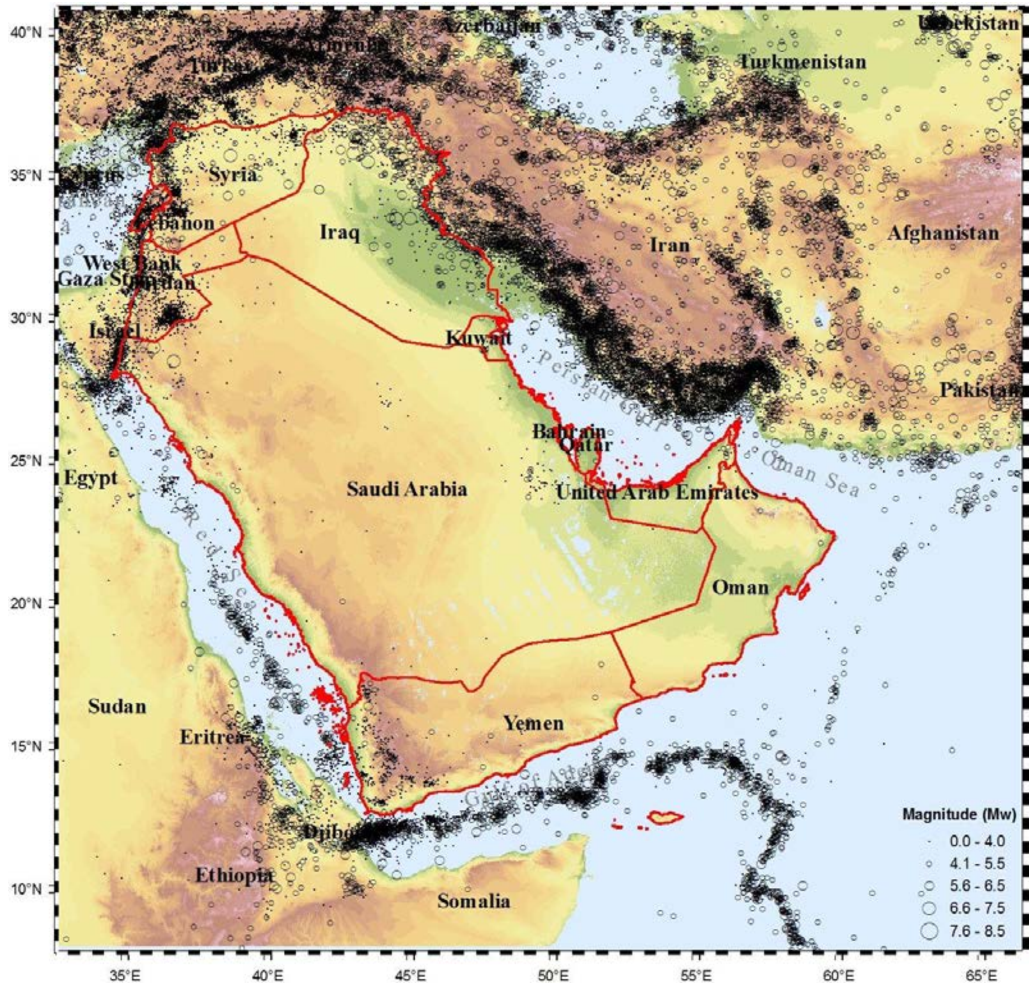

Figure 2. Earthquake epicenters (800 to 2014) in the Middle East surrounding the Arabian Peninsula and adjacent regions

The first is the Zagros fold and trust belt, which extends about 1,200 km with NW–SE trend between eastern Turkey, where it connects to the Anatolian mountain belt, and the Strait of Hormuz, where it connects to the Makran subduction zone, through west of Iran and northeast Iraq to Turkey. More than 50% of Iranian earthquakes with small to moderate magnitude happened in Zagros region. The second belt expands from the central Red Sea region south to Afar and then east through the Gulf of Aden. The third belt extends from the northern tip of the Red Sea in a northeasterly direction through the Gulf of Aqabah, Dead Sea, Lebanon, and Syria, and terminates in southern Turkey. The fourth belt is the Alborz range in north of Iran, which is an active EW trending mountain belt of about 600 km long and also the Kopet Dag Mountains in the north eastern part of Iran, which have been responsible for several catastrophic earthquakes in the past (Ambraseys and Melville 1982; Berberian and Yeats 2001). Both thrust and strike-slip faulting have been reported in this belt (Jackson and McKenzie 1984; Guest et al. 2006). Table 1 lists some of the major historical and recent earthquakes with devastating consequences in the Middle East.

Table 1. Some of the major and destructive earthquakes in the Middle East

Earthquake	Date	Magnitude	Fatalities
Aleppo-Syria	1138	M=8.5 not known pricisely	230,000
Tabas-Iran	1978	Ms=7.8	15,000
Beirut-Lebanon	551 AD	MS=7.2	30,000
Buin Zahra-Iran	1962	Ms=7.2	12,225
Rudbar-Manjil-Iran	1990	M=7.4	40k-50k
Erzincan-Turkey	1939	M=7.8-8	33,000
Bam-Iran	2003	Mw=6.6	31,000
Galilee -Lebanon	1837 AD	Ms=7.1	-
Ardabil-Iran	893	M=6.3 not known pricisely	150,000

PREPARATION OF DIGITAL FAULTS DATABASE

In order to implement the comprehensive fault database for the Middle East region, numerous published researches carried out in the last decades have been studied. Various research reports, published papers and field studies on active faults in the region have been investigated in order to compile this database. Efforts have been made to implement these studies in a GIS-based database by geo-referencing unscaled data based on corresponding coordinate system. Analogue maps have been geo-referenced and faults lines have been digitized in GIS shape-file format. Figure 3 shows a GIS view of this fault database with some sample georeferenced image maps taken from published papers. Figure 4 shows the same fault map overlaid on SRTM map (DEM), used for location correction of reported faults. Figure 5 represents geographical location of all faults collected in the developed database in the Middle East region.

The customized GIS tool used for this tool allows user-friendly access to all data and published materials in the database using GIS tools. User can select any fault line on the map and get access to all related published materials and seismotectonic characteristics such as name, strike and dip angles, fault length, fault mechanism and horizontal and vertical slip rates (Figure 6). The user can also see information on historical earthquakes field observations and photographic images, satellite images, seismotectonic geo-referenced images and published articles for all known faults (Figure 6). Figure 7 shows geo-referenced images, published articles and also tectonic image for the Jordan Valley Fault for example.

In this study, an open-source GIS software is used to develop a user-friendly tool so that this comprehensive database can be updated and completed easily to compile all new detected faults based on newer researches. All new related geometric characteristics and linked seismic activity can also be imported easily by using the conducted tool.

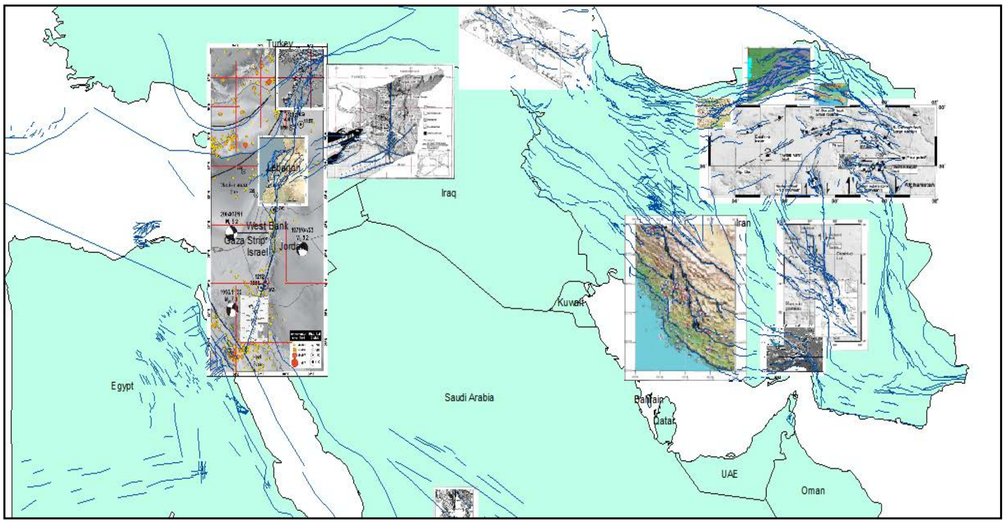

Figure 3. The Middle East faults mapping process in GIS-based software

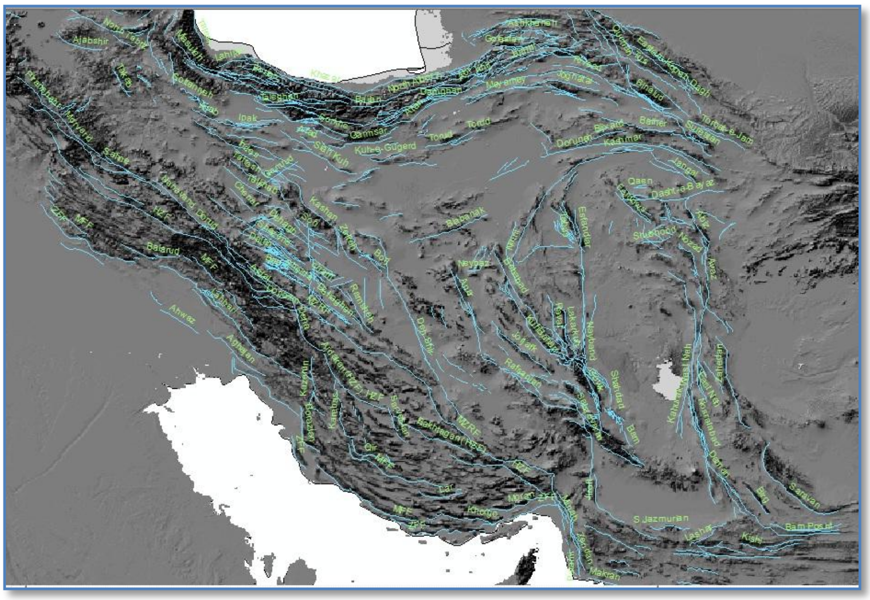

Figure 4. Location correction of active faults in Iran using SRTM map

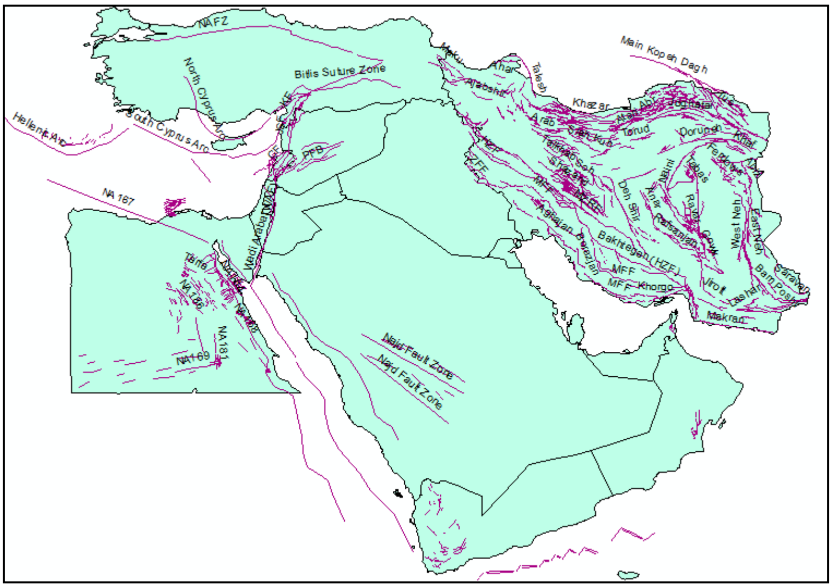

Figure 5. The Middle East active faults map conducted in the new developed database

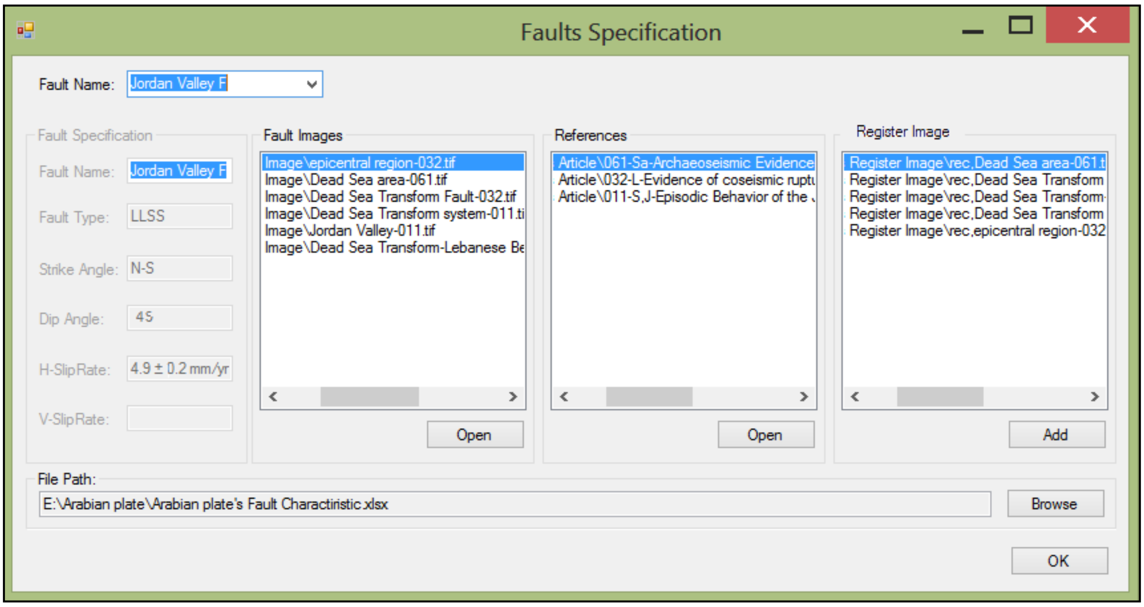

Figure 6. Developed digital fault database for the Middle East region

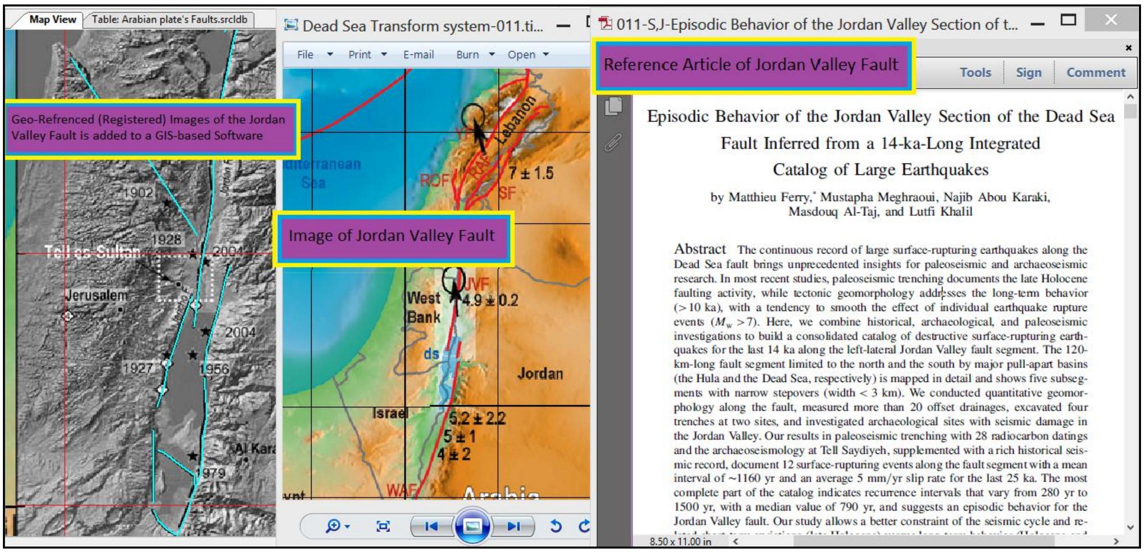

Figure 7. Geo-referenced image, referenced studied article and also tectonic image of the Jordan Valley Fault

CONCLUSIONS

In this study a GIS-based database is developed for all actives faults of the Middle East area. This comprehensive database facilitates efficient organization of faults characteristics such as strike, dip angle, fault length, fault mechanism, horizontal and vertical slip rates. This new developed tool includes all publically available researches on seismotectonic and active faults of the Middle East. It also contains information on historical earthquakes, field observations and photographic images, geo-referenced images and published articles for all known faults within region under consideration. This digital database provides facility to update and complete information from latest researches.

Due to massive concentration of faults and high seismic activity in Iran, using SRTM digital topographic map in 3 second resolution, geographical locations of Iran known faults were compared with visible trains on the DEM map and where necessary location correction are made.

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