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GIS Analysis of Spatial Associations Between Epicenters of Earthquakes, Geological Features and Oil Fields in Kuwait

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Abstract

One of the fundamental aspects in understanding spatial distributions of earthquakes is their relation to the associated geological features at different scales of observation. This is best studied systematically by the techniques available in GIS (Geographic Information System). In this Project, various GIS techniques are applied on in identifying the spatial relationships between the epicenters of earthquakes and the associated geological features in Kuwait. The involved in the digitization of the lithological and structural features, and overlay analyses between these features and the locations of epicenters and oil fields in Kuwait. The results clearly spatial associations epicenters and oil fields, and also epicenters and certain geological and structural features. The obtained results could help in further statistical modeling

Keywords: local earthquake – tectonic plates - Arabian Peninsula – seismic magnitude - Kuwait national seismic network (KNSN).

1. Introduction

Kuwait is located in the northeast of the **Arabian Peninsula**, between latitudes (28˚ 30' , 30˚ 05') and longitudes (46˚ 33' , 48˚ 30') , and its area is about 17818 square km , situated near eastern margin of the Arabian plate about 200-300 km from the collision zone , between the Arabian and Eurasian plates **(Rodgers and AL-Enezi 2006). Seismotectonics** of Kuwait: The Arabian plate is defined by five tectonic features, with the Zagros and Taurusmountain in the northeast defining the continental collision between the Arabian, Persian and Turkish plates. In the east, the Arabian plate sub ducts beneath the **Makran region** of Pakistan and Iran, and southeast is the Owen fracture zone (figure1). In the south and southwest are the spreading centers on the seafloor along the axis troughs in the Gulf of Aden and the Red sea. Kuwait is located on the coast of the northwest tip of Arabian Gulf **(SADEK 2004).**

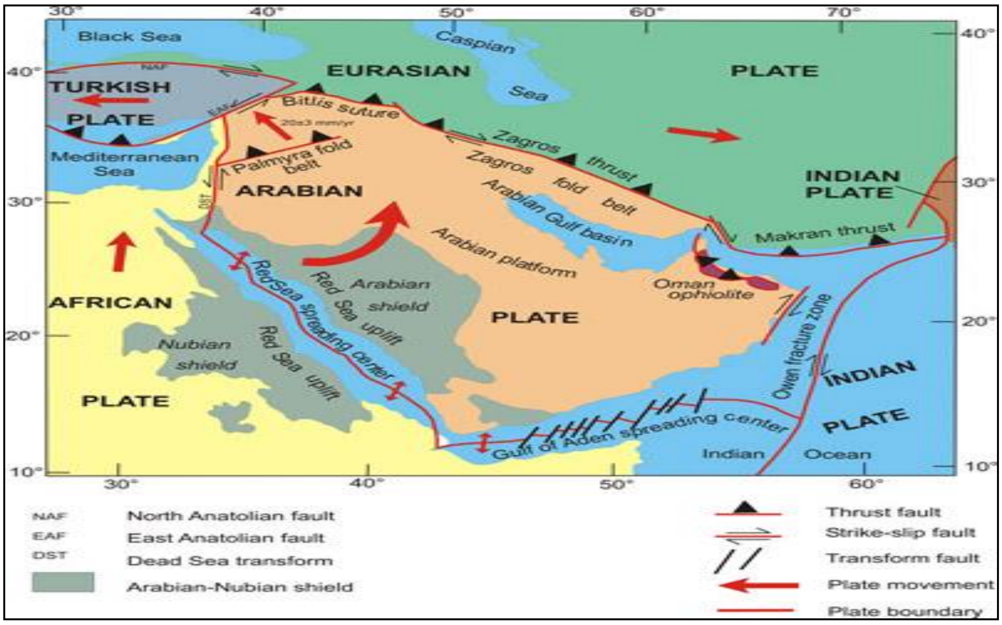

Figure 1: tetonic plates of arabian pinensula

State of Kuwait consists of five structural trends (Figure2), which are: (a)three sub-parallel anticlinal trends appear on the west section of the Kuwait arch. These three trends trap oil in the lower cretaceous and Jurassic strata. (b) North-south trending structures, are founded on basement horsts, these trends contain the largest oil fields in Kuwait **(Burgan)** in middle Cretaceous, Lower Cretaceous and Upper Jurassic strata. (c) Northwest trend of Kuwait. (d) East-northeast anticlines occur in the middle flank of the Kuwait arch and to the west and north, they have oil in the Jurassic and Lower Cretaceous strata, and Middle Cretaceous strata. (e) the **Ahmadi Ridge** appears south and southeast of the state.

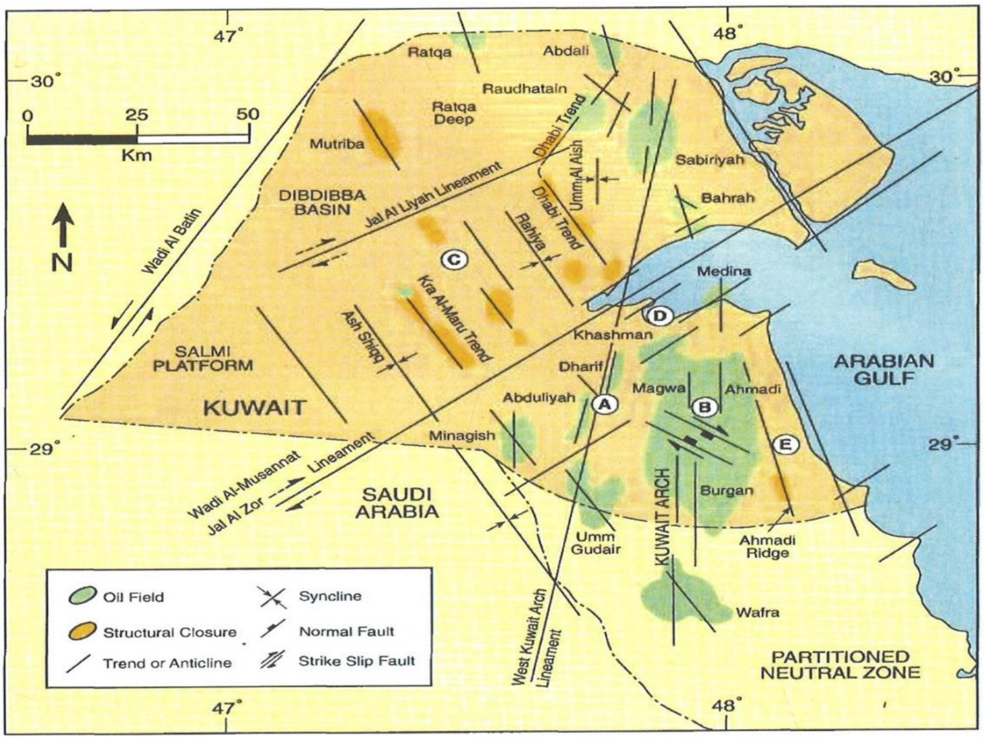

Figure 2: Structural elements of onshore Kuwait

Through the map(Figure 2), the apparently simple anticlines oil fields structures are cut by normal faults, and it seems near vertical and mostly appear in swarms. Their distribution is as a radial type. On the other hand, these features probably have a quite effect on seismic activity of the state **(Carman 1996)**.
Lithology of Kuwait(figure3): the state has approximately eleven geological layer distribute all over the area. In contrast, these geological layers are differ in percentage, for example, in lithology map of Kuwait, its observed that **Dibdibah Formation** covers most of Kuwait, on the other hand marine sand covers just a small area of the state (Figure 3).

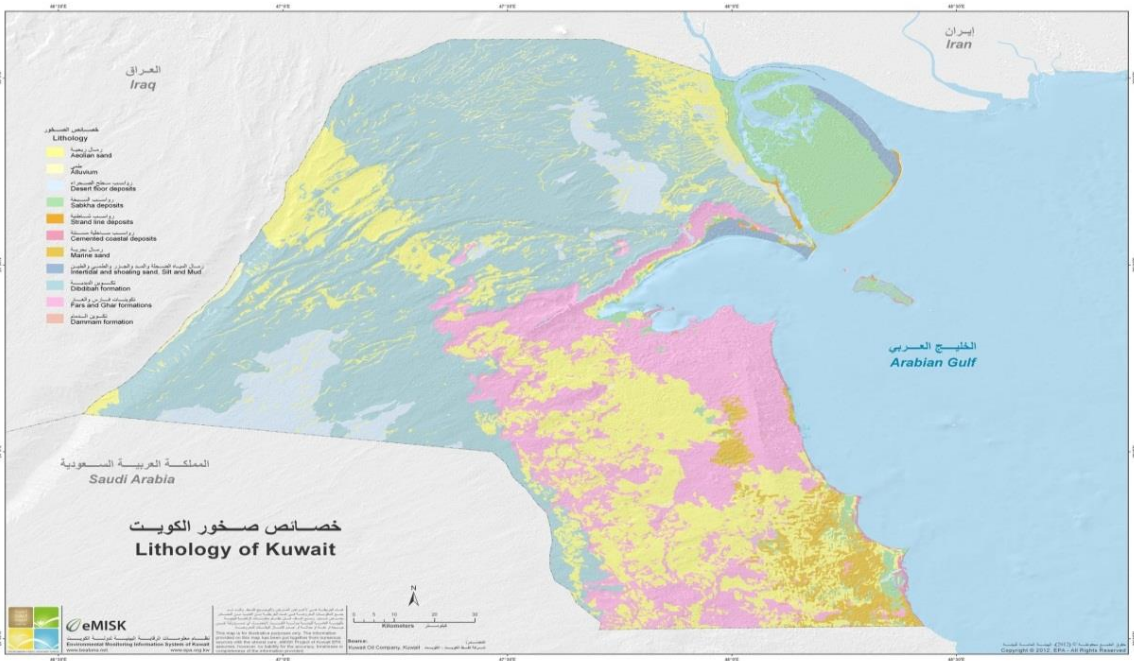

Figure 3: Lithological map of Kuwait

The map consists of eleven units distributed all over region, which are:

1- Aeolian sand
2- Alluvium
3- Desert floor deposits
4- Sabkha deposits
5- Strand line deposits
6-Cemented coastal deposits
7- Marine sand
8- Intertidal and shoaling sand
9-Dibdibah Formation
10- Fars and Ghar Formation
11- Dammam Formation

There are some geomorphological feature that may effect on seismic situation in Kuwait. First**, WhadiAlabatin** fault is located in western section. Many studies described that it is representation of interaction between the Arabian and Zagros folds, where Al-Sarawi (1980) suggested that there are three faults beneath Wadi Al-Batin area, and a major fault with maximum displacement of 25-35 m **(Alsarawi 1980)**. Second, **Jal- azzor e**scarpment and anticlines oil field features, **Burgan, Magwa**, **Ahmadi**, **Bahra**, **Sabirya** and **Rawdhatain**

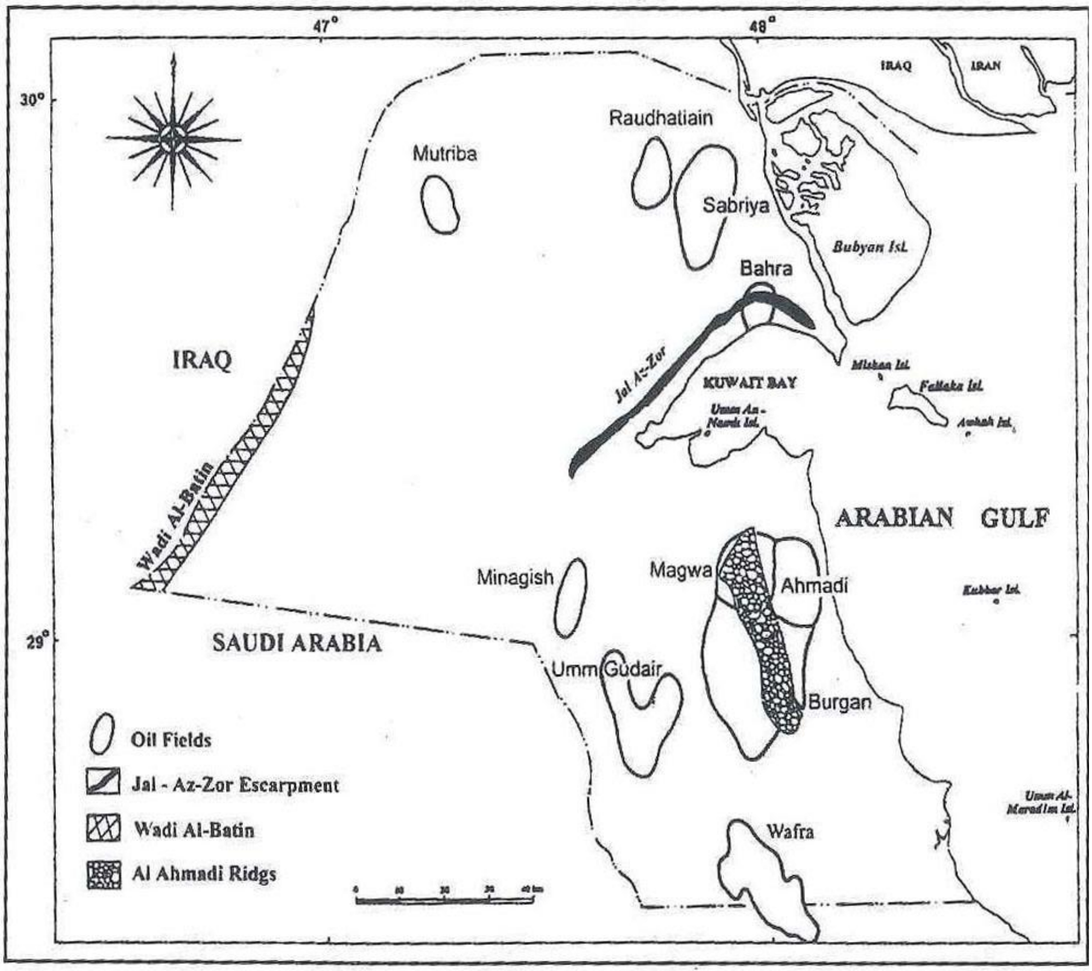

Figure 4: Geomorphological map of Kuwait

Kuwait in a quiet tectonic area in the **Arabian Plate**, and The edges of the Arabian Plate is characterized as active, which opens up the Red Sea in the west and the Gulf of Aden in the south-west, and rotates counter –clockwise to hit the Eurasian plate along the Zagros and Taurus. The remaining energy is consumed in manufacturing left-wing movement along the Dead Sea, which leads to the accumulation of energy and the occurrence of earthquakes.

All these geological and geomorphological features are considered in previous studies to know if their relationship between geological structure, lithology, type of faults, oil fields and seismological activity, as well as, probabilities seismic hazard in some areas in the state.

Through previous studies, that tried to discover and reveal what the main reasons of seismic hazards in Kuwait state, **Kuwait National Seismic Network (KNSN)** conducted several field studies, the most important of it, the study of seismicity and improved velocity structure in Kuwait by (**AL-Enezi and Gok 2006**) which concluded, seismic events in the north of Kuwait tend to be deeper (8-25) than those in the south (0-25).

The fact that most of the relocated events occur beneath the known sedimentary structure extending to 7 km suggests that they are tectonic in origin, occurring in the crystalline crust. Shallow events within the sedimentary crust in the (southern) **Minagish** region may be related to oil field activities, although the current study cannot unambiguously determine the source of current seismicity in Kuwait. The improved velocity model reduces the scatter of travel time residuals relatives to the locations reported in the **KNSN** bulletin and may be used for ground motion prediction and hazard estimate studies in the state. The source spectra of earthquakes show close similarity between the tectonic events from other regions such as the **North Anatolian Fault Zone**.

The seismicity of Kuwait can be still related to the hypocarbon removal even though most events occur below the sedimentary structure of the shallow upper crust and have moment-rate spectra similar to other tectonic events. This study shows that the spread of seismic activity is concentrated in two areas(figure8). The first north-east of Kuwait and the second south-west of Kuwait, The centers of earthquakes in the northern region is more depth than the southern region. And active tectonic plates that located outside the province are the most important reason that lead to the occurrence of earthquakes.
The second study is performed by **(Sadek 2004)**, entitled seismic map for the state of Kuwait, Where the study concluded that the analysis considered regional seismicity accounting for the **Zagros belt** and more important the local seismicity defined by earthquake events recorded within the state of Kuwait. The resulting product of the study is a seismic hazard map of the state of Kuwait showing expected peak ground accelerations with 10% probability of exceedance over 100 year return period. It is clearly demonstrated that local seismicity is important and should be included in future studies of hazard assessment.

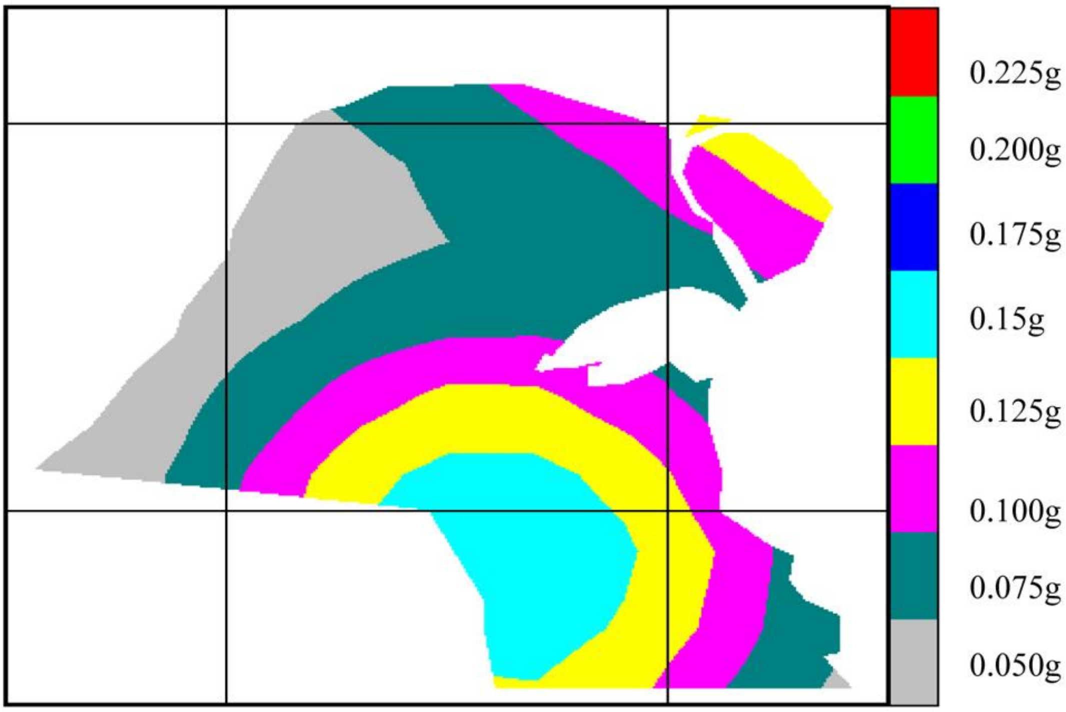

Figure 5: Seismic hazard map of Kuwait

2.Aims and objectives

The essential purpose of this study is to answer the question, what are the causes of local earthquakes in the state? And the main objectives are, how we can manage geological feature by using GIS? What are the processes that could lead to explore the causes of the problem?
This study is focused on the distribution of the probability of the occurrence of earthquakes on all areas of Kuwait, as well as, the relationship between **Zagros belt**, **Persian plate** and the probabilities of earthquakes occurring , the previous study focused on the earthquakes probabilities of the region for the next 100 year.
Previous studies have focused on its potential occurrence of earthquakes in areas of Kuwait. Each of these studies has given the result on the reasons for these earthquakes, some of it concluded that trend of structures and geomorphological features in addition to What inferred the existence of events and the relation between faults and its directions, as well as oil fields in the north and south of the state.

In this study, the use of GIS technology to figure out what the underlying causes are for the occurrence of earthquakes. This technique is the latest and most modern methods that exploit the spatial analysis models for a number of phenomena and analyzed quantitatively and descriptively.

3. Data and Methods

Through what has been monitored by Kuwait national seismic network (KNSN), which established in 1996, this digital real-time seismic network consists of seven short-period (three-component) and one very broadband seismometers. Distributed in the map figure 6, and table 1.

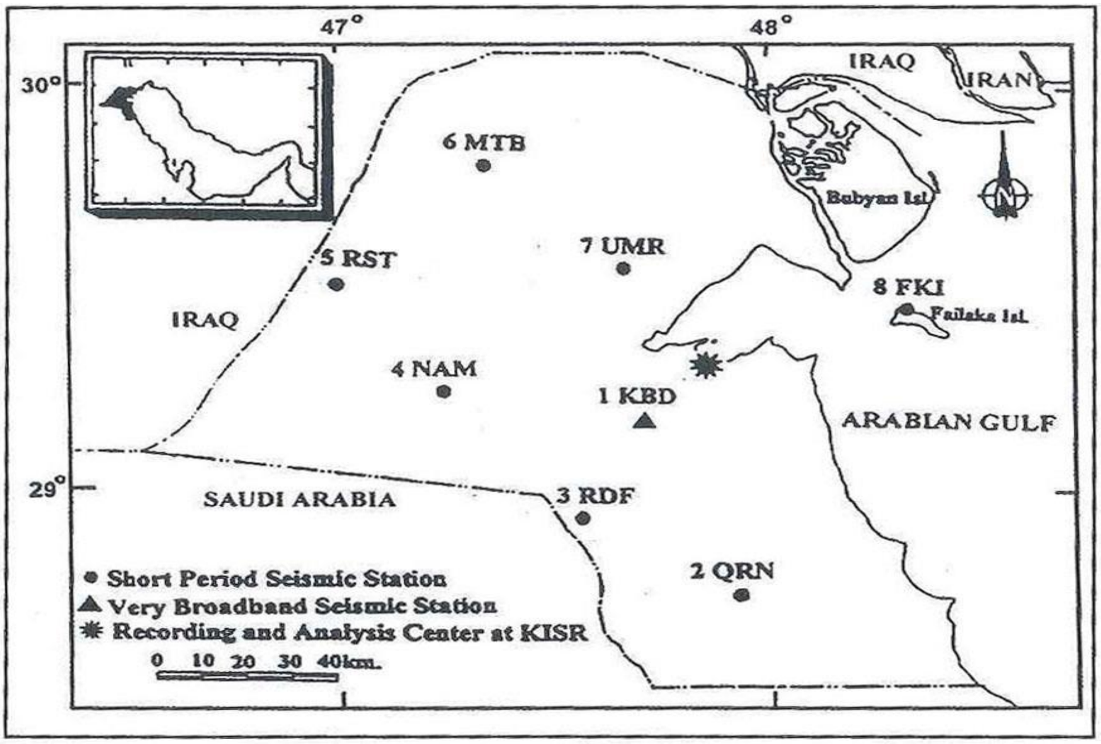

Figure 6: KNSN Stations

Table1: KNSN Seismic field station and their location

Station name (code)	Latitude(N)	Longitude (E)	Elevation(M)
Al-kabd(KBD)	**29˚10.533'**	**47˚41.600'**	124
Al-Qurain (QRN)	**28˚44.665'**	**47˚55.063'**	135
Al-Redifah(RDF)	**28˚55.553'**	**47˚32.983'**	180
Al-Naaiem(NAM)	**29˚14.935'**	**47˚14.527'**	218
Umm Al-Ruwaisat	**29˚30.017'**	**46˚59.833'**	218
Mutribah (MTB)	**29˚48.191'**	**47˚20.326'**	125
Umm Al-Rimmam (UMR)	**29˚33.115'**	**47˚42.950'**	82
Failaka(FKI)	**29˚26.825'**	**48˚18.790'**	6

All earthquake events were taken from 1997 to 2012 **(see tables supplements)**, where consist of 676 earthquakes that hit all over state's areas. On the other hand, the researcher used **ArcGIS Desktop 10**, as a tool and instrument to link spatial data together and then do analysis that serve the topic of the search. In the beginning, researcher entered vector map for Kuwait and make it to raster, after that he chose a coordinate system to the map, so that for conduct all the gained data to catch best analysis possible, the researcher divided the methodology to several steps, which are:

a- From **ArcCatalog 10** program, choose **Personal Geo-database**, to be a database that include all layer that created in , for example, from Geo-database choose feature class to create a new layer that has known coordinate system and has a type classification (polygon, line, point) first, to insert Kuwait base map , from feature class choose the type (polygon) and the coordinate system which is (GCS_WGS_1984 Zone), after that draw the map and make it as a base map.(figure7)

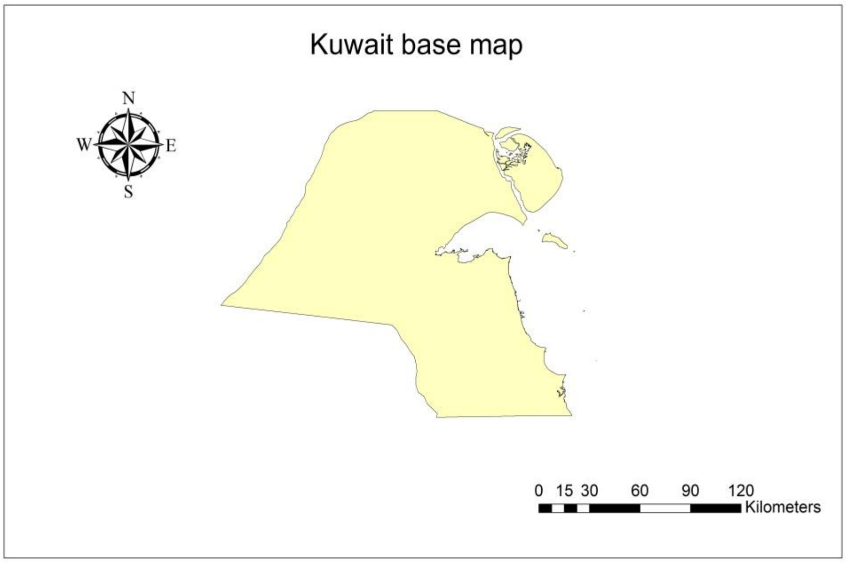

Figure 7: Kuwait base map

b- Second step is about insert seismicity data **(see tables supplements)**, which was taken from KNSN from year 1997 to 2012 consist of 676 events. From Microsoft excel add the table which has a known X,Y coordinate system to ArcGIS from add data tool, then overlay seismic layer on Kuwait base map from overlaying tool-Arctool box, we can observe that from figure 8 , points is consist of 5 classes, dark brown points are (high magnitude up to 4.3M) and yellow points are (less magnitude*).*

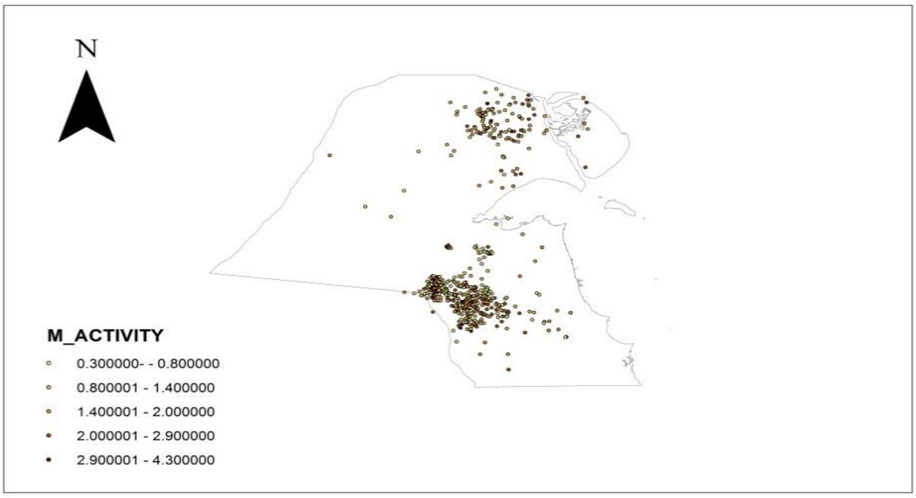

Figure 8: Magnitudes classified into groups

c- Third step is overlay structure map which contains from oil field, structural closure and types of faults, on Kuwait base map and then create buffer zone from Arctoolbox choose analysis tool, proximity, and the choose buffer in 2 kilometer square in line features , such as trends and Kuwait arch to help us to know more carefully the relationship between earthquake events and Kuwait structure, the final step is choosing spatial join between two layer which are: 1-m_activity, 2-the layer that we want to join such as trend in figures 9 and 10.

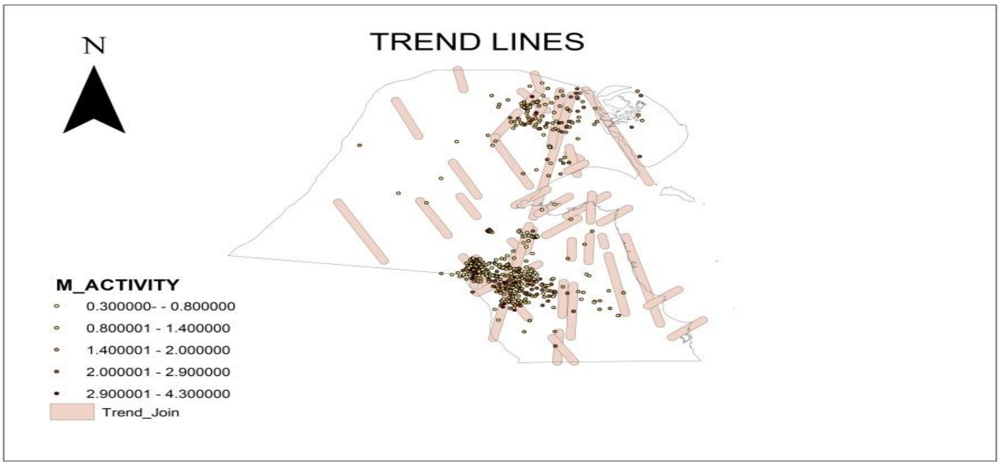

Figure 9: Spatial join tends with seismic points

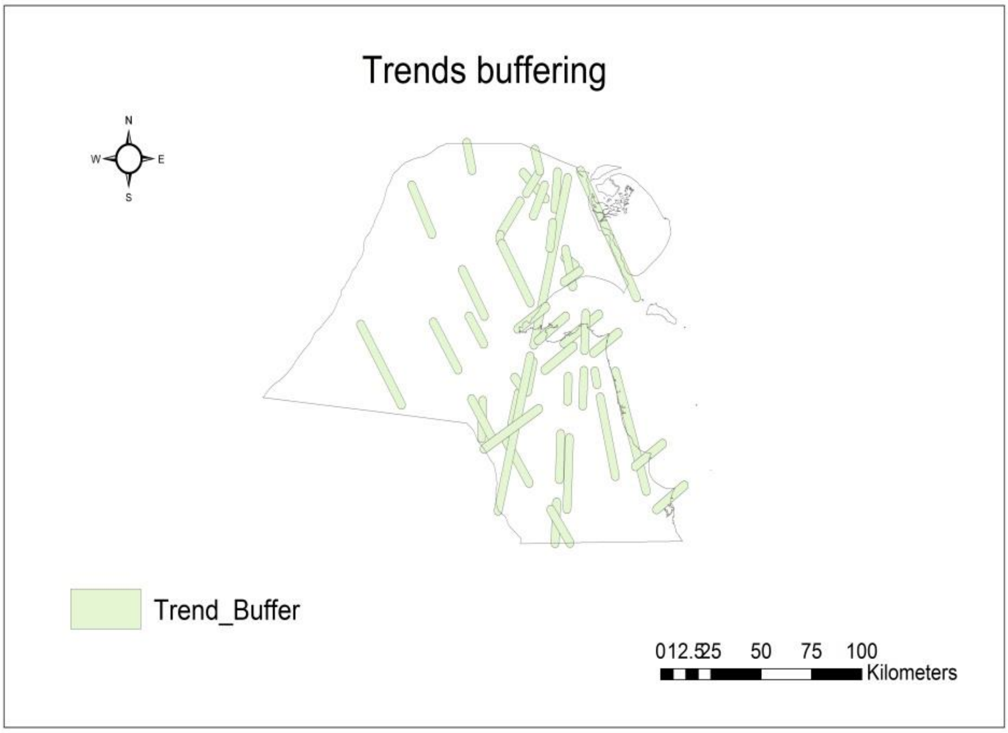

Figure 10: Trend buffers

d- The fourth step is to draw polygon for oil fields that consist of eleven fields spread all over the state , and then connect it with magnitude layer, and join it to show the relation between them.

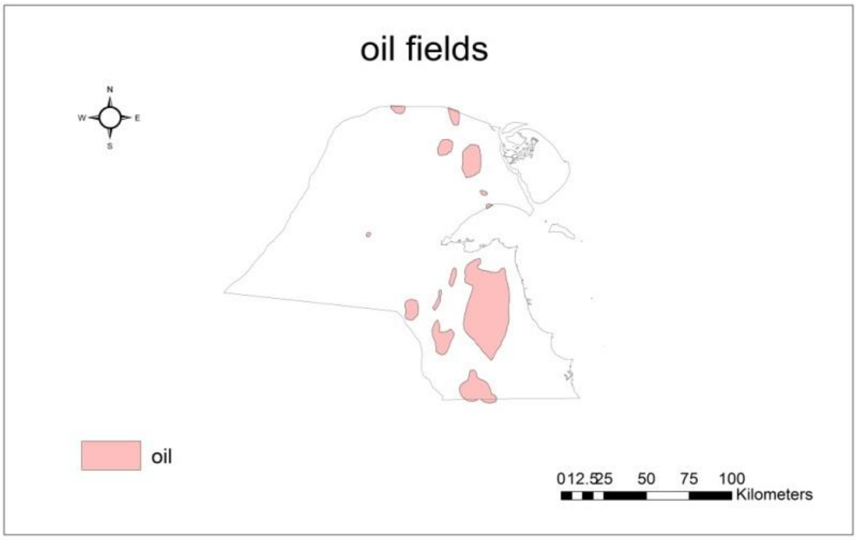

Figure 11: Kuwait oil fields

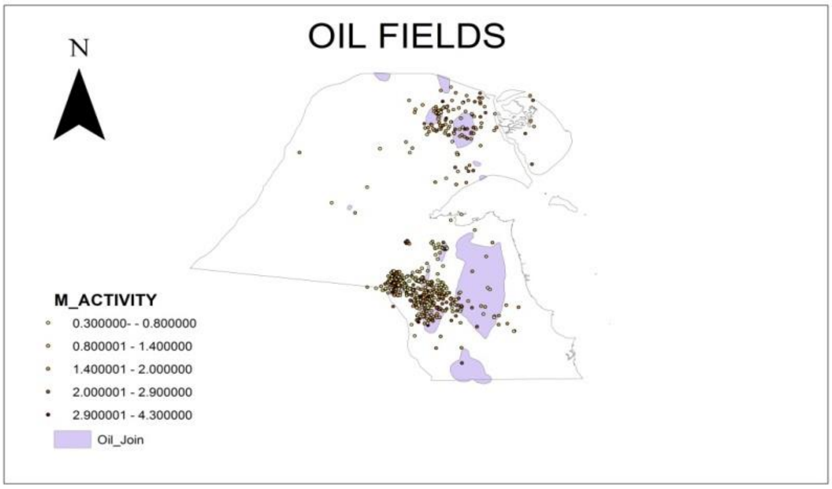

Figure12: Joining Oil Fields with Seismic Events

5. Results:

The main causes for local earthquakes are reveal from overlying geological features by using GIS, the mining activities in oil fields considered the first cause for the seismic activities, as well as lithology with shallow effect in the events.

6. Conclusions:

Association between the geological structural features and epicenters indicate the influence of the structural features in localizing the movements due to earthquakes. Favorability for the occurrence of an epicenter at any location when that variable is present and negative weight indicates the favorability when the variable is absent. Subsurface structure, appears to have some influence in localizing epicenters. This may be a reflection of continuity between these features to ant great depths, where the foci are located. Among the geological variable set, some variables are indicative of their 'negative' control on epicenter location. However, the geological meaning if this negative relation is nor too clear. Further work, using statistical modeling is needed to evaluate the relationships.

7. Recommendations:

Local earthquakes in Kuwait are very important issue, that need for more studies to explore it in an international base. Efforts should be existing from government and scientific research institutes to tackle any interventions and disasters in the future. As well as to evaluate the present situation and its effects on the urban zones
.

8. Acknowledgments:

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9. Tables supplements:

Year	Month	Day	Hour	Minute	Second	Latitude	Longitude	Depth	Magnitude
1997	12	30	18	18	32.2	28.808	47.69	7.1	4.3
1998	11	11	0	23	23.5	30.002	47.939	7.6	2.9
1998	11	23	0	8	12	29.948	47.94	5	2.8
1999	5	29	15	26	5.2	29.604	47.906	9.7	2.5
1999	6	1	11	19	8.8	29.965	48.191	19.3	2.6
1999	6	11	0	44	40.4	29.077	47.539	3.4	2.5
1999	7	8	10	38	10.2	29.243	47.591	6.2	2.8
1999	7	8	22	25	34.2	29.237	47.586	4	2.8
1999	7	9	0	39	26.8	29.229	47.588	5.3	3.4
1999	8	19	9	3	8.4	29.559	48.684	6.5	2.5
2000	11	9	16	9	16.4	29.794	48.155	4.5	2.7
2001	4	22	1	41	45.4	29.818	47.866	6.3	3.1
2001	12	1	9	3	0.1	29.836	47.762	1.1	2.9
2001	12	1	9	3	0.3	29.873	47.777	22.4	3.1
2001	12	1	9	3	0.1	29.836	47.762	1.1	2.9
2001	12	1	9	3	0.3	29.873	47.777	22.4	3.1
2002	8	19	7	17	58.3	28.905	47.524	10.6	2.6
2002	11	29	14	42	51.2	29.05	47.539	4.9	2.9
2003	1	7	15	11	37.6	29.047	47.539	3.9	2.8
2003	1	26	17	55	53.8	29.026	47.576	3	2.6
2003	1	26	17	56	20.7	29.001	47.576	7.9	2.5
2003	7	14	23	18	23.1	29.05	47.537	3.5	2.5
2003	7	20	13	27	22.4	28.948	47.662	7.5	2.5
2005	9	18	6	22	11.7	28.834	47.637	13.2	2.7
2005	9	20	13	30	56.7	29.034	47.549	3.2	2.5
2005	10	15	11	39	58.9	28.993	47.613	4.5	2.5
2005	10	18	8	30	3.8	28.993	47.625	5.4	3.1

2005	11	24	16	9	52.6	29.02	47.529	4	2.6
2006	3	21	6	55	38.3	28.971	47.745	4.3	2.7
2006	3	21	6	55	38.3	28.971	47.745	4.3	2.7
2006	4	3	14	24	8.9	29.072	47.536	3.2	2.6
2006	6	1	10	11	14.2	29.045	47.532	4	2.8
2006	7	31	14	49	15.2	28.925	47.707	7.7	1.9
2006	8	10	22	30	22.8	28.914	47.717	2.4	2.1
2006	8	11	0	8	39.6	28.921	47.713	5.9	2.4
2006	8	13	20	14	10.6	28.986	47.698	3.4	1.5
2006	8	30	8	52	10.7	29.087	47.522	0.1	2.2
2006	9	2	20	35	5.2	28.934	47.806	4.2	1.7
2006	9	13	16	8	55.5	29.052	47.516	3.5	1.8
2006	10	3	9	15	7.8	29.042	47.543	1.9	1.4
2006	10	3	10	55	3.3	29.05	47.534	0.5	1.6
2006	10	6	1	37	32.6	29.874	47.847	8.4	1.3
2006	10	11	20	34	8.1	29.042	47.534	2.3	1
2006	10	13	4	23	28.1	28.952	47.753	4.2	1.9
2006	10	21	23	49	39.4	29.199	47.767	3.2	3
2006	10	22	5	44	22.9	29.206	47.759	3.8	1.3
2006	11	1	23	57	2.6	28.307	48.871	2.4	1.6
2006	11	9	14	38	28.8	28.926	47.653	4.3	1.8
2006	11	18	1	37	48.8	28.899	47.9	8.8	2.1
2006	12	5	2	31	49.2	29.182	47.746	4.4	1.1
2006	12	11	15	19	8.3	28.692	47.85	1.2	1.8
2006	12	29	10	22	30.2	28.977	47.521	3.9	3.6
2006	12	31	10	27	1.6	29.044	47.539	3.6	1.2
2007	8	17	22	46	14.8	28.824	47.644	7.3	4.3
2007	8	17	23	3	13	28.842	47.65	7.3	3.1
2007	12	25	13	21	35.2	29.894	47.735	8.1	2.7
2007	12	29	21	26	39.5	28.926	47.779	8	2.6
2008	3	10	4	48	48	29.013	47.708	4.6	2.7
2008	8	1	19	48	37.7	28.963	47.712	5.2	2.7
2012	2	4	4	7	5	28.889	47.742	7	2.7
2012	2	13	8	54	29.8	29.96	47.76	10	3.6
2012	8	2	13	25	31.1	29.62	47.82	8.1	2.6
2012	8	2	16	47	58.3	29.88	47.94	8.1	3.9
2012	8	2	16	54	46.1	29.8	47.898	8.1	2.5
2012	8	2	20	28	17.3	29.88	47.94	8.1	2.6
2012	9	7	15	8	7.5	28.899	47.731	5.5	2.6
2012	12	16	23	51	56.5	28.922	47.661	7.4	2.6

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