GEOLOGICAL HAZARDS IN IRAQ, CLASSIFICATION AND GEOGRAPHICAL DISTRIBUTION

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ABSTRACT

The recorded geological hazards in different parts of Iraq are of 15 types. Although they are not well recorded and documented, but still a series of Geological Hazard Maps at scale of 1: 250 000 is compiled in the State Company of Geological Survey and Mining (GEOSURV) that covers the whole Iraqi territory in 39 quadrangles. Moreover, Geological Hazards Map of Iraq at scale of 1: 1000 000 is compiled too. Each of those maps is enclosed by a report in which the existing geological hazards are documented, zoned and ranked. Except the data of GEOSURV, and seismicity and meteorology, almost no other geological hazards data are available, in Iraq.

This study depends mainly on the aforementioned maps, beside the available data concerning the geological hazards, like historical books, journals and field observation. Each type is zoned according to its Time of Occurrence and Intensity of Damages caused, consequently a weight is given, which differs in different areas, in Iraq, for the same type. The geological hazards are ranked according to the given weights, their distribution and total scored weights, in different parts of Iraq are demonstrated statistically.

For each of the 15 recorded types of the geological hazards, examples are given, with documented damages in properties and lives lost. The damages and lives loss are also statistically demonstrated. Many hot spots were found in different parts of Iraq. The most dangerous and effective geological hazard was found to be the floods, in rivers and valleys, whereas the least effective one was found to be the Tectonic active areas. Two new classifications for the geological hazards are introduced. The natural radiation hazards are excluded from this study.

المخاطر الجيولوجية في العراق، تصنيفها وتوزيعها الجغرافي

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المستخلص

توجد خمسة عشر نوعاً مختلفاً من المخاطر الجيولوجية في العراق، وبالرغم من كونها غير موثقة بشكل جيد، إلا أن سلسلة من خرائط المخاطر الجيولوجية من مقياس 1: 000 250 قد أعدت في الشركة العامة للمسح الجيولوجي والتعدين (جيوسيرف)، والتي تغطى مساحة العراق بتسعة وثلاثين لوحة، إضافةً الى خريطة المخاطر الجيولوجية للعراق من مقياس 1: 000 1000. وهذه الخرائط مرفقة بتقارير توضح أنواع المخاطر الجيولوجية، توزيعها الجغرافي، تصنيفها وترتيبها مع ذكر أمثلة متنوعة توضح الخسائر المادية والبشرية. باستثناء المعلومات الموثقة في جيوسيرف والرصد الزلزالي ومحطات الأنواء الجوية، لا تتوفر معلومات أخرى عن المخاطر الجيولوجية في العراق، إلا ما ندر، وذلك في بعض الكتب التاريخية والجرائد اليومية.

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اعتمدت هذه الدراسة بشكل أساسي على الخرائط المذكورة في أعلاه، إضافةً إلى أفضل المعلومات الموثقة في مصادر متنوعة عن المخاطر الجيولوجية. وكل نوع من المخاطر الجيولوجية قد صنف بمفهومين: الأول نسبةً إلى الفترة الزمنية المطلوبة في حدوثها، وقسمت إلى ثلاثة أنواع وهي آنية ولمدة عدة أيام، والثانية تستمر إلى 25 سنة والثالثة أكثر من 25 سنة. وأعطيت للأولى ثلاثة درجات وللثانية درجتان وللثالثة درجة واحدة، وهذه بدورها قسمت إلى نوعين: أضرار كبيرة وعندها تعطى نفس الدرجة، وأضرار بسيطة وعندها تعطى نصف الدرجة. والمفهوم الثاني يعتمد على الأضرار الناتجة من جرائها، وقد قسمت إلى خمسة أنواع، ابتداءً من الأولى وهي أضرار بسيطة جداً والى الخامسة وهي أضرار كبيرة جداً في الممتلكات والأرواح. وعليه أعطيت للمخاطر الجيولوجية وزناً معيناً لكل منها، واعتماداً على الأوزان المذكورة في أعلاه فان الوزن الكلي يتغير من مكان إلى آخر في العراق ولنفس النوع. وتم ترتيب المخاطر الجيولوجية نسبةً إلى أوزانها، واستعرضت توزيعها الجغرافي ووضحت في خرائط مختلفة.

أعطيت أمثلة متنوعة لكل من أنواع المخاطر الجيولوجية مع ذكر الخسائر الناجمة في الممتلكات والأرواح في مناطق مختلفة من العراق. وهذه الخسائر مُثلت إحصائياً وظهرت العديد من المناطق الساخنة في العراق. ووجد أن أكثر المخاطر الجيولوجية خطورةً هي الفيضانات والسيول، أما أقلها خطورةً فكانت المناطق النشطة بنيوياً. تم في هذه الدراسة استحداث تصنيفين جديدين للمخاطر الجيولوجية في العراق. وان المخاطر الجيولوجية الناجمة عن الإشعاع الطبيعي قد استبعدت من هذه الدراسة.

INTRODUCTION

Iraqi territory has diverse topography, morphology and rocks cover; therefore, 15 types of geological hazards are developed over the whole territory. The whole territory could be classified into seven physiographic provinces (Fig.1). In the middle part, the Mesopotamia Plain is developed that starts from the Arabian Gulf, in the south extending northwest wards for about 730 Km, attaining to a height of about 150 m (a.s.l.), near Baiji. It comprises of alluvial sediments of the Tigris and Euphrates Rivers with their distributaries, and Shat Al-Arab, exhibiting different geological hazards, like floods, piping, sabkhas, sea water intrusion, and depressions. To the west of this vast plain, the Iraqi Southern and Western Deserts cover almost one third of the whole territory; it is covered by sedimentary rocks with very rugged topography in different parts; as in Ga'ara Depression. The surface topography increases in height westwards attaining height of about 1000 m (a.s.l.), near Jabal Anaza, exhibiting different types of geological hazards, like floods, mass movements, karstification, swelling clays, depressions. Both deserts are dissected by very dense valleys exhibiting floods. In the Southern Desert, the karst phenomenon, which is very intensely developed, forms another type of geological hazards. To the north of the Mesopotamia Plain and the deserts, exist the Jazira Area, in the west (west of the Tigris River and north of the Euphrates River) and mountainous area to the north. The Jazira Area exhibits very dens karstification, due to the presence of gypsum beds, and characterized by the presence of numerous salt pans. The mountainous area covers the remaining part of the territory, it is divided into two parts: Hilly areas attaining (500 – 1000) m (a.s.l.), and mountainous areas attaining (1000 – 2500) m (a.s.l.) with maximum height of 3600 m (a.s.l.); in the extreme northeastern part. These two parts are covered mainly by different sedimentary rocks, but in the extreme northeastern parts, by igneous and metamorphic rocks. This diversity in rocks and topography leads in exhibiting different geological hazards like mass movements, floods, karstification, neotectonic movements, pollution, earthquakes, mining disasters and gypsum induced hazards.

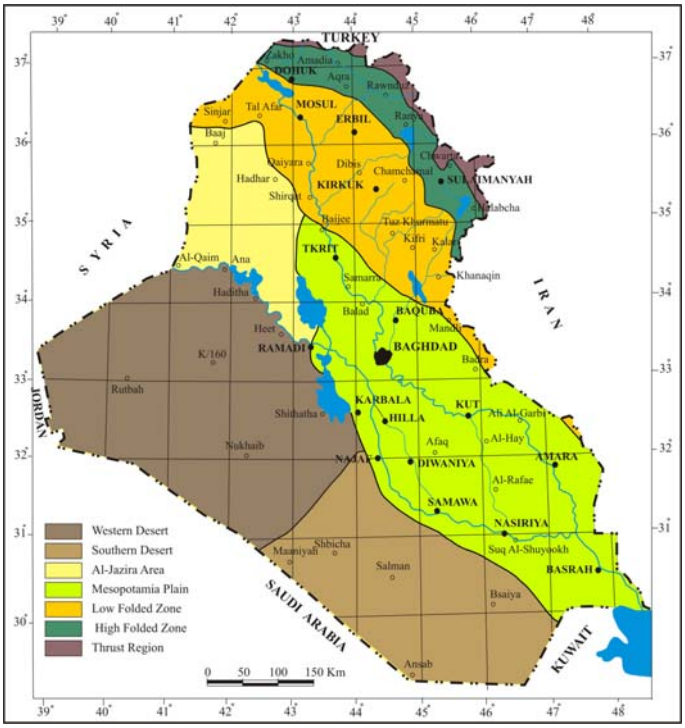

Fig.1: Physiographic provinces, exhibiting different types of geological hazards

METHODOLOGY AND MATERIALS USED

Iraq is covered by 39 quadrangles at scale of 1: 250 000; the geological maps of the same scale were published by GEOSURV during 1992 – 2009, depending on the geological maps at scale of 1: 100 000. The complied Geological Hazard Maps at scale of 1: 250 000 depend mainly on the published Geological Maps at scale of 1: 250 000 by GEOSURV (1992 – 2009). However, the compiled maps that cover the whole Iraqi territory are presented only in 35 sheets, because some of the quadrangles are combined with their adjacent quadrangle in one sheet (Fig.2).

The preparation of the Geological Hazard Maps at scale of 1: 250 000 with the enclosed report were acquired depending mainly on the available geological maps and other relevant maps and reports. This technique was used because a "geologic – hazard area is an area of definable extent that has similar geological attributes and which geological hazard could be caused by, or adversely effect, some human activity" (Soule, 1980). Data concerning the geological hazards are mainly available in GEOSURV; others like seismological or meteorological data (I.M.O., 2000) are available too, but no precise data about the damages and lives lost are available, unfortunately, to the authors.

Granger and Hayne (2001) used the same technique in Australia. This method is also followed by UNESCO (1976) in Soule (1980) and in the United States of America, "where engineering geological maps that already are prepared from surficial geological maps are deemed most desirable as geological hazards map" (Soule, 1980). Therefore, the geological units that are involved with geological hazards are changed to geological hazard units (areas) and that will elucidate the susceptible areas for the given geological hazard(s). Those geological units, however, which are not related to geological hazards, are considered on the maps as **"areas possibly free from geological hazards"** (scored **Zero** weight). Moreover, other information, such as pollution sources, quarries, mass movements, earthquake epicenters, etc. was added from other available maps and reports.

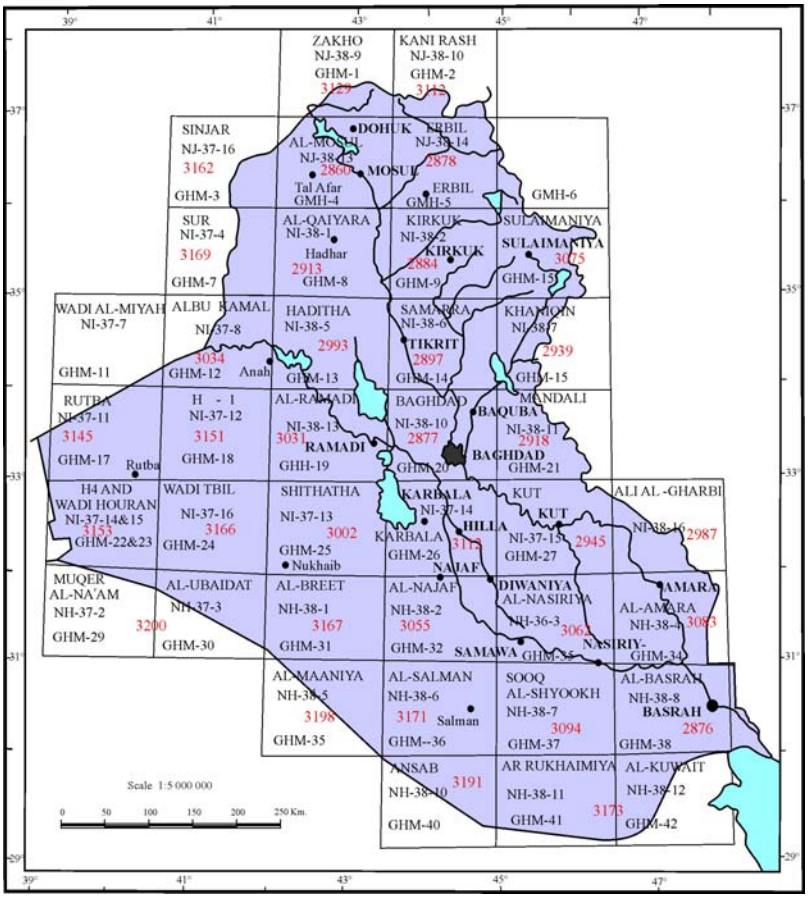

Fig.2: Geological Hazard Map Quadrangles at scale of 1: 250 000,
with their serial numbers, names and GEOSURV library depository numbers (in red)

The following data were used in concluding this study:

- Geological Map of Iraq, scale 1: 1000 000, 3rd edit. (Sissakian, 2000a)
- Geological Hazards Map of Iraq, scale 1: 1000 000 (Sissakian and Ibrahim, 2005)
- Neotectonic Map of Iraq, scale 1: 1000 000 (Sissakian and Deikran, 1998)
- Tectonic Map of Iraq, scale 1: 1000 000 (Al-Kadhimi *et al*., 1996 and Fouad, 2010)
- Geomorphological Map of Iraq, scale 1: 1000 000 (Hamza, 1997)
- Geological Hazard Maps of Iraq at scale of 1: 250 000, 39 quadrangles (GEOSURV, 2003 – 2009)
- Hydrogeological Maps of Iraq scale 1: 250 000, 39 quadrangles (GEOSURV, 2001 – 2008)
- Topographic maps of different scales
- Aerial photographs and Landsat images of different scales
- Google Earth images, 2009
- Other available materials like historical books, reports, field observations.

It is worth to mention that the geological hazards caused by natural radiation are excluded from this study, because the involved data are not available to the authors. However, they are restricted in the northeastern, central and southern parts of Iraq, in restricted areas.

GEOLOGICAL HAZARDS

▪ General

Geological hazards are defined as "naturally occurring or man-made geological condition or phenomenon that represents a risk or is a potential danger to life and property". Examples are landslides, flooding, earthquakes, ground subsidence, coastal and beach erosion, faulting, dams leakage and failure, mining disasters, pollution, waste disposal and sea water intrusion" (Bates and Jackson, 1980). Moreover, Johnson and Luza (1981) divided the geological hazards into two types: **Natural geological hazards** and **Man-made geological hazards** emphasizing on the activities of man that may play the essential role in development of geological hazards in present or future. According to Soul (1980) geological hazards mean "a situation or state of affair that has been caused by an interaction between a human activity and an adverse geologic condition or conditions". It is worth mentioning that the majority of the damages caused by geological hazards in Iraq are man-made.

Because geological hazards are related to certain geological and/ or man-made conditions(s), therefore each type happens in certain area, when one or more of these condition(s) occur, or is in a potential occurrence (ready to be triggered). However, in certain areas more than one type of geological hazards may occur. For details about the geological hazards in Iraq, refer to Sissakian (2000b).

The 15 types of the geological hazards (Fig.3) were presented in the Geological Hazards Map of Iraq at scale of 1: 1000 000 (Sissakian and Ibrahim, 2005), they were zoned according to two concepts (Sissakian and Ibrahim, 2002): **First**: the **Term of Occurrence**, which depends on the required time to feel their effect; on properties and lives lost, this zonation includes three zones: **1) Short Term**, which means immediately after occurring of the geological hazard and lasts for few days. **2) Medium Term** that occurs within 25 years. **3) Long Term** that occurs after more than 25 years. **Second:** the **Intensity of Damages** on properties and lives loss, this zonation includes five zones, Zone 1 exhibits minimum damages, whereas Zone 5 exhibits maximum damages. The total acquired weight from both zonations for each type of the geological hazards was used in this study for their ranking purposes and other statistical and graphic demonstrations.

▪ Types of the Geological Hazards

The recognized 15 types of the geological hazards, in Iraq, by Sissakian (2000b) and Sissakian and Ibrahim (2005) are:

1- Floods, 2- Earthquakes, 3- Mass movements, 4- Karstification, 5- Depressions, 6- Gypcrete, 7- Swelling clays, 8- Pollution, 9- Gypsum induced hazards, 10- Tectonic active areas, 11- Sand dunes, 12- Marshes (Organic soils), 13- Sabkhas, 14- Mining disasters, and 15- Sea water intrusion.

The occurrence of each type of the geological hazards in each quadrangle at scale of 1: 250 000 with their total scored weights is presented in Table (1).

▪ Frequency of Occurrence Classes

According to the frequency of occurrence, for each type of the geological hazards in each quadrangle area (at scale of 1: 250 000)**,** the geological hazards in Iraq are classified into four classes:

- **Low Occurrence Class**, includes 3 types
- **Medium Occurrence Class**, includes (4 – 6) types
- **High Occurrence Class,** includes (7 – 9) types
- **Extremely High Occurrence Class,** includes (10 – 11) types

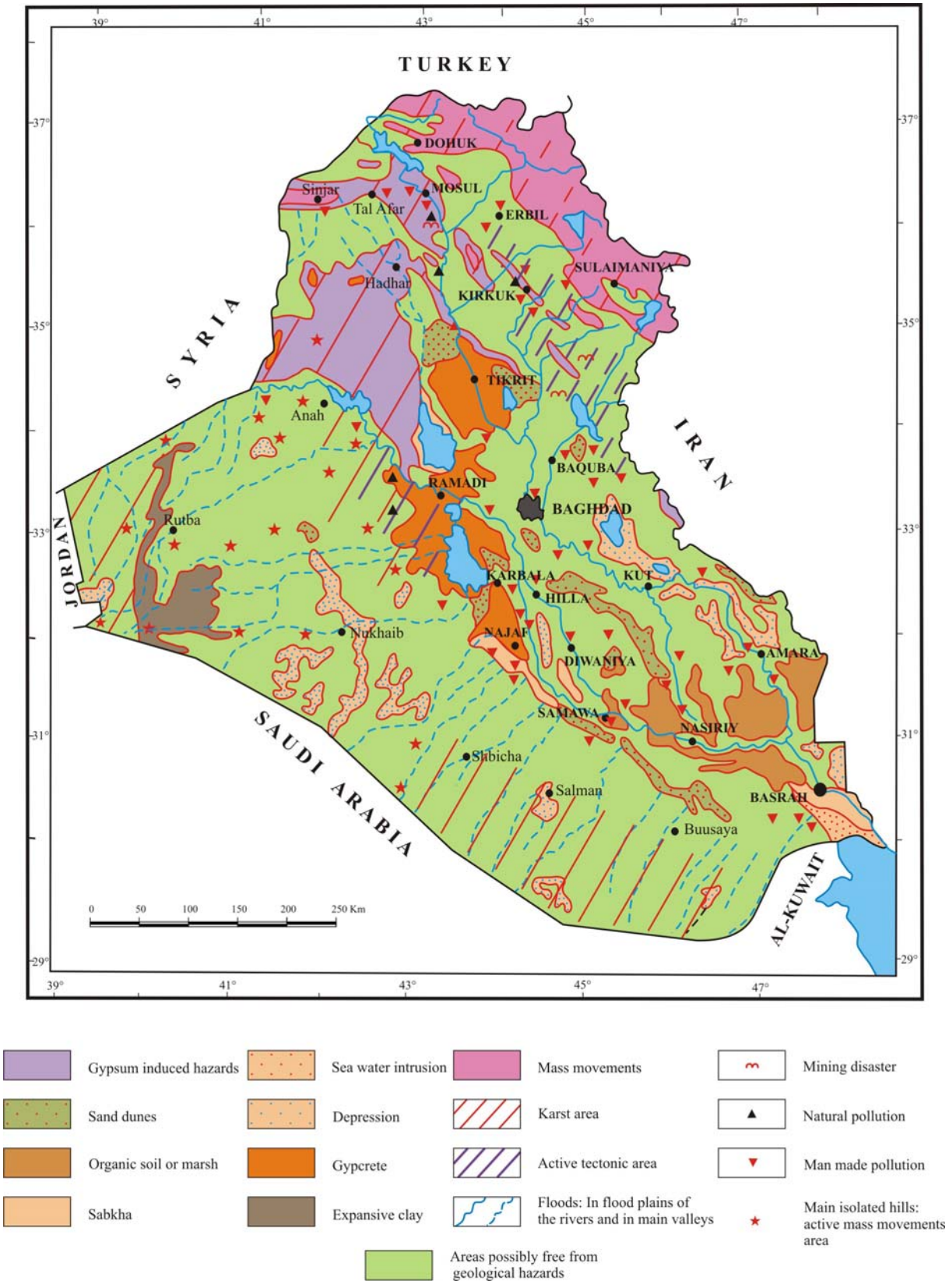

Fig.3: Simplified Geological Hazards Map of Iraq
(modified from Sissakian and Ibrahim, 2005)

Table 1: Occurrence of the geological hazards with their total scored weights (within the 35 quadrangles)

QUADRANGLE NAME	GEOLOGICAL HAZARDS																
	Floods	Earthquakes	Mass movements	Karstification	Depressions	Gypcrete	Swelling clays	Pollution	Gypsum induced hazards	Tectonic active areas	Sand dunes	Marshes (organic soil)	Sabkhas	Mining disasters	Sea water intrusion	Number of Geological hazards	Total Scored weight
Zakho	2.5	2.5	6	2					2							5	15
Kani Rash	2.5	2.5	6	2												4	13
Sinjar	5	2.5	2.5	2				2	2							6	16
Mosul	6	6	7	6				9	4					4		7	42
Erbil and Mahabad	7.5	4.5	7.5	1.5				2	1.5	1.5						7	26
Sur	2.5		2.5	2					2		2		2			6	13
Qaiyarah	11	2.5	5	4	2.5	6		4	3		2		5			10	45
Kirkuk	10	2.5	4		2.5			10	1.5	1.5	2		2.5			9	35.5
Sulaimaniyah	9	9	9	4				4	2	1.5						7	
Wadi Al-Miyah and Albu Kamal	5		2.5	4	2			4	2				2			7	21.5
Haditha	10		2.5	8	2	4		2	2	1.5	3		2			10	37
Samarra	9.5	3.5	2.5		2.5	3		7	1.5	1.5	4		2	3		11	41
Khanaqin	9.5	2.5	2.5	1.5				3	1.5	1.5				3		8	24
Sab'a Ebyar and Rutbah	7.5		5	2	2		5	3.5								6	25
H 1	5		3.5	5	2					1.5	2					6	19
Ramadi	7.5		2.5	2.5	2	2		7	2	2.5			4			9	32
Baghdad	11	7			2.5	6		4			4	2	2			8	38.5
Mandali	7	2	2	2				3	1.5	1.5	3					8	20
H 4 and Wadi Hauran	3.5		2.5	2	2		2									5	12
Wadi Tabil	2.5				2		2									3	6.5
Shithatha	7.5		2.5	1.5	3	2		2		1.5			2			8	22
Karbala	7.5		2.5		2	2		5			6	2	2			8	29
Kut	7.5	5		2.5	4		2	2			2	2				8	27
Ali Al-Gharbi	2.5	2.5	2.5		3			2			2					6	14.5
Muger Al-Naam and Ubaidat	3.5				2		2									3	7.5
Birreet	2.5			2	2					1.5						4	8
Najaf	5		2.5	2	2	2		4		1.5	4		2			9	25
Nasiriyah	7.5				2			4		1.5	5	2	2			7	24
Amarra	4	2.5			2			4				6				5	18.5
Ma'aniyah	2.5			2	2											3	6.5
Salman	3.5			2	2											3	7.5
Sooq Al-Shiyookh	7.5			2	2			2		1.5	2	2				7	19
Basrah and Abadan	3	2.5			2.5	2		2			2	2	2		3	9	21
Ansab	2.5			2	2											3	6.5
Rukhaimiyah and Kuwait	2.5			2	2											3	6.5

The frequency of occurrence of each type of the geological hazard in Iraq is demonstrated statistically in Fig. (4) and as geographical distribution in Fig. (5). Figure (5) shows the geographical distribution of the four classes of geological hazards in Iraq. The Low Class exists in the desert area and covers six quadrangle areas. The Medium Class exists randomly in different parts of Iraq; western, northern, eastern and southern parts and covers ten quadrangle areas. The High Class exists more widely in the central, northeastern and southeastern parts and covers sixteen quadrangle areas, whereas the Extremely High Class exists in the north of the central part of Iraq and covers only three quadrangle areas. It is very clear from the distribution of the four classes (Fig.5) that the frequency of the occurrence increases with the increase of the population and density of the infrastructures.

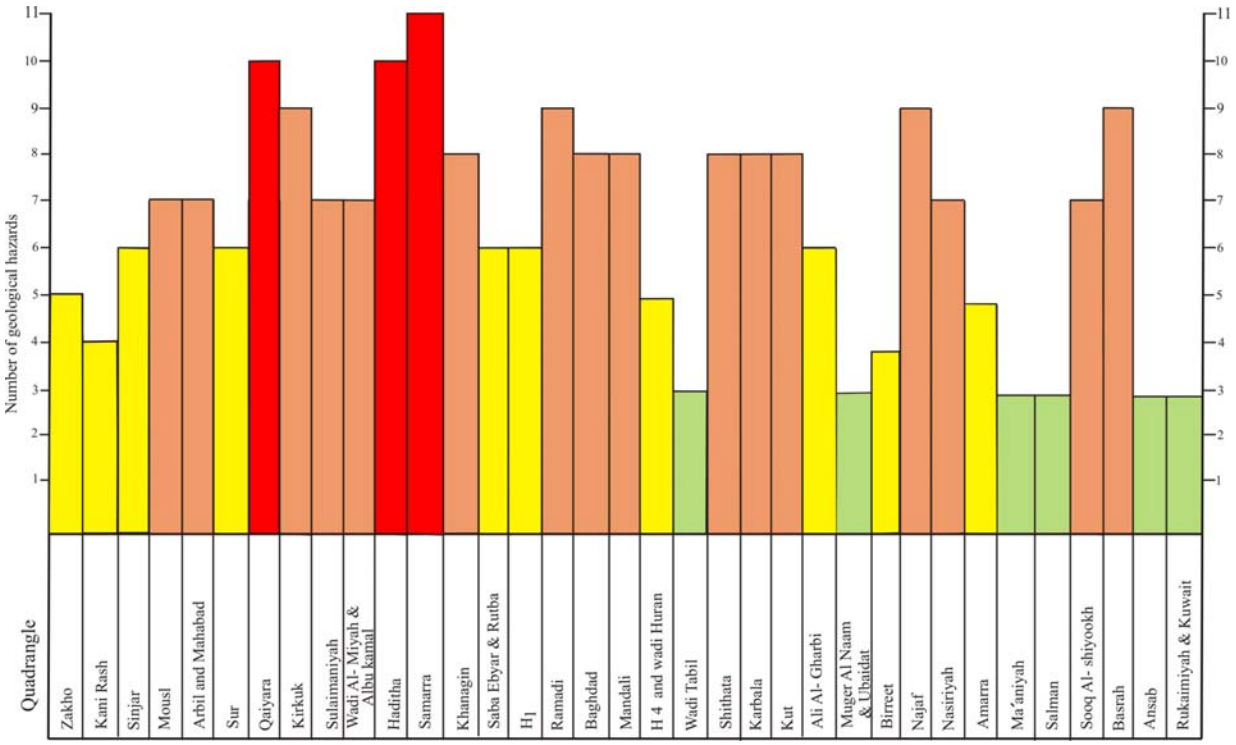

Fig.4: Frequency of occurrence within geological hazards in Iraq
(as distributed over quadrangles at scale of 1: 250 000)

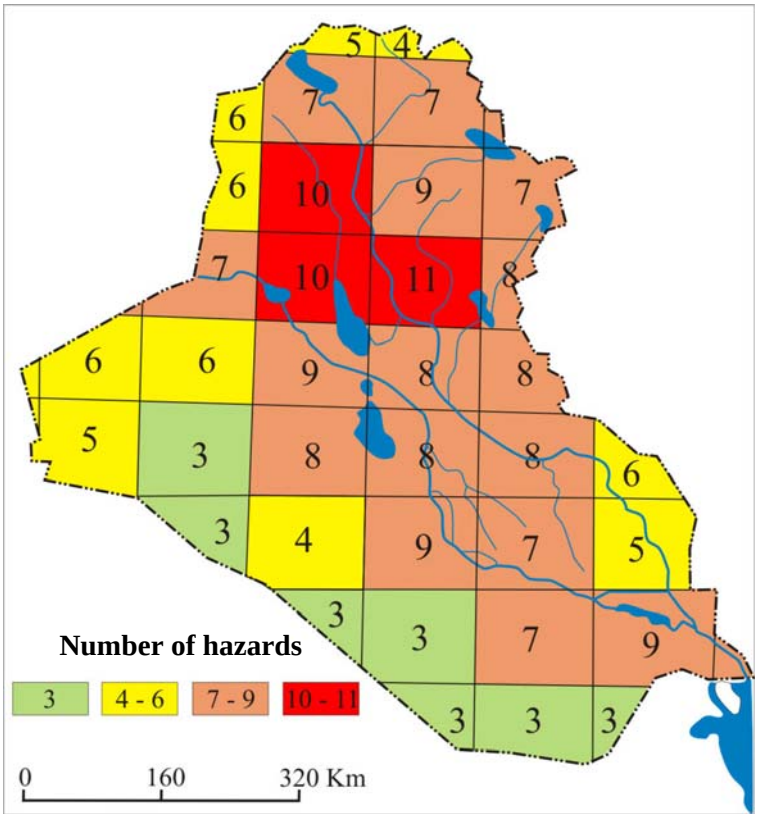

Fig.5: Map of the Frequency of Occurrence Classes of the geological hazards
(within each quadrangle area at scale of 1: 250 000)

▪ **Damages and Lives Loss**

Although the caused damages and lives lost; due to the geological hazards are not well documented, but still a significant data were furnished by GEOSURV (2003 – 2009) within the geological hazard maps at scale of 1: 250 000 and the enclosed reports. The recorded damages and lives loss were given certain weights that start by **2 degrees** (as minimum) and end by **11** (as maximum), for a single type of a geological hazard, whereas the total scored weight for all existing types of the geological hazards within a certain quadrangle area (at scale of 1: 250 000) starts with **6.5 degrees** and ends by **45** (Table 1). The scored weight by each geological hazard in the 39 quadrangles is demonstrated graphically (Fig.6.1 – 6.15). This was done by pointing the center of each quadrangle by the scored weight of a certain type of the geological hazard, and then the center points were contoured, in interval of one degree. In reviewing the constructed maps (Fig.6.1 – 6.15), it is clearly visible that the damages and lives loss increase in certain parts of Iraq, and in contrary very large parts of Iraq are either free of damages and lives lost or almost are negligible. Many hot spots, however, could be recognized.

▪ **Classes of Geological Hazards**

The geological hazards are classified, in this study, into four classes; depending on the total scored weights for all existing types of the geological hazards, in each quadrangle. The four classes are shown in Table (2).

Table 2: Geological hazard Classes depending on the total scored weight

CLASS	TOTAL SCORED WEIGHT
Low hazards	6.5 – 12
Medium hazards	13 – 25
High hazards	26 – 36
Extremely high hazards	36.5 – 45

The range of the total scored weights in the four classes is not uniform (Table 2). This is because the classes did not depend on the scored weights only, but number of the geological hazards, in each quadrangle and the coverage involved area too.

The Geological Hazards Classes map (Fig.7), which is constructed by pointing the centre of each quadrangle at scale of 1: 250 000 and marking the total scored weights for all existing hazards, then contouring them, shows the distribution of the aforementioned four classes. It is clear that the majority of the Western and Southern Deserts belong to the Low Hazards Class; because no infrastructure exists there and are almost free of habitants. The Medium Hazards Class covers five areas; within the Iraqi territory: **1)** Narrow strip in the extreme western part, **2)** Northern part, **3)** Eastern part, **4)** Narrow strip that extends west of the Euphrates River and parallel to it, and **5)** Lower part of the Mesopotamia Plain. The first four areas, are also poorly populated with rare infrastructure, therefore the damages and lives lost are rare. In the last area, although it is highly populated, but the recorded hazards have low weights, either due to the type of the geological hazards that act in those areas, or due to lack of main infrastructures. The High Hazards Class covers very small part of the Iraqi territory; only three quadrangles; Erbil – Mahabad, Karbala and Kut are involved. The involved areas are highly populated with main infrastructures; therefore the damages and lives lost are comparatively high. The Extremely High Hazards Class covers almost the central part of the Iraqi territory, where the infrastructure is the highest with very dense population.

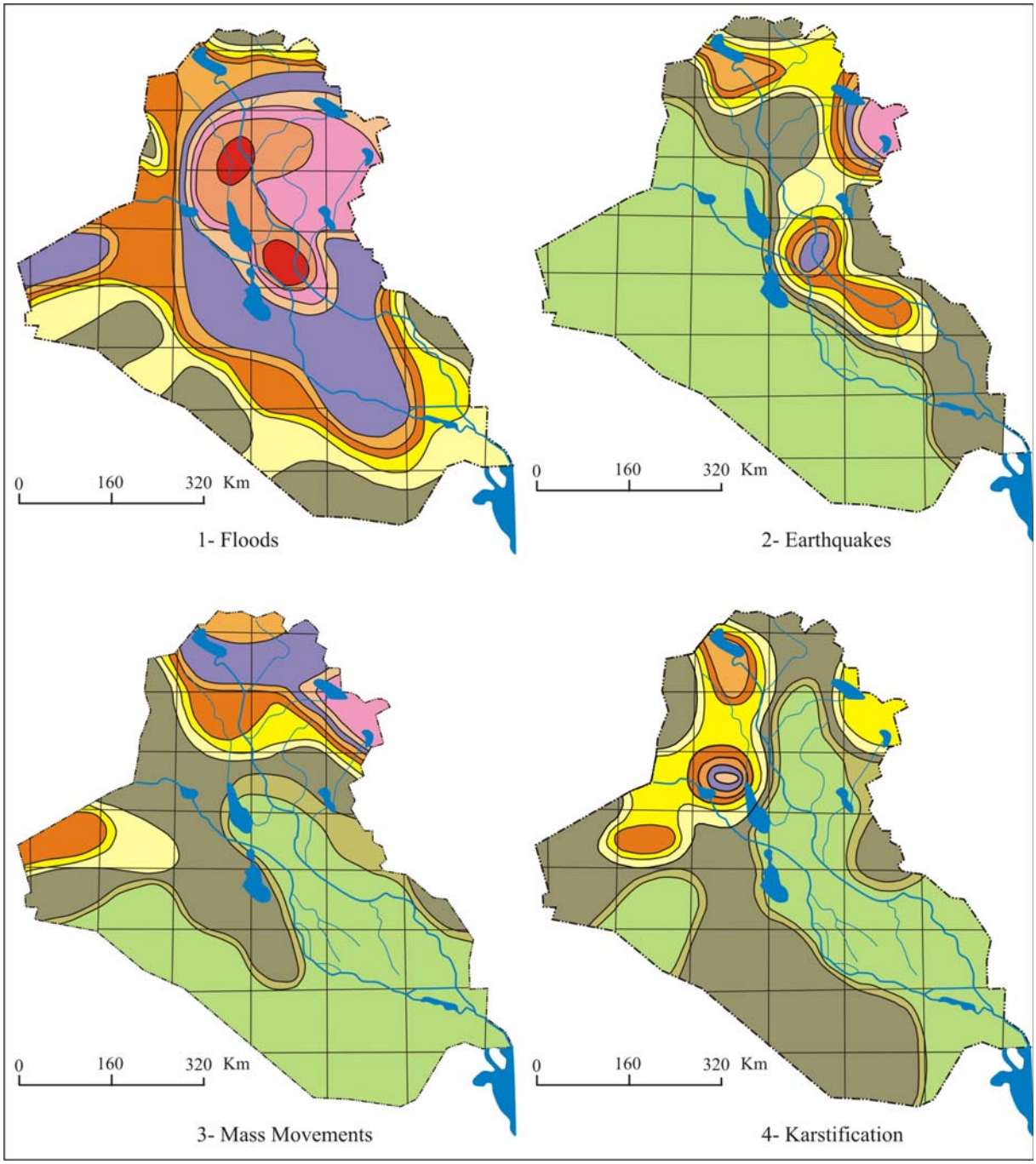

Fig.6 (1 – 4): Total scored weight maps of the geological hazards
For legend, refer to Fig.6 (13 – 15)

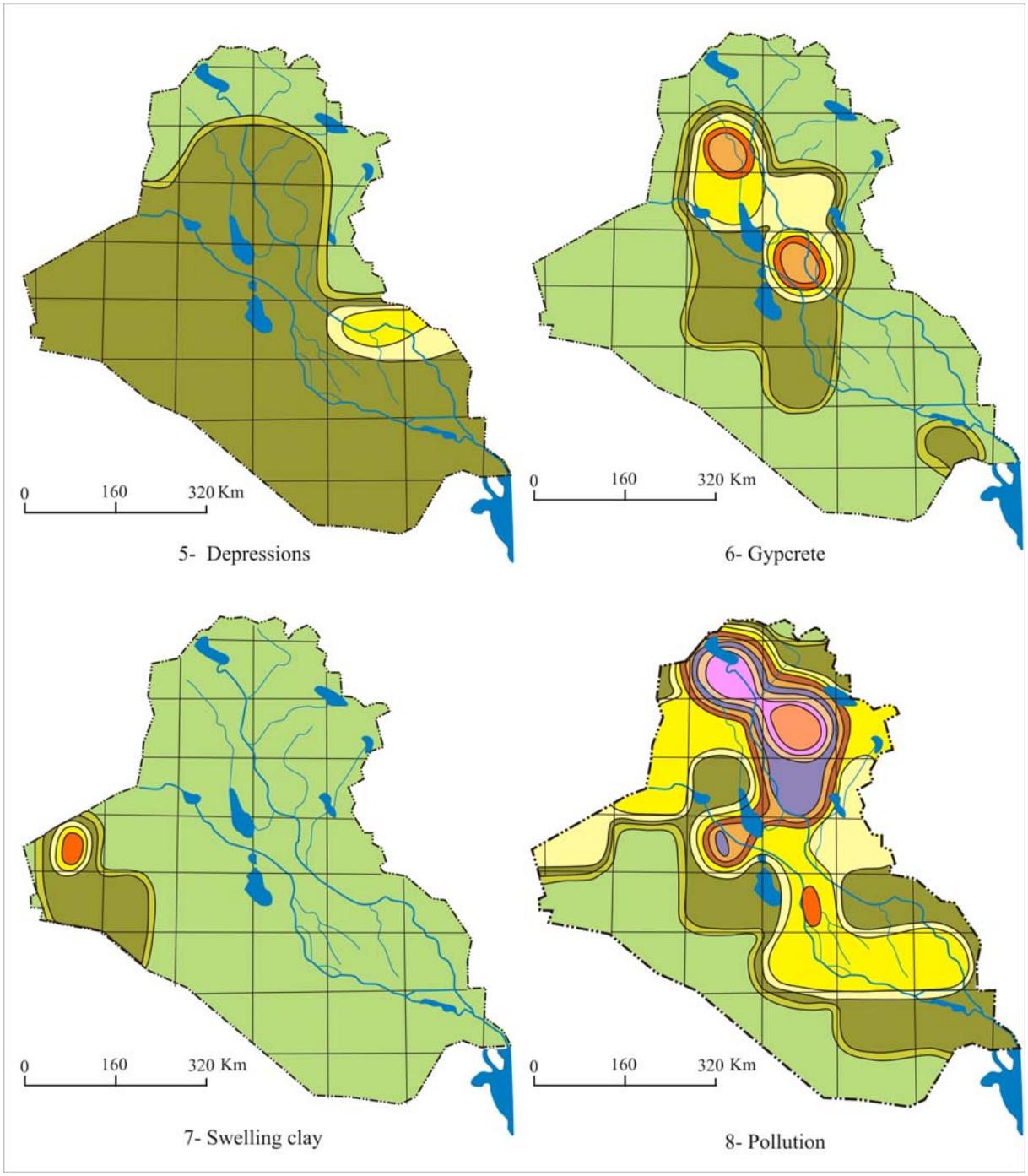

Fig.6 (5 – 8): Total scored weight maps of the geological hazards
For legend, refer to Fig.6 (13 – 15)

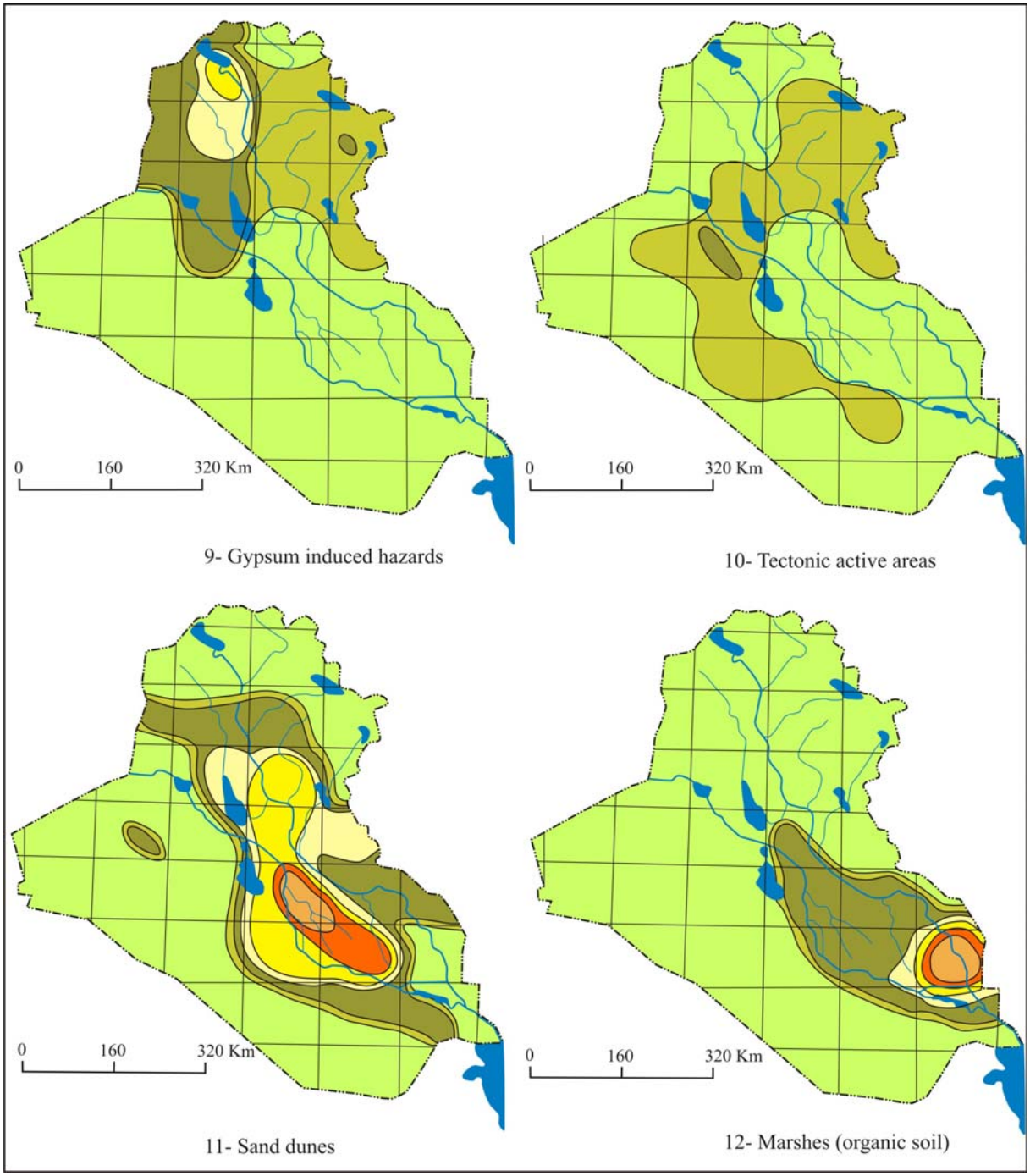

Fig.6 (9 – 12): Total scored weight maps of the geological hazards
For legend, refer to Fig.6 (13 – 15)

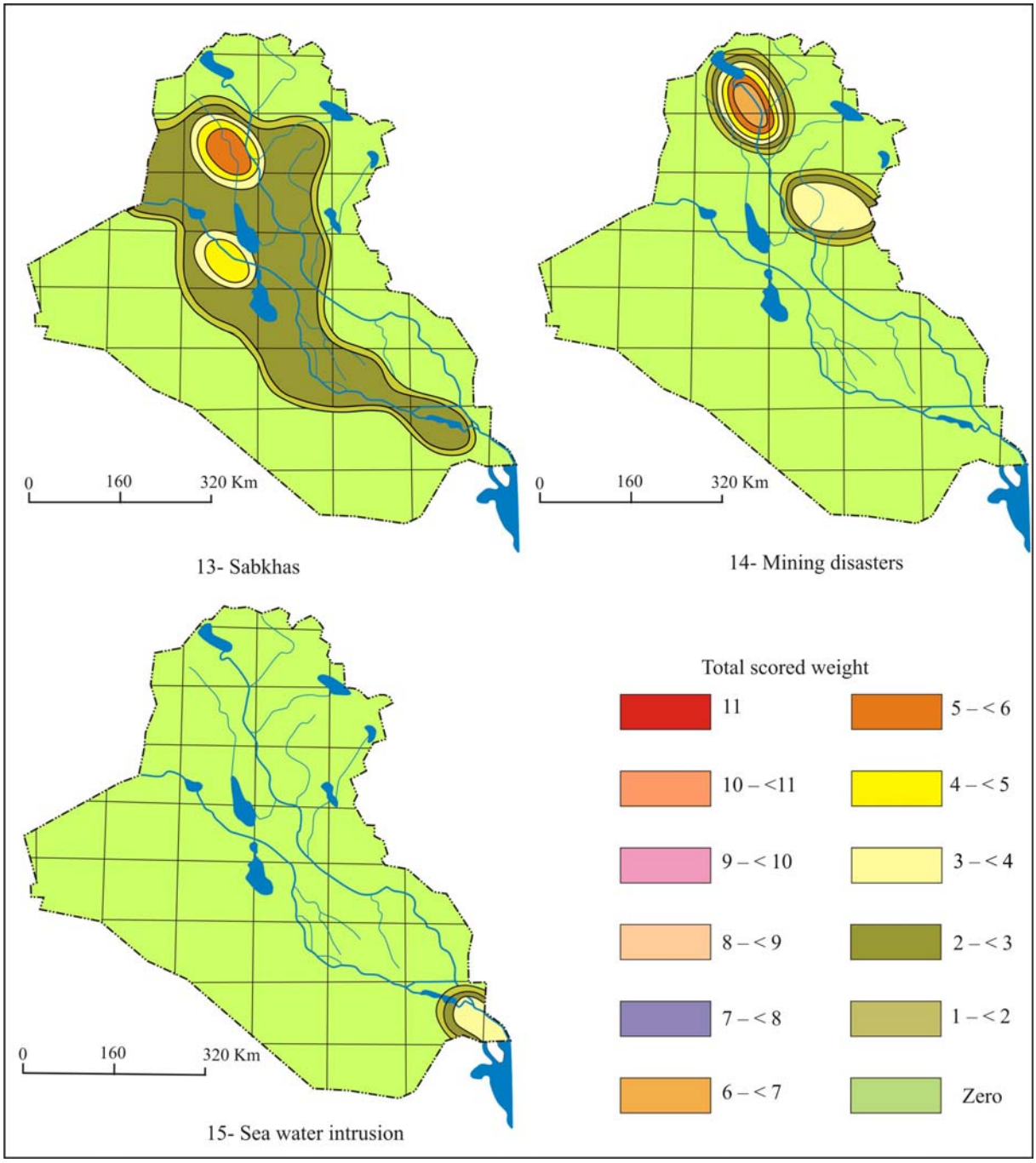

Fig.6 (13 – 15): Total scored weight maps of the geological hazards

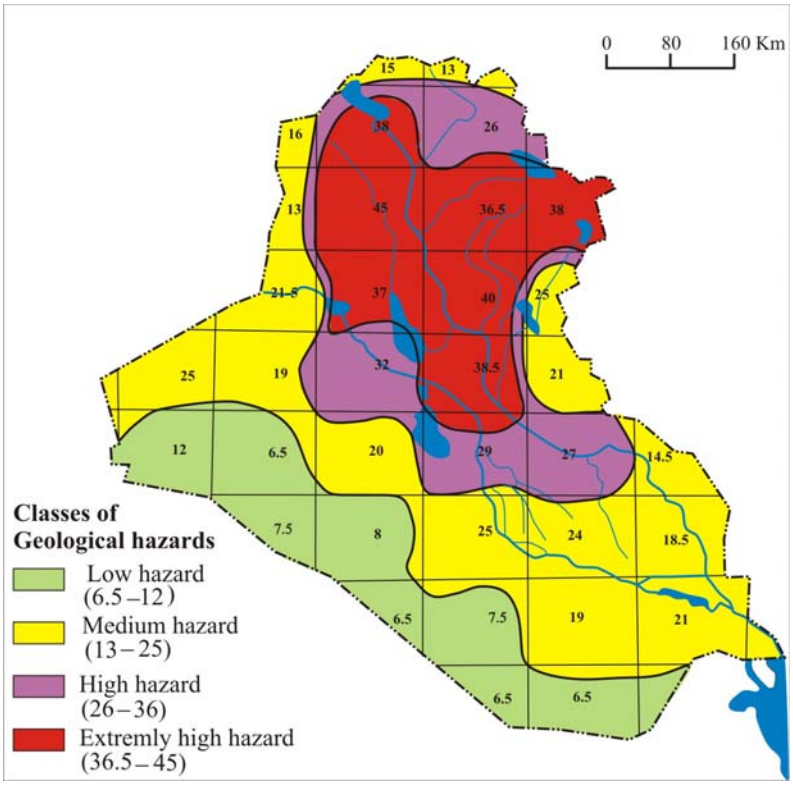

Fig.7: Geological Hazards Classes map

▪ **Examples From the Geological Hazards**

The 15 geological hazards that act in different parts of the Iraqi territory are reviewed hereinafter with few examples from the recorded damages and lives lost; for each type. Each geological hazard is demonstrated in a special map that clarifies its geographic distribution over the Iraqi territory (Fig.8.1 – 8.15). By coinciding the total scored weights map for each type of geological hazard (Fig.6.1 – 6.15) with that which shows its geographic distribution (Fig.8.1 – 8.15), the intensity of each type of the geological hazards within the Iraqi territory could be realized. The 15 types of geological hazards are mentioned hereinafter with examples; those that bear no reference are from the senior author's observations.

– **Floods:** Floods are the most widely expressed type of geological hazards in Iraq. They could be developed in all parts of the Iraqi territory (Fig.8.1), either in the main rivers and their tributaries or in the main valleys, which are shown in Fig. (8.1). Although the amount of the rainfall is drastically decreased during the last years, but still some flood events were recorded. The scored weights of the geological hazards are shown in Fig. (6.1). Therefore, floods still could be expected and because their assessment needs long period of records, which may attain 100 years (Johnson and Luza, 1981). Some examples are given bellow.

- During 1934, a heavy rain shower caused the flood of the main valleys in Tel Kaif district, north of Mosul, causing the death of about 40 children, in a kindergarten.
- During 1954, the flood of the Tigris River caused the inundation of Al-Rasheed army camp and majority of Al-Rasafa district; the estimated cost of the damaged military ammunition and others was 15 000 000 Iraqi Dinars, which was twice the governmental budget, and evacuation of 250 000 people (Al-Warid, 1989).

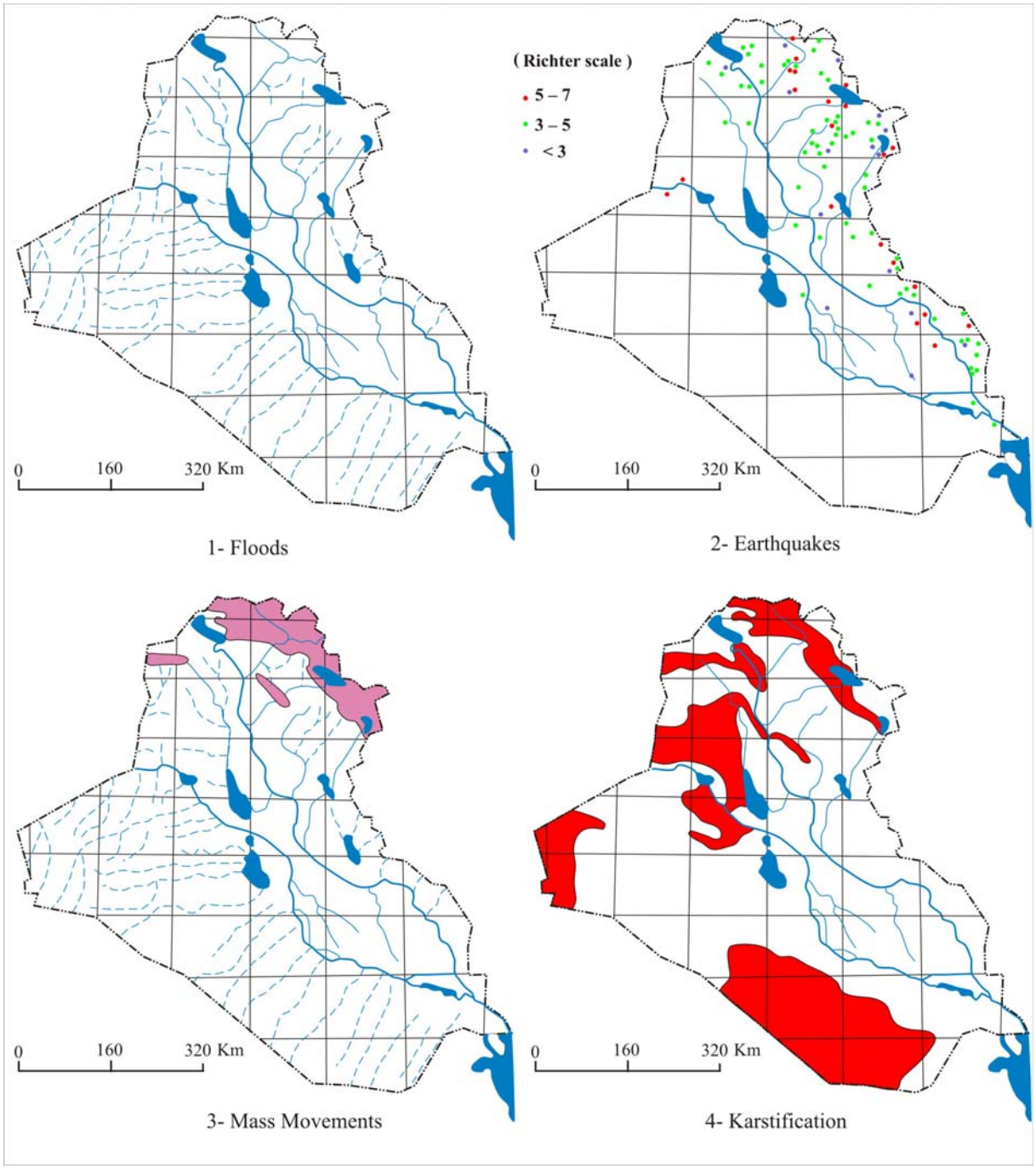

Fig.8 (1 – 4): Geological hazard maps

- In1957, after very heavy rain shower, the flooded valleys that flow from Azmir Mountain down to Sulaimaniyah City caused the death of 15 persons and damages of more than 500 shops (Al-Hasany, 1988).
- On November 1963, two persons from one family were dead due to over flooding of a valley west of Kirkuk, near Baba Gur Gur.
- On November 1973, three to five persons were dead, within a car during their crossing along the bridge of the flooded wadi Ezghaidan, south of Haditha.
- On 17/ 10/ 1987, after a very heavy rain shower that lasted for about 10 hours, between Rutbah – Akashat vicinity, the main valleys flooded and caused the damage of many culverts along Akashat – Al-Qaim road and along 40 Km the road embankments were totally damaged. The Highway No.1 also suffered from the same event, in the same area, the drain ditches along both sides and middle part of the highway were filled by the eroded materials leading to closure of the ditches, and many slopes were failed too.
- On November 2003, eight to eleven persons were dead, within three cars during their crossing the bridge of the flooded wadi Ezghaidan, southeast of Haditha.
- On 1/03/ 2004, the flood of Euphrates river near Nasiriyah vicinity; 300 Km southeast of Baghdad caused flooding of tens of villages and damaged large agricultural fields, especially in Aqai'qa County (Al-Sabah News paper, March 2003).
- On 08/ 03/ 2005, the flood of Euphrates river near Nasiriyah vicinity; 300 Km southeast of Baghdad caused flooding of 25 villages, evacuation of thousands of the villagers and damaged large agricultural fields, especially in Aqai'qa County (Al-Zaman News paper, March 2005).
- On November 2006, many bridges and culverts were damaged along many main roads in Sulaimaniyah vicinity.
- On November 2007, the constructed dam across Chaq Chaq River, in Sulaimaniyah was collapsed due to over flooding after heavy rain shower.
- On April 2010, the flooded wadi Al-Ubaidh, near Al-Nukhaib, southwest of Iraq, caused the death of 20 persons by swiping their bus from the main bridge along the main Najaf – Ar'ar road.

– Earthquakes: Although now catastrophic earthquake is recorded during the recent history in Iraqi territory, but still many events were recorded that have caused damages and lives loss. The epicenters of the recorded events with their magnitudes are presented in Fig. (8.2), whereas the geological hazards scored weights map is shown in Fig. (6.2), some examples are given bellow:

- In July 1940 and January 1950, earthquakes hit Baghdad; the effects were felt within a circle with diameter of 150 Km; many houses were collapsed (Al-Warid, 1989).
- On 17/ 10/ 1946, 1/ 1/ 1950 and March, 1956 strong earthquakes hit Baghdad causing large damages in properties (Al-Warid, 1989).
- In 1992, Kasimiyah village; 50 Km east of Erbil was trimmed by an earthquake; tens of houses were collapsed but no lives lost was recorded (Sissakian *et al*., 1992).

– Mass Movements: The mass movements are distributed mainly in the northern and northeastern parts of Iraq, also along the banks of main valleys and cliffs, and some isolated hills in the Southern and Western Deserts of Iraq (Figs.3 and 8.3); their regional distribution is shown in Fig. (3), whereas the geological hazards scored weights map is shown in Fig. (6.3), usually, roads are damaged due to different types of mass movements, some examples are given bellow.

- The following main roads suffer from different types of mass movements, usually landslides, mud flows or creep, causing the blockage of the traffic; examples are:
  * Zakho – Kani Massi
  * Sulaimaniyah – Azmir – Qala Cholan
  * Chwarta – Gimo
  * Sulaimaniyah – Dokan – Bustana
  * Descending road from Matin Mountain; northwards to Baigova
- Ganke Village; north of Sulaimaniyah City along the road to Gimo Mountain; is located directly over an old landslide; it is in a very critical position concerning the slope stability.
- In 1972, a large landslide caused by heavy rain shower in Galley village; northeast of Sulaimaniyah led to the death of (20 – 25) persons (Dr.Kamal Haji, personal communication).
- Many landslides still are active and causing serious problems to Darbandi Khan Dam, large allocations are spent to treat the landslide, but still they are active, hitherto.

– Karstification: Different parts in Iraq suffer from intense karstification (Figs.3 and 8.4) (Sissakian and Al-Mousawi, 2007). The geological hazards scored weights map is shown in Fig. (6.4). Limestone beds in many geological formations suffer from intense karstification, among them are: Euphrates, Anah, Pila Spi, Bekhme, Qamchuqa, as well gypsum beds within Fatha Formation, some examples are given bellow:

- The karstification had caused severe economic losses in different parts of Iraq, examples are:
  * Mosul and Haditha Dams
  * Haditha rock slabbing factory
  * Geological complexity at Al-Hussainiyat vicinity in the Iraqi Western Desert, due to karstification of Jurassic and Cretaceous formations had complicated the geological mapping and mining of the Karst Bauxite deposit.
- Lives loss also were recorded due to karstification, among the events are:
  * Three persons were dead due to fall of their car in a well-known sinkhole; "Salman Rosa", in 1956. The sinkhole is very near by to Haditha – Anah road, which was unpaved during the event.
  * Four police men were dead in 1975 due to fall of their car in a sinkhole near Al-Ma'aniyah police post during patrolling in a dark night, it is located in the Iraqi Southern Desert (personal communication with a police sergeant in Al-Sahin police post, 1979).
  * Tens of people were dead after being lost their way to be out from caves in Qara Dagh Mountain, south of Sulaimaniyah (Norri, 1951).

– Depressions: Many depressions are developed in different parts of Iraqi territory (Figs.3 and 8.5); they vary in size from few square hundred meters to few square kilometers. They are almost flat, filled by fines, which are rich in SO_3 and/ or organic material; they also could be rapidly inundated by rain water. The geological hazards scored weights map is shown in Fig. (6.5). Few examples are mentioned bellow:

- Kilo 160 – Nukhaib – Ar'ar main road; southwest of Iraq, crosses a main depression called "Habbariyah Depression", the culverts and road embankments suffer from continuous damages due to over flooding of the depression during heavy rain showers, certainly the maintenance needs high financial allocations.
- Baghdad – Kut – Basrah main road suffers from the same aforementioned problem.

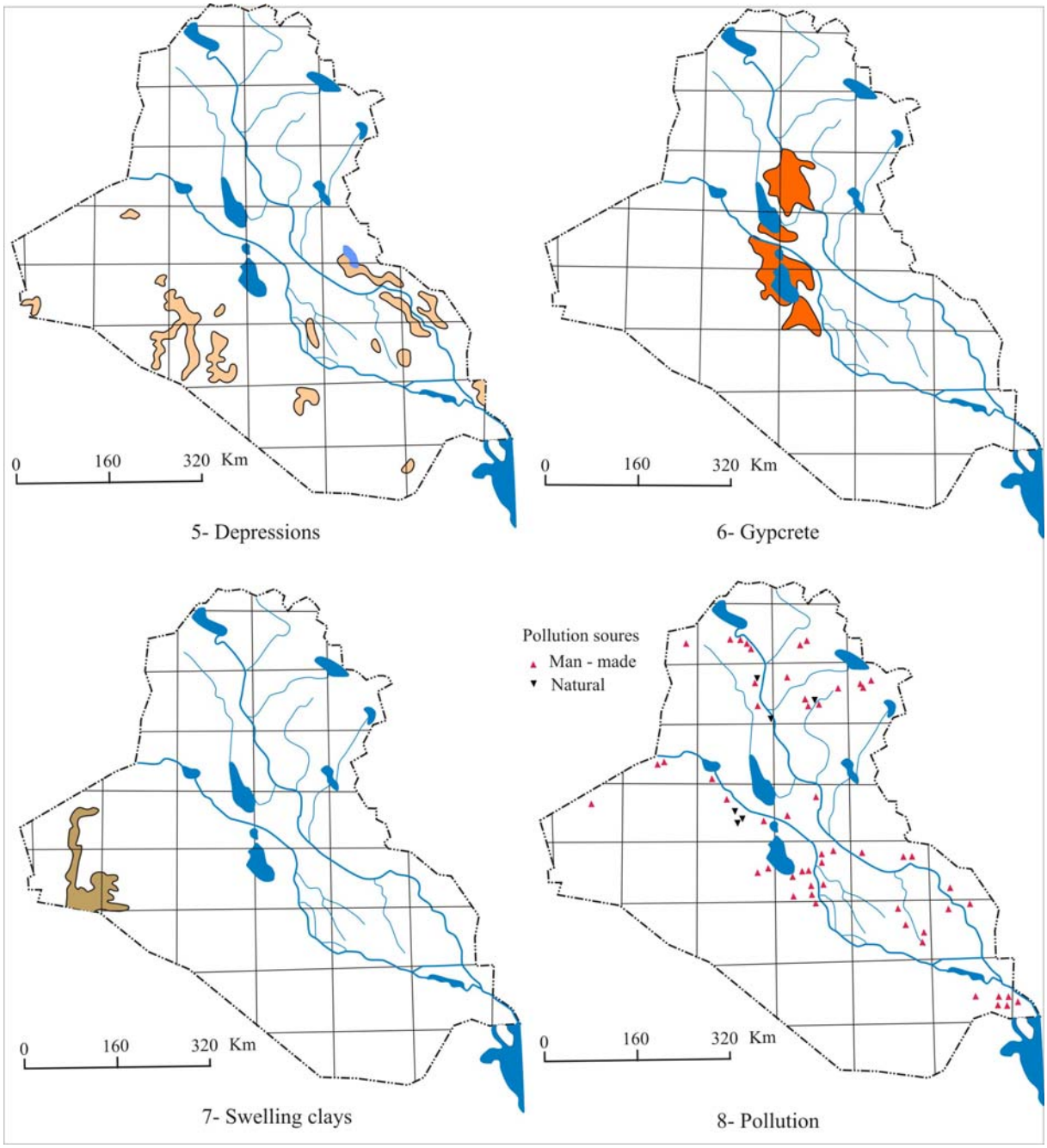

Fig.8 (5 – 8): Geological hazard maps

– Gypcrete: Gypcrete is a highly gypsiferous soil, it causes severe damages to the structures that are constructed over areas covered by gypcrete, because it has very high dissolving ability when oversaturated by water, especially when the thickness is high, which ranges from (1 – 5) m (C.E.S.A., 1992). Considerable parts of the Iraqi territory are covered by gypcrete (Figs.3 and 8.6), whereas the scored weights map is shown in Fig. (6.6), some examples of the caused damages are given bellow:

- Large parts between Baiji and Samarra area; along both sides of the Tigris River, were considered as unfavorable areas and excluded from site selection of a Nuclear Power Plant (C.E.S.A., 1992).
- When the agricultural fields are in areas covered by gypcrete, the farmers suffer from development of large cracks and solution cavities in the soil due to irrigation, this means lost of huge quantities of irrigation water, consequently more power is needed to pump more irrigation water.
- North Fertilizers Plant, which is located near Baiji, 200 Km north of Baghdad, suffers from damages in the foundations, due to the dissolving of the gypcrete by rain water that flows from Makhul Range towards the plant (Al-Bdaiwi and Hijab, 1999).
- Among the other constructed structures over gypcrete that suffer from foundation problems are: Summer residence houses along the eastern bank of Tharthar Lake, Baiji Electric Power Plant, Tikrit Hospital.
- During site selection for dumping of toxic wastes in Iraq; large parts were excluded because they are covered by gypcrete (Specialist Group, 2010).

– Swelling Clays: Swelling (expansive) clays form the main constituent of Digma Formation (Late Cretaceous) that has considerable coverage area in the Iraqi Western Desert (Figs.3 and 8.7). Moreover, some Miocene formations; such as Injana and Mukdadiya also include such cays. The geological hazards scored weights map is shown in Fig. (6.7), some examples of the caused damages are given bellow:

- The residential area of Akashat Mine is located in area covered by the Digma Formation; tens of houses suffer from severe damages due to swelling clays.
- The Highway No.1, about 30 Km northwest of Rutbah town, in the Iraqi Western Desert suffers from disturbances and abnormal undulations, which is not present elsewhere along the highway. This is due to the presence of swelling claystone of the Digma Formation**.** About 10 Km in length, the highway suffers from these disturbances**.**

– Pollution: Pollution is one of the major types of geological hazards all over the world (Coates, 1981) they are either natural or man-made (Johnson and Luza, 1981). In Iraq, both types are present; their distribution is shown in Figs. (3 and 8.8), whereas the geological hazards scored weights map is shown in Fig. (6.8), some examples of the caused damages are given bellow:

- Cement factories blow huge amounts of cement dust that pollutes the air and damages the nearby vegetations and plants. The estimated precipitated dust from Badoosh cement factory in Mosul is 20 ton/ Km^2/ month; it has very harsh effect on eyes and skin inflection and respiratory system, it is worth mentioning that the allowable amounts of the fallen dust is 150 ton/ Km^2/ month in both France and Russia, whereas in Austria is 120 ton/ Km^2/ month (Al-Sa'igh and Al-Kattan, 1986). The distribution of cement factories in different parts of Iraq is demonstrated by Muradian *et al*. (1984) and Sissakian and Ibrahim (2005).
- Brick factories are present in different parts of the Iraq territory (Muradian *et al*., 1984 and Sissakian and Ibrahim, 2005); they blow smoke of the crude burnt oil that has harsh effect

on human's health. A good example is in Al-Nahrawan vicinity, where tens of brick factories are located. They blow the black smoke, because of burning crude oil. The whole area is contaminated by black smoke, which extends with the blown wind for tens of kilometers. Besides, the quarries, which have destroyed the landscape, cause illegal dumping locations for garbage and other waste.

- Among other factories that are source of pollution are: Al-Qaim Phosphate complex, Northern and Southern Fertilizers plants; in Baiji and Basra, respectively, Rock slabbing factories in Haditha, Sinjar and Sulaimaniyah, Glass factory in Ramadi, Mishraq Salphur mine, oil refineries, in different parts of Iraq. Their distribution in different parts of Iraq are demonstrated by Muradian *et al*. (1984) and Sissakian and Ibrahim (2005).
- Gas and bitumen seepages in Kirkuk, Qaiyarah, Hit, Kubaisa, Kifri, etc. their distribution in different parts of the Iraq territory is demonstrated by Sissakian and Ibrahim (2005). These are natural pollution sources. People living nearby vicinities suffer from congenital anomalies; being born blind, deaf, dumb and suffering from paralysis and mental deficiency and other diseases.
- Eternal fire in Kirkuk; near Baba Gur Gur and Kubaisa; near Al-Awasil also play the same role in pollution of the air and the consequent affects, as aforementioned.
- Tens of mineralized springs are natural pollution sources, their distribution in different parts of Iraq are demonstrated by Araim (1990) and Sissakian and Ibrahim (2005). They either yield sulfate water with H_2S emission or saline water, in both cases the nearby soil and vegetation is polluted, beside the air; in the former case.
- On July, 2003 a fire accident in Mishraq Sulfur mine caused enormous economic lost in a large area that extended to Mosul, about 45 Km northwards, the villagers abandoned their villages for more than 10 days, the nearby plantation was enormously affected; large fields were faded and/ or withered, large number of cattle were perished, the air in Mosul city was polluted by toxic fumes.

– Gypsum Induced Hazards: Gypsum is the main constituent of the Fatha Formation, beside marl, claystone and limestone. The presence of this combination of rocks with different competencies had led to severe problems for many engineering structures. The distribution of gypsum in the Iraqi territory is shown in Figs. (3 and 8.9), whereas the geological hazards scored weights map is shown in Fig. (6.9), few examples of recorded problems are given bellow:

- Mosul city is almost totally constructed in an area built up by the Fatha Formation; therefore large parts suffer from the damages of roads, sewage system, and collapse of some houses (Numan and Adeeb, 1997).
- A lot of water wells and springs yield from gypsum aquifers, they all yield polluted water by SO_3 and associated by H_2S emission, consequently in nearby areas the soil is polluted as well as the air, which has direct toxic effect on human's health, beside the damage caused to the vegetation and plantation in such areas involved.
- During site selection for dumping of toxic wastes in Iraq; large parts of the Iraqi territory were excluded because they are covered by gypsum (Specialists Group, 2010).
- Severe engineering problems were met during construction of a special project (Al-Shmoo'a Factory); west of Mosul, due to the presence of gypsum beds (Jassim *et al*., 1987).

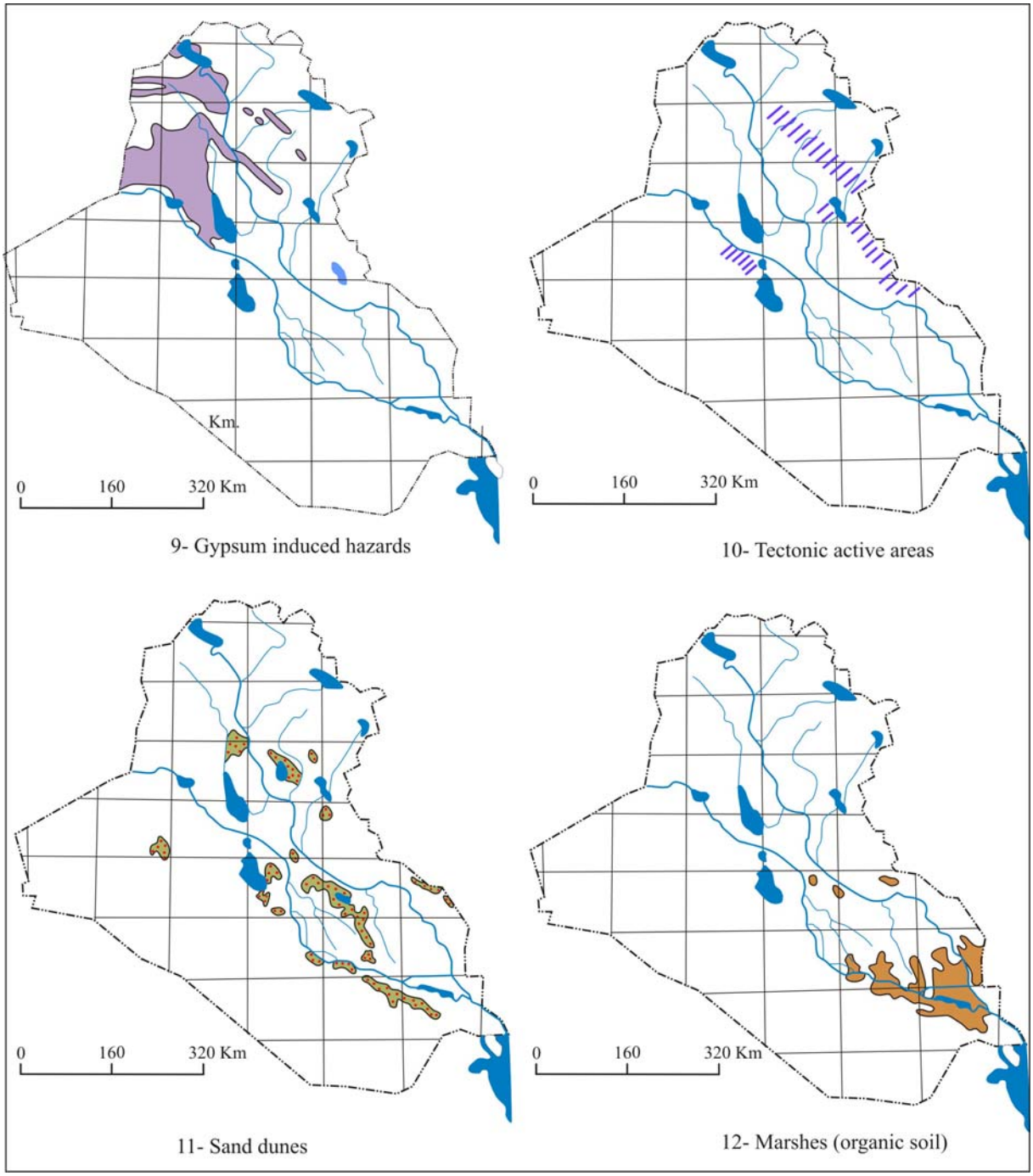

Fig.8 (9 – 12): Geographic distribution maps of the geological hazards

– Tectonic Active Areas: These are restricted to areas that involve faulting during Pleistocene and onwards, the faulted rocks of Bai Hassan Formation are good indication. The involved areas are shown in Figs. (3 and 8.10). This type of geological hazard is a very slow process, the maximum estimated rate of subsidence and up warping; in the Iraqi territory is (–1.6 and 0.8) cm/ 100 years, respectively (Sissakian and Deikran, 1998). Therefore, the effect is felt after long time, consequently the recorded weight for such type of hazards is low. The geological hazards scored weights map is shown in Fig. (6.10). No example is available for such type of geological hazards, except exclusion of large parts during site selection for dumping of toxic wastes in Iraq (Specialist Group, 2010).

– Sand Dunes: Sand dunes cover considerable parts of the Iraqi territory (Figs.3 and 8.11); they have harsh effect on the human's health, especially skin, eyes and respiratory system diseases, besides the corrosion ability of the wind blown sand on the nearby constructed structures. Moreover, it is an effective source for desertification. Different types of hazards were recorded in different parts of Iraq; the geological hazards scored weights map is shown in Fig. (6.11), few examples are given bellow:

- A military air base was abandoned west of Tikrit, central part of Iraq, due to the presence of sand dunes; nearby the base.
- Large parts between Baiji and Samarra area; on both sides of the Tigris River, were considered as unfavorable areas and excluded from site selection of a Nuclear Power Plant (C.E.S.A., 1992).
- Large parts of the Highway No.1 between Diwaniyah and Hilla were not completed since 1985, due to the presence of a main field of sand dunes along and the nearby path of the highway; their presence was an obstacle for the construction.
- Many other main roads, like Nu'maniyah – Hashimaiyah, Samawa – Najaf and others, suffer from blockage due to accumulation of the sand dunes.
- Recently, south and west of Samawa city suffer from the creep of sand dunes. They are covering (continuously) agricultural fields, roads and even some mapped outcrops.

– Marshes: Considerable parts in the south and eastern parts of Iraq are covered by marshes (Fig.8.12), although large parts were dried since 1992, but the rejuvenation of the marshes started since 2004, therefore, the exact coverage area is not well known, hitherto. The marshes are considered unfavorable areas for construction of any type of structures; because they are covered by water with depth that reaches up to few meters and due to the presence of organic soil (Coates, 1981). Although no many structures are constructed in marsh areas, but still they impose geological hazards, the geological hazards scored weights map is shown in Fig. (6.12), few examples are given bellow:

- Extremely large financial allocations were spent in marsh areas during oil exploration activities, such as construction of dykes and roads, using special machinery to access the marshes, which are very expensive.
- The Baghdad – Basrah railway crosses a big marsh called "Hor Al-Hammar"; east of Nasiriyah, southern part of Iraq, although a special dyke is constructed for the path of the railway, but still the railway suffers from many maintenance difficulties and the speed of the train is highly reduced along the marsh area.
- In 1985, during execution of a drilling project by GEOSURV in "Hor Al-Shuwaicha", central eastern part of Iraq, a drilling rig was inundated due to a sudden rain shower that increased the water level in the marsh. The drilling rig was left in the site for four months, without being operated, until the water was dried from the drilling site (Mr. Sabah Y. Yacoub, personal communication, 2010).

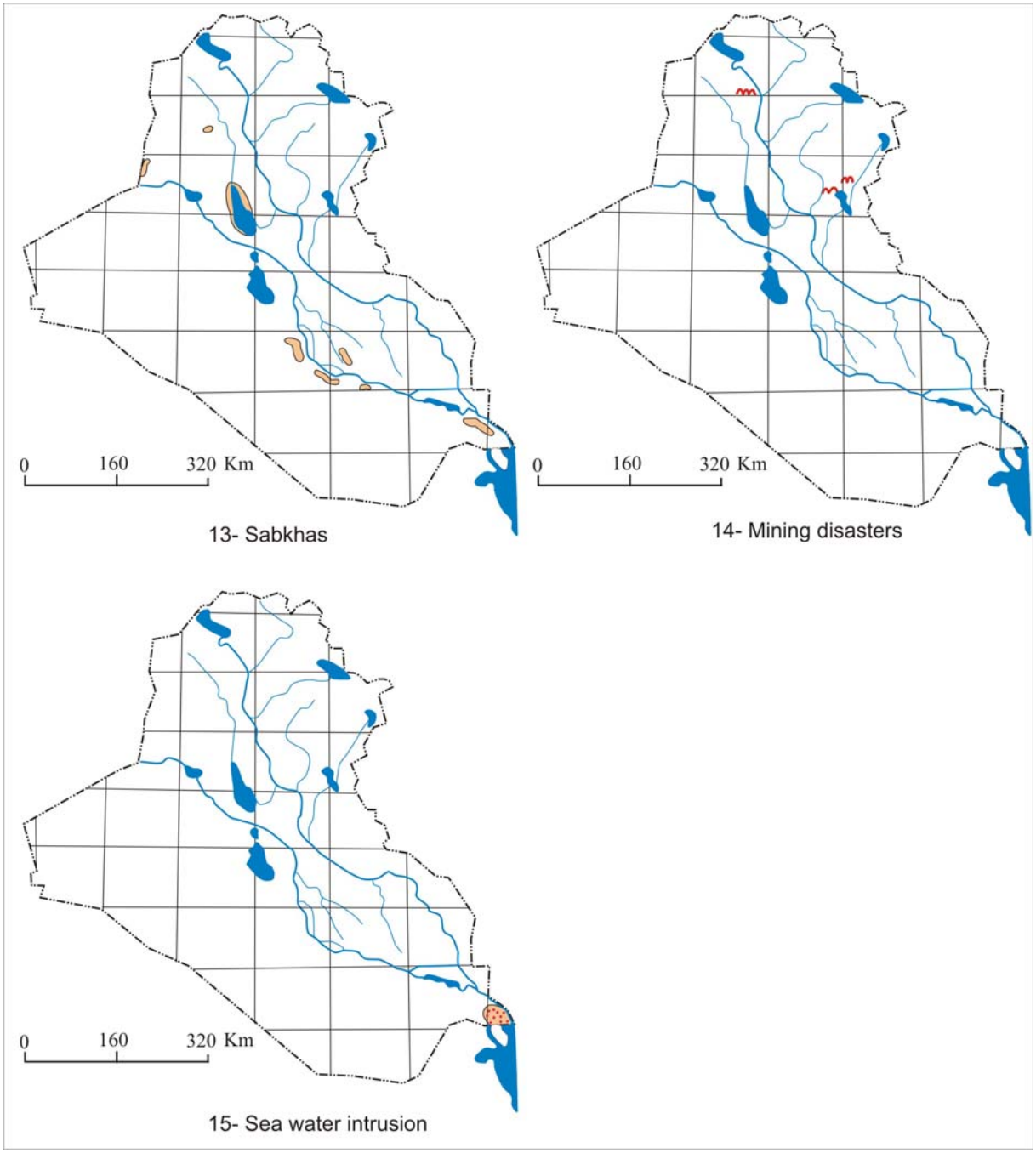

Fig.8 (13 – 15): Geographic distribution maps of the geological hazards

– Sabkhas: Sabkhas cover different parts of the Iraqi territory, usually surrounding depressions (Fig.8.13), they are unfavorable areas for construction of any type of structure; unless special treatments are used, which are extremely costly. This is mainly due to very shallow water table, which is usually less than 1 m and high SO_3 content. Although no many structures are constructed in areas covered by Sabkhas, but still they impose geological hazards, the geological hazards scored weights map is shown in Fig. (6.13), few examples are given bellow:

- The Ramadi – Hit – Al-Qaim road and Railway cross large area that is covered by sabkha nearby Hit town. Special road embankments and dykes for the railway are constructed to avoid the effect of the sabkha.
- In the extreme southern part of Iraq, all roads and other infrastructures are suffering from high percentage of salt, which acts as high corrosion agent; examples are the Saltern of GEOSURV, and in Al-Fao vicinity.

– Mining Disasters: Mining disasters are very rare in Iraq (Figs.3 and 8.14) because mining activities in Iraq are rare. The geological hazards scored weights map is shown in Fig. (6.14), some examples are given bellow:

- South of Qara Tappa, 130 Km northeast of Baghdad, many persons were dead due to collapse of preliminary mines, prepared by local people for Bentonite mining.
- In Na-Salih village, east of Kifri, 140 Km northeast of Baghdad, many people were dead due to collapse of preliminary bitumen mines; others were dead due to sudden collapse of the ground due to empty chambers caused due to mining of the bitumen.
- Mishraq Sulfur mine also suffers from mining disasters, represented by ground subsidence that ranges (9 – 12) m, consequently pipes and other mechanical fittings were damaged, many other production and exploration boreholes were abandoned too (Dr. Thabit Mahder Bashi, personnel communication, 2002). Moreover, 30 production wells and boilers were damaged due to damage of the pipes. Besides the pollution of the Tigris River water by the melted sulfur that appeared inside the river as small volcanoes (Mutib *et al*., 2009).

– Sea Water Intrusion: Only very small part in Iraq is under the influence of this type of geological hazards, it is in the extreme southern part along the Arabian Gulf (Fig.8.15). The sea water intrusion, both surface and groundwater is considered as a geological hazard (Bates and Jackson, 1980). The high salinity of the water changes the physical and mechanical properties of the soil and makes the soil unfavorable for construction (Capper and Casie, 1960). Unfortunately, no data are available for the recorded hazards; however, the scored weights map is shown in Fig. (6.15), but the authors believe that after drying operation of the marshes in the southern part of Iraq; the sea water intrusion will be more effective and reaches to more distances in land of the Iraqi territory. Only one example of the caused damage is given bellow:

- On June 1939, the sea water reached to Basrah town with a height of 3 m and caused the draft of thousands of date palms and other fruit tress, with infliction of many kinds of diseases (Al-Hassany, 1988).
- Recently, during late 2009 and beginning of 2010, the sea water had reached the extreme southern marshes, like "Hor Al-Salal", causing the draft of almost all existing marsh vegetations (personnel communication with the local people of the first author on 1/ 5/ 2010).

DISCUSSION

Although the available data about the effect of the geological hazards are not adequate, but still considerable data are furnished in this study with adequate maps that elucidate their geographic distribution over the whole Iraqi territory with different zonations and classifications. It is very obvious that the damages in properties and lives loss are directly proportional with the density of population and available infrastructure. However, this is not the true case every where within the Iraqi territory, because the geological nature of the rocks and soils plays a main role in exhibiting the geological hazards. The presented maps and accompanied zonations, and supposed classifications of the existing geological hazards would have different information and conclusions if the used data were more adequate and sustainable.

The floods were scored the highest degree and considered the most dangerous and effective among the other 15 types of the geological hazards. This weight was acquired although the floods, in the last decades were not so prominent due to decrease in the rainfall amount; in Iraq and neighboring countries. However, still the floods were scored the highest degrees, because their assessment needs long period of records, which may attain 100 years (Johnson and Luza, 1981).

The earthquakes, although are considered as one of the most destructive geological hazards in the world, but they did not acquire higher degrees in Iraq (9 degrees in Sulaimaniyah quadrangle and 7 in both Baghdad and Mosul quadrangles). This is because Iraq is not so close to the known active Zagros Seismic Zone and the available data about the damages and lives loss are not adequate. However, some recent (2009) earthquakes were recorded in Nasiriyah – Amara – Samawa vicinities (during preparation of this article), south of Iraq. The authors believe that they are attributed to the active Abu Jir Fault Zone.

From the other effective geological hazards are the mass movements, which have caused large economic lost to the roads, especially in the northern and northeastern parts of Iraq. Their true damages are also not well recorded. On the other hand, gypcrete has also caused enormous economic lost to main infrastructures in different parts of the Iraqi territory. Their effect is still advancing in different main infrastructures, confirming the supposed zonations (Sissakian and Ibrahim, 2002), where their effect appears after few years from their construction, on the infrastructures.

The remaining geological hazards also have caused considerable economic lost and lives loss, in different parts of the Iraqi territory. As the other geological hazards, their assessments would be more than the mentioned in this study, if the available data are more precise and comprehensive.

CONCLUSIONS

The following could be concluded from this study:

- The most common geological hazard, in Iraq is the Flood and has scored the maximum weight, among the other 15 types of the existing geological hazards.
- The less common geological hazard, in Iraq is the Tectonic Active Areas and has scored the minimum weight, among the other 15 types of the existing geological hazards.
- The recorded damages and lives loss were given certain weights that start by 2 degrees and end by 11, for a single type of a geological hazard, whereas the total scored weights within a certain quadrangle area (at scale of 1: 250 000) starts with 6.5 degrees and ends by 45, as a maximum scored weights for all existing types of geological hazards.
- The intensity of the geological hazards is classified into four classes, according to the total scored weight, for each quadrangle map at scale of 1: 250 000: Low Hazards Class

(6.5 – 12 degrees), Medium Hazards Class (13 – 25 degrees), High Hazards Class (26 – 36 degrees) and Extremely High Hazards Class (36.5 – 45 degrees).

- Seven quadrangles, among the whole Iraqi territory were classified to impose Extremely High Hazards, these are: Baghdad, Samarra, Haditha, Qaiyara, Kirkuk, Mosul and Sulaimaniyah.
- The frequency of occurrences of the geological hazards within each quadrangle at scale of 1: 250 000 is classified into four classes: Low Occurrence Class; includes 3 types, Medium Occurrence Class; includes (4 – 6) types, High Occurrence Class; includes (7 – 9) types and Extremely High Occurrence Class; includes (10 – 11) types.
- Three quadrangles, among the whole Iraqi territory were classified to impose Extremely High Occurrence, these are: Samarra (11 types) and both Qaiyarah and Haditha (10 types) and were considered as "Hot spot areas".
- The lives loss are very low as compared to the economic losses caused by the geological hazards.
- Two hot spots were recorded concerning the floods, in Baghdad and Qaiyarah Quadrangles, both were scored 11 degrees.
- One hot spot was recorded concerning the pollution, in Kirkuk Quadrangle, which scored 10 degrees.
- Considerable parts within the Iraqi territory are under the influence of the geological hazards. However, considerable parts too are classified as "areas almost free from geological hazards", which have scored **zero** within the ranking of the geological hazards. Moreover, large parts that are under the influence of the geological hazards have classified within the Low Hazards Class and within the Low Occurrence Class, which means almost no hazards.
- The assessments of the recorded 15 types of the geological hazards in Iraq will show different styles if the data are more precise and comprehensive.

EDITORIAL NOTE

The first author had compiled the Geological Hazards Map of Iraq, at scale of 1: 1000 000 in 2005 and started in compilation of the Geological Hazard Maps at scale of 1: 250 000 since 2003 with contribution of the late Faiza A. Ibrahim, she died on 19/ 08/ 2007. Her contribution in the compilation of the mentioned maps, which are used as a basic data for this article, is highly appreciated and this article is a modest dedication for her sole.

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