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Urban geology of Tabriz City: Environmental and geological constraints

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Abstract. Urban geology is the study of urban geologic environments to provide a scientific basis for rational land use planning and urban development and provides information on geologic environments as a basis for city planners. Based on AEG recommendations, urban geological studies covered the urbanism and historical backgrounds, geological setting, engineering geological constraints and environmental assessments of understudied cities. The aim of this study is to provide a good view of urban geology of Tabriz city the capital of East Azerbaijan province in Iran. The topics of discussions about Tabriz city urban geology are included geologic (geomorphology, geology, climatology and hydrogeology), engineering geological (earthquake, landslide and geotechnical hazards investigations) and environmental characteristics (air, soil and water hazards assessment).The results of the urban geologic studies indicated that Tabriz city in terms of engineering geological and environmental constraints is at high risk potential and in terms of seismic activity and landslide instability is highly potential. In terms of air, soil and water pollution there are many important environmental concern in this city.

Keywords: Tabriz; Azerbaijan; geology; engineering geology; civilization

1. Introduction

Urban geology provides information on geologic environments as a basis for city planners (Assari and Mahesh 2011a, b, Assari and Assari 2012, Assari *et al*. 2012a, b, 2016). Geological information of site investigation for municipal settings like site selection, design and construction of engineering structures is very critical (UNESCO 1997-1998, AEG 1982-2004, Hatheway 2005). Without detailed geological information in urban planning, construction or municipal development can impose additional costs and risks for hidden and apparent problems on the project (Gocmez *et al*. 2006). So the first and important step in the urban planning studies is to determine the geologic situation of cities. In this regard the urban geology has provided a good explanation.

Several years of professional experiences and studies in the urban geology has been published by the Association of Engineering Geologists (AEG 1982-2004). Nowadays, this technical advice is utilizing as a standard format in urban geological studies. Standard elements of urban geological considerations for cities by AEG recommendation is classified in 13 parts (SAIEG 1997). This procedure is generally classified into 4 major categories:

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- The urbanism and historical backgrounds.
- The geological setting.
- Engineering geological constraints.
- Environmental constraints.

There categories are used in the present study for urban geology investigation of Tabriz city.

Tabriz is the most populated (about 1.5 million) and historical city in the northwest of Iran, and the capital of East Azerbaijan Province. The city of Tabriz is located at 1350 meters above sea level and inside the valley of the Quru-chay between the Sehend volcanic complex Mountains. This Valley ends in the plain and the eastern coast of Urmia Lake (Azarafza and Mokhtari 2013). This city is the major hub for heavy industries such as automobiles, machine tools, refinery, petrochemical, textile and cement factories and the most authoritative scientific and cultural institutions (Statistical Center of Iran 2012).

This city has a long history dating back to 1500 BC (Fisher 1968, Ansary 2010). Many historical places have been discovered in the city belonged to the patriarch, Safavid and Qajar dynasties (EATDA 2014). For instance, Tabriz historic Bazaar in 2010 was registered as a World Heritage Place (Assari and Mahesh 2011). MatrakçıNasuh, the 16th century Ottoman polymath who had visited this city and painted the Tabriz city plan (Atil 2002). The beginning of civilization and establishment of the Tabriz city is unclear. Some archaeologists assume that likely the Garden of Eden was located in Tabriz (Cline 2007). Recent excavations in the Iron Age Museum place in the north of Goy machit (Blue Mosque), discovered a grave yard from the first millennium BC (EACHHTO 2010). This city by natural disasters or the invading armies was destroyed (Balilan-asl 2015). Tabriz was selected as the capital by several rulers of Atropates era. It was capital of Ilkhanate (Mongol) dynasty in 1265 (Fisher and Boyle 1968). This city has come to greatest glory in 1295 of the reign of Ghazan Khan. It was also capital of Iran during Kara Koyunlu dynasty from 1375 to 1468 and then during AkKoyunlu from 1468 to1501 (Aigle 2014).

2. Geologic setting

2.1Geomorphology

Tabriz is the largest city in northwest of Iran in East Azerbaijan province is located between Eynali and Sahand mountains in a fertile area at banks of Aji-chay and Ghuri-chay rivers at coordinate of 38.0667° N, 46.3000° E (Azarafza and Mehrnahad 2011). This city is at west of Urmia Lake (Azarafza *et al*. 2013b) and the majority of the population of the city have spoken in Azerbaijan Turkish language (Türkçe) followed by Persians, Azerbaijani (Baku) and Turkey (Sigov 2015). In terms of geography Tabriz is a mountain town with cold winters and mild summers (Smith and Baker 2014). The topographical status of Tabriz city is shown in Fig. 1. As is shown in Fig. 1, there is a drastic change in geomorphology of the region due to widespread geological structures processes.

2.2 Geology

Tabriz city that has been built on the Tabriz plain is composed of young and unconsolidated deposits of mostly rivers and glacial sediments belong to Cenozoic and Quaternary formations with different textures and grading. The city is totally covered with recent alluvial sediments, but theperformed excavation indicates the existence of conglomerate, sandstone and marl layers under the mentioned alluvial sediments (Agha-Nabati 2007). The northern part of the city is limited to Eynali volcanic Mountain and its southern part is limited to Sahand volcanic complex (Azarafza and Mehrnahad 2011). Fig. 2 shows the geological map of Tabriz region.

In terms of Structural Geology and Tectonics status, Tabriz region is located along Alp-Himalaya active belt and witness many tectonized occurrences folding and faulting, which causes 1,400 seismic events and earthquakes with often disastrous effects on rural and urban settlements (IIEES 2015).

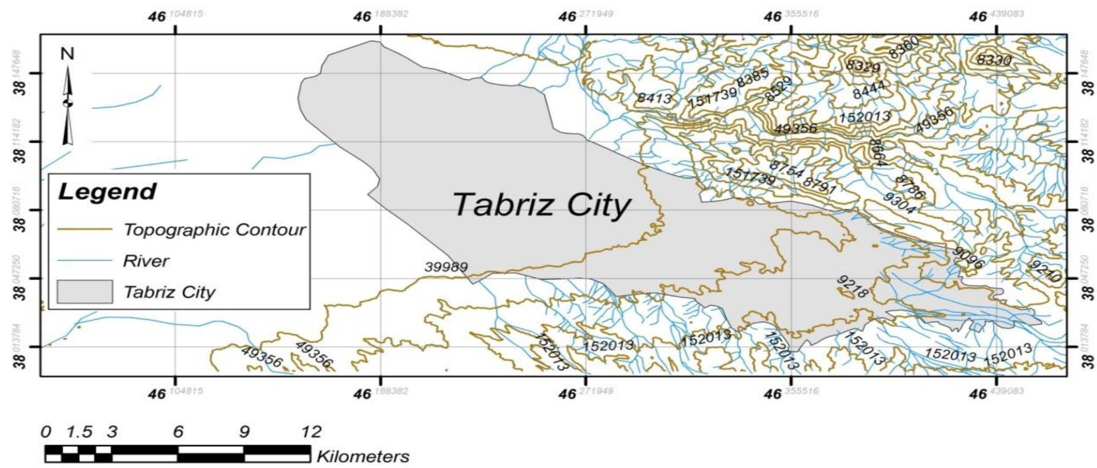

Fig. 1 Topographical status of Tabriz city

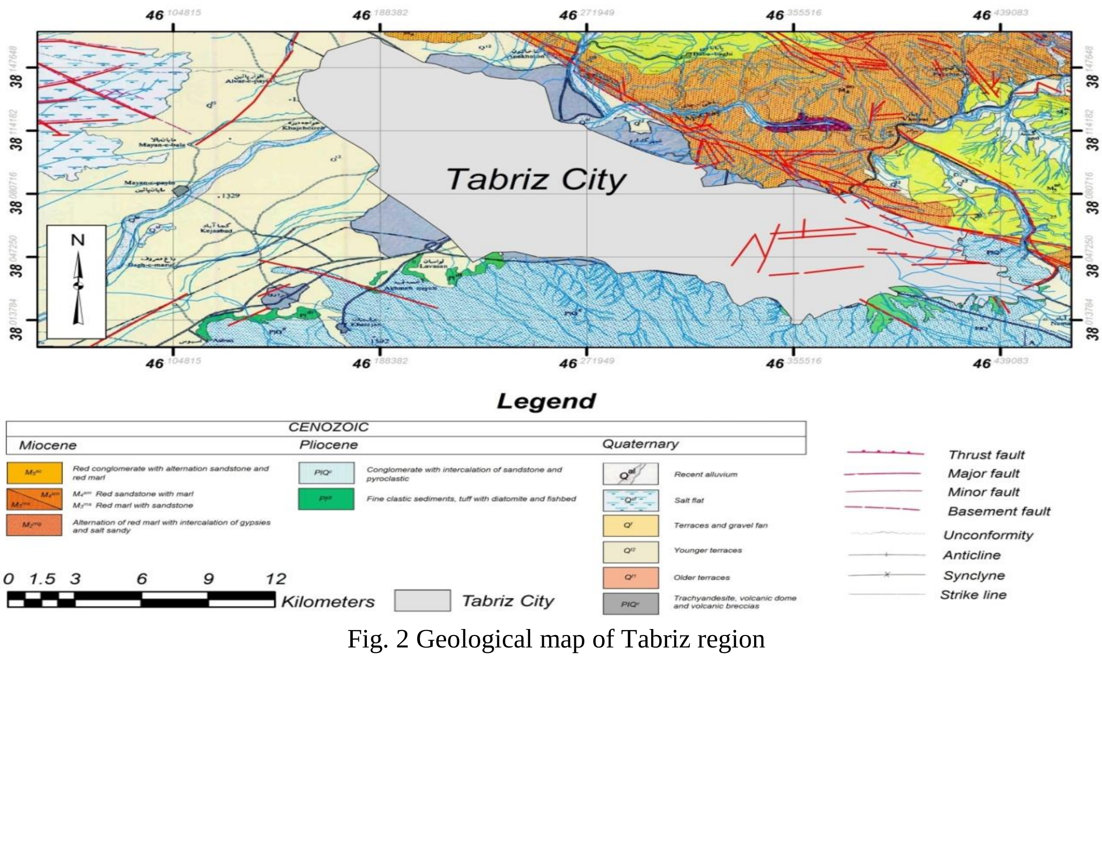

Fig. 2 Geological map of Tabriz region

2.3 Climatology

Tabriz city with a semi-arid climate has 4 seasons of mild climate in spring, warm and dry in summer, rainy in autumn and snowy cold in winter (Peel *et al*. 2007). Annual rainfall of the city is about 311 mm (12.24 in) that most occurrences are in autumn and winter seasons. In hot summer days, the temperature rises to 29.3°C and in cold days in winter temperatures reduces to -25.7°C (IMO 2014). The climate map of Tabriz region is presented in Fig. 3.

2.4 Hydrogeology

Obtaining the aquifer hydraulic properties and hydrological and hydrogeological characteristics of water resources is crucial for ground water management in the study area. The role of Hydrogeology in water supply for urban areas is quite evident. In addition, changes in the hydrogeological status present a serious problem facing the city. This indicates the negative effects of human activities or natural geological changes on the environment. Hydrogeological map has been prepared for the city of Tabriz and is presented in Fig. 4. As is shown, water supply for city

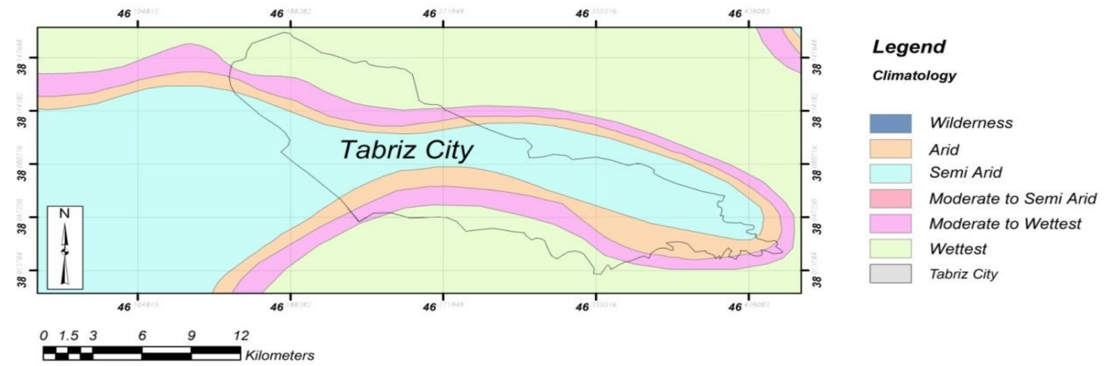

Fig. 3 Climatologyical map of Tabriz region

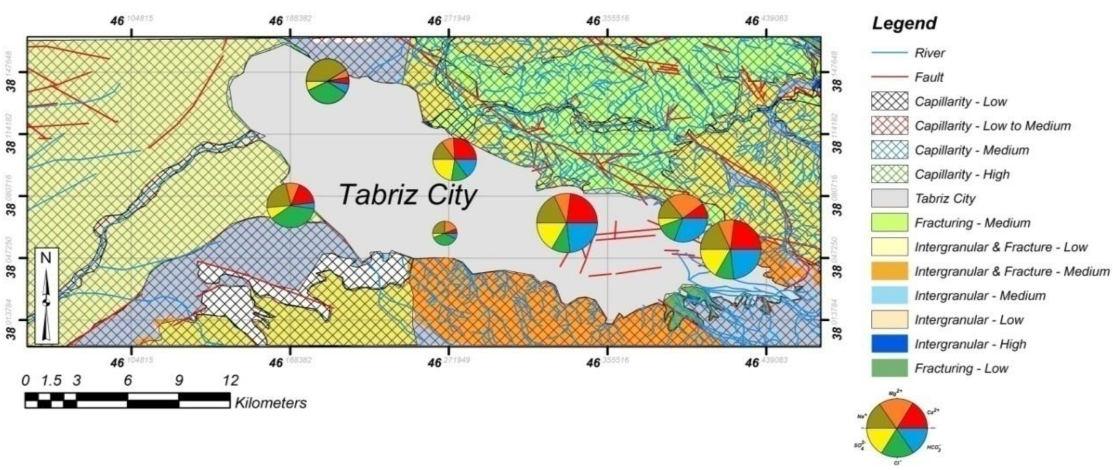

Fig. 4 Hydrogeological map of Tabriz region

of Tabriz is from the surrounding mountains and especially rivers in north and east of the city. The water from the western part is discharge into the Urmia Lake basin at SW of the city.

3. Engineering geological constraints

3.1 Earthquake hazards

Iran is a segment of one of the biggest compressional deformation regions in the world. This country is located in the collisional zone of Eurasia- Arabia plates and the resultant of these plates convergence lead to the rotation of Iranian plate Iran- Eurasia rotational pole (Jackson *et al*. 1995). This special tectonic situation causes many earthquakes in the country (Azarafza *et al*. 2013a, Azarafza *et al*. 2014). Azerbaijan region is known as one of the most seismictectonical active zones of Iran (Mirzaei *et al*. 1998). High seismic potential in Azerbaijan region causes many earthquakes (Azarafza and Mehrnahad 2011). A major factor in seismicity of the area are the main active faults including Tabriz North South Faults, Marand Fault, Urmia - Zarinerood Fault, Marageh North Fault, Moro and Misho Faults, etc. The tectonic, seismotectonic and seismicity maps have been prepared for Tabriz region and are shown in Figs. 5 to 7. As are shown, Tabriz city has the highest seismicity potential.

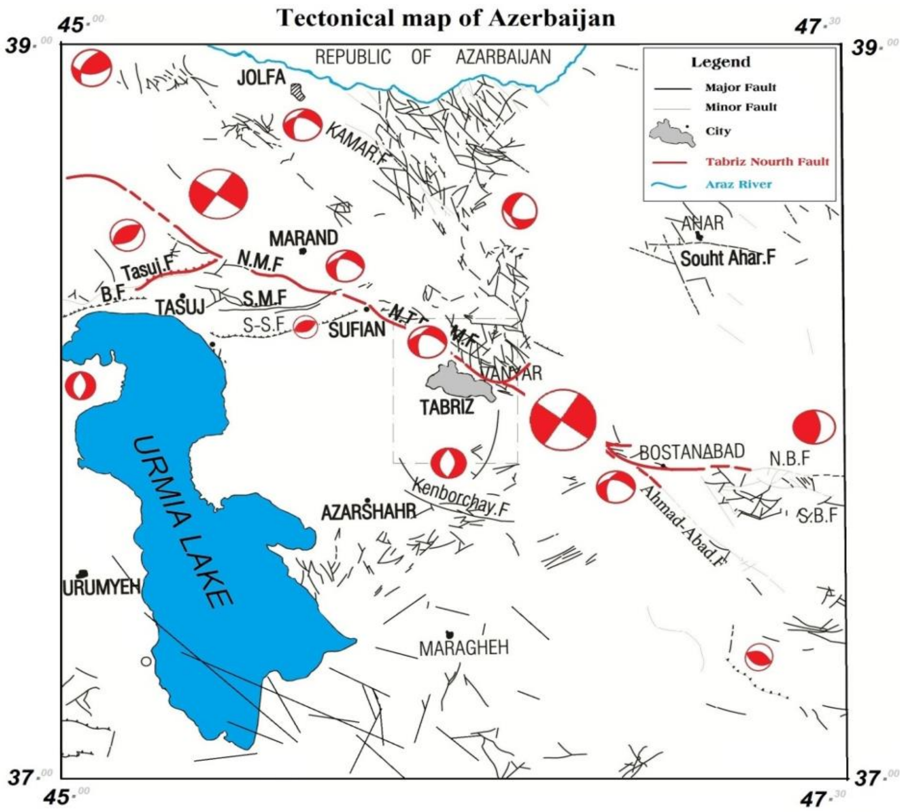

Fig. 5 Tectonical map of Azerbaijan region

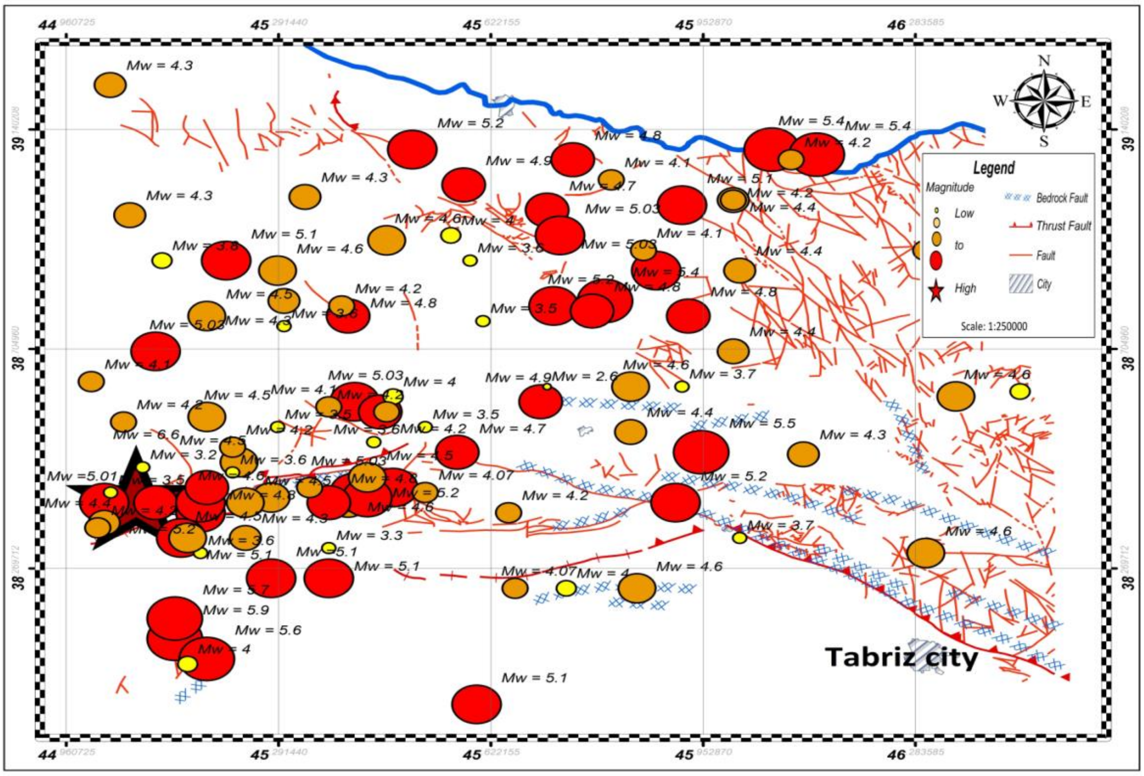

Fig. 6 Seismotectonical map of Tabriz - Poldasht region

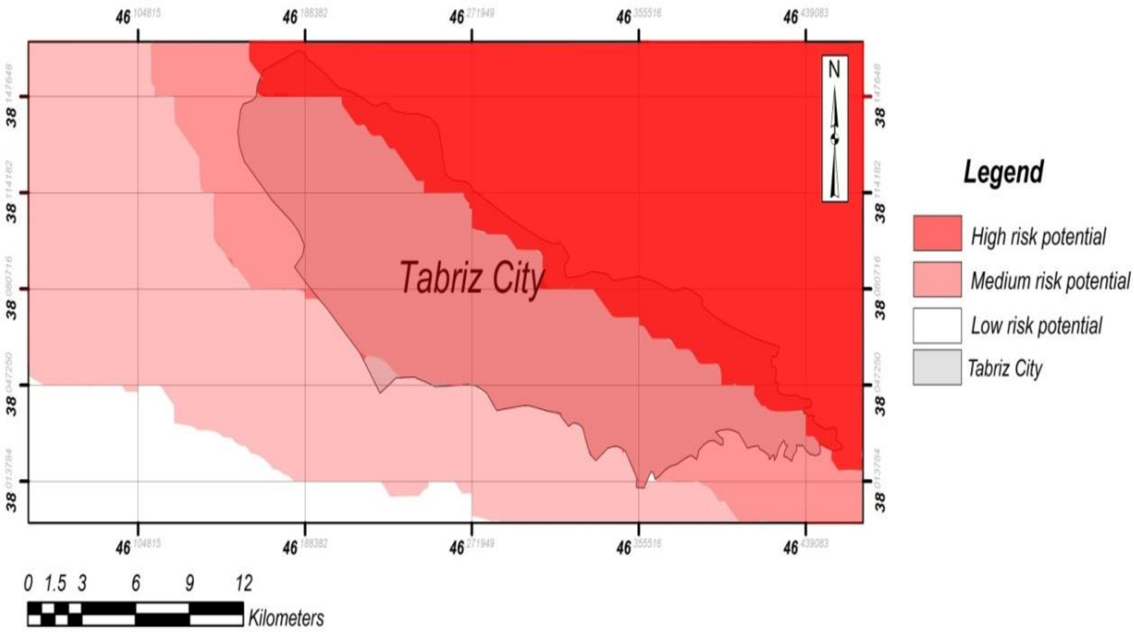

Fig. 7 Seismicity map of Tabriz region

3.2 Landslide hazards

Landslides are recognized as ground movements with different shapes and type such as rock falls, rock toppling, slope failures, rock, soil and mud debris flows (Cruden and Varnes 1996). Landslides occur when ground slope condition is unstable. Changes in the stability of slopes displayed by the safety factor. The reduction of safety factor represents instability of slopes (Azarafza *et al*. 2013c). Landslide hazard analysis and mapping can be beneficial for disaster losses, and helping to provide sustainable development making guidelines for land-use planning. Landslide analysis would be greatly beneficial to assess the hazardous potential and identify susceptible zones in urban areas and help to make a sustainable development (Chen and Wang 2007).

Since, Tabriz city is placed in a volcanic valley (see Figs. 1 and 2), there are high potential for landslide occurrences. Preparation of slope dips status map shown that, the landslide potential in this area is high. The prepared map of slope dips status for Tabriz city is shown in Fig. 8. As is shown, the potential of landslide instability in the northern and southern parts of city is very high.

3.3 Geological engineering-geotechnical hazards

According to geological studies conducted for Tabriz city, this city is located on varioussediments related to Cenozoic formations (see Fig. 2).The main part of Tabriz city on young andunconsolidated depositsmostlyfrom riverand glacial sediments with variety of granulation and texture.

The geotechnical properties ofTabriz alluviumswere obtained by geotechnical boreholes and in-situ and laboratory tests (carried out on taken samples). These tests were conductedbased on

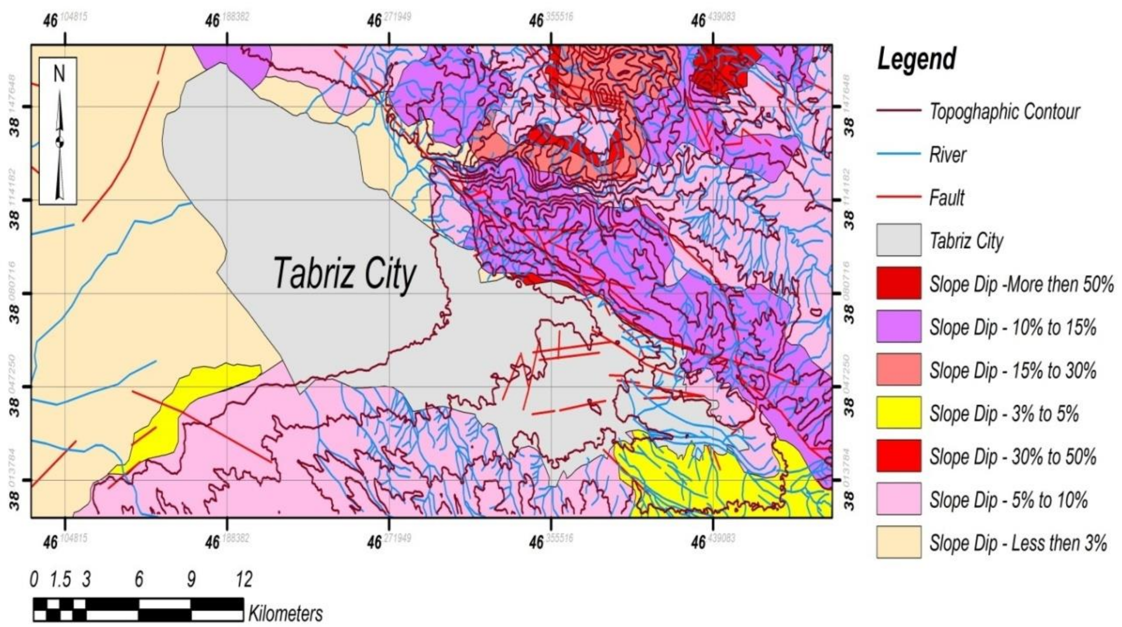

Fig. 8 Dips status map of Tabriz region

international standards (Ojuri and Fijabi 2012, Azarafza and Asghari-Kaljahi 2016). The results of drilling operations and loggingare shown in Fig. 9. Also, the results of geotechnical studies performed on Tabriz alluviums are summarized in Table 1.

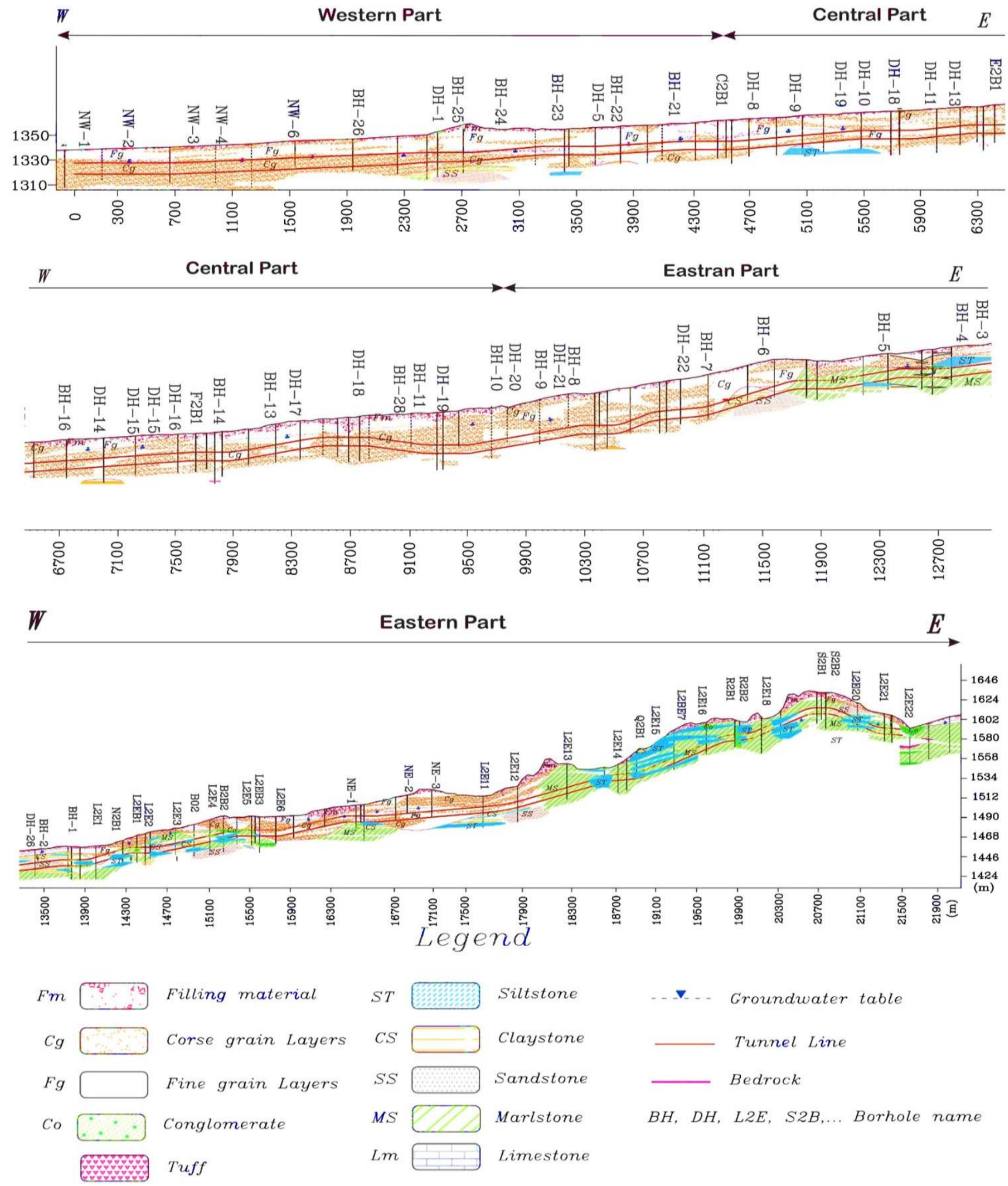

Fig. 9 Geological cross traced by boring results (Mohammadi 2015)

Table 1 The results of geotechnical investigation of Tabriz alluviums

Parameters	Partitions		
	Sedimentary Rocks	Coarse grained	Fine grained
Soil type (USCS)	-	SM	ML to CL
Unit weight (g/cm^3)		1.73 to 2.03	
Bulk density (KN/m^3)	19.57	19.15	18.75
Dry density (KN/m^3)	16.40	16.40	16.33
E (MPa)	34	24	34
G (MPa)	12.78	8.88	12.87
υ	0.33	0.35	0.32
C (Kpa)	35.0	33.4	18.3
ϕ (Degree)	27	13	38
UCS (MPa)	1-5	0.25 to 1	
K (cm/s)	2.1×10^{-8} to 6.5×10^{-6}	1.3×10^{-6} to 1.8×10^{-3}	1.8×10^{-7} to 5.8×10^{-5}

4. Environmental constraints

4.1 Air pollution

City of Tabriz after Tehran is the second most polluted city of Iran (IMO 2014). The most important air pollutants are CO_2, CO, NO_x, SO_2 and their compounds (Quadri *et al*. 2014). Due to the emergence of vehicular traffic and modern industries such as thermal power plants, petrochemical industries and oil refinery in west of the city, the air pollution is constantly increasing. Nowadays, according to the efforts of local industry to comply with new limits on pollution, as the National Environmental Code, the level of industrial pollution has reduced to 558,167 (tons/ year) (WHO 2006). Although this is a significant improvement, air pollution remains a serious burden to overcome.

In order to investigate the air quality, an index called AQI is used (Air Quality Index). The AQI is a piecewise linear function of the pollutant concentration (EPA 1989).

Environmental organizations in different countries of the world installed sensor devices of air pollutants in different parts of their cities for informing the air pollution and timely warnings and these devices record pollutants data in 24 hours of day. In Iran, the Environmental Protection Organization of Iran (EOI) has installed 13 pollutant stations in Tehran and a few stations in other big cities. There are 5 stations in Tabriz city. Based on the data obtained from these stations, the AQI corresponding to pollutants of Tabriz and the status of air pollution are presented in Fig. 10.

4.2 Soil pollution

Contamination of soil is caused by the presence of man-made chemicals or altered earth materials in the natural soil environment. The man-made sources typically are from the industrial activities, agricultural chemicals or improper disposal of wastes (Dasgupta *et al*. 2013, Li *et al*. 2013). The most important soil pollution involved is petroleum hydrocarbons, aromatic hydrocarbons, solutes, pesticides, biocides and heavy metals (Panahi *et al*. 2013). Soil

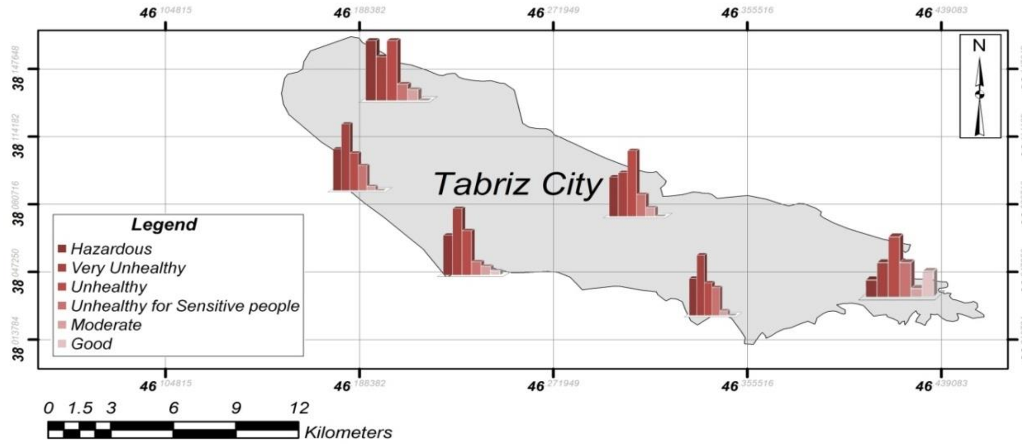

Fig. 10 Maximum of AQI corresponding to pollutants of Tabriz

contamination usually has a direct relation with industrialization degree and intensity of chemicals consumption (EPA 1989).

Contaminated soil directly affects human health through direct contact with soil or via inhalation of contaminated dust. Potentially greater threats are posed by the infiltration of soil contaminated into groundwater aquifers used for human consumption, sometimes in areas far from sources of groundwater contamination (Alfors *et al*. 2012, Parveen *et al*. 2014). Health consequences from exposure to contaminated soil vary greatly depending on pollutant type, pathway of entrance to human body and vulnerability of the exposed population. Chronic exposure to chromium, lead and other metals, petroleum, solvents, and many pesticide and herbicide formulations can be carcinogenic, cause congenital disorders, or can cause other chronic health conditions. Industrial or man-made concentrations of naturally occurring substances, such as nitrate and ammonia associated with livestock manure from agricultural operations, have also been identified as health hazards in soil and groundwater (Alfors 1973).

Knowing the concentration of pollutant, including the important part of environmental engineering in urban areas. Mapping of soil pollution in urban areas is the most essential part of the urban geology survey. (Bullock and Gregory 1991). To achieve this goal, sampling from a different locations with network sampling plan are required. Samples should be taken and analyzed according to the standard methods (Showalter and Lu 2012). By measuring the material contained in samples, the soil pollution of that site can be explained.

Soil pollution map of Tabriz city base on soil pollution analysis (Hazardous content and concentration of heavy metals) was prepared and is shown in Fig. 11. For the preparation of this map, sampling from 5 districts in the city was conducted. Generally the heavy metals which usually are analyzed in urban areas are Cd, Cr, Cu, Hg, Ni, Pb and Zn (Wang and Lu 2011). According to Fig. 11, the concentrations of Pb and Zn are more than other metals in the city.

4.3 Water pollution

In Tabriz city the groundwater is the primary source of drinking water and also the major sources for agricultural and industrial activities. A fast discharge of groundwater supplies in Tabriz city rises from the increase of the human population. The main issue is related to pollution of

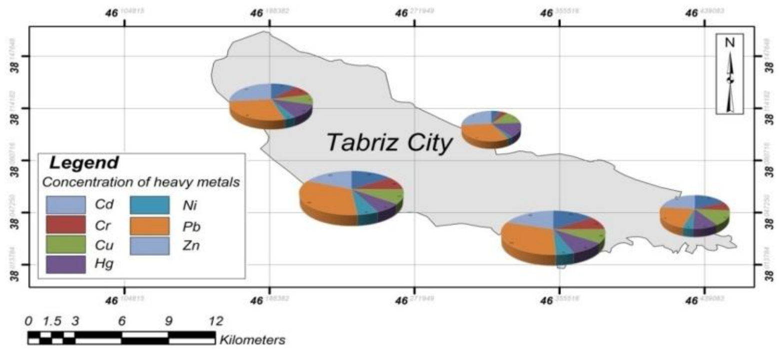

Fig. 11 Soil pollution analysis of Tabriz region

groundwater and its chemical composition. In order to determine the chemical composition of groundwater, many sampling were conducted. Sampling locations are shown in Fig. 12. After analyzing of water samples, the concentration of Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^- and NO_3^- were determinate. The results of the hydrogeochemical analysis and their Spatial distributions are presented in Fig. 13 and the piper diagram for the groundwater in the studied area is shown in Fig. 14.

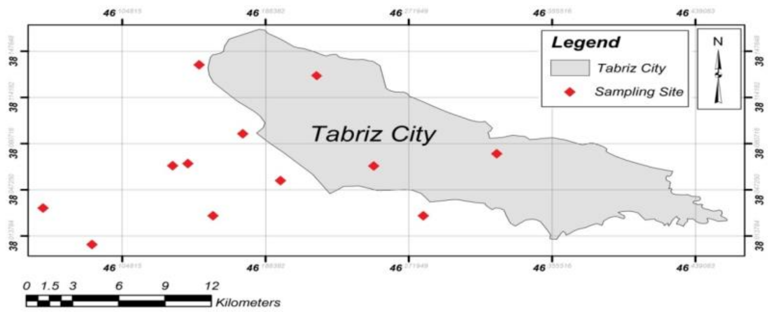

Fig. 12 Sampling locations in Tabriz region

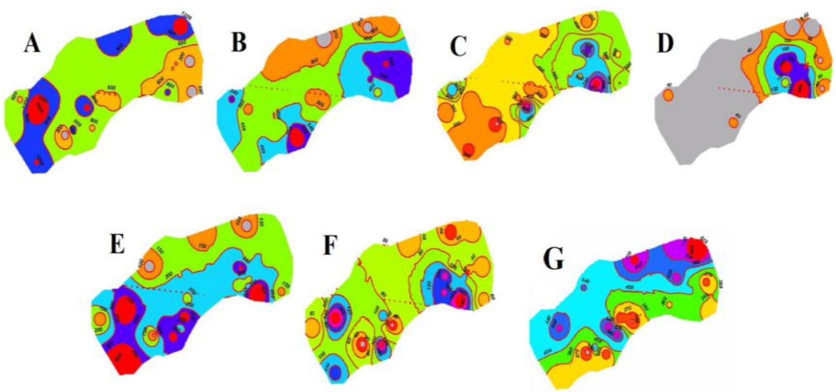

Fig. 13 Spatial distributions of (A) Cl^-, (B) HCO_3, (C) SO_4^{2-}, (D) NO_3^-, (E) Ca^{2+}, (F) Mg^{2+}, (G) Na^+ of the groundwater in the study area

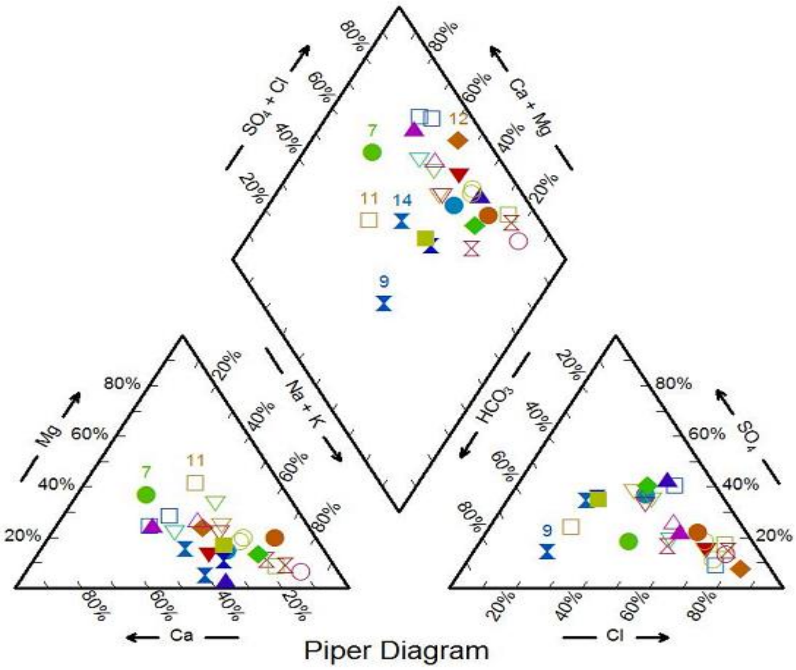

Fig. 14 Maximum of AQI corresponding to pollutants of Tabriz

5. Conclusions

Based on the obtained results, Tabriz city in terms of environmental status is very sensitive. The contamination of air, soil and water in the city is very high and is in dangerous situation. The environmental pollution is higher than the average health recommendation by international standards. Geologically, Tabriz city has a high potential of seismicity and landslide risk. The reason is that Azerbaijan region is tectonically very active.

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