Effect of stratigraphy on earth fissuring in the northern Mahyar plain, Iran

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Abstract: Earth fissuring is one of the natural hazards that can occur due to differing mechanisms. The northern Mahyar plain, located in the south of Isfahan, Iran, has undergone extensive fissuring for the last thirty years. These fissures have caused damage to houses, farms, channels and the major Isfahan-Shiraz highway, which require continuous repairs. It is believed that a reduction in the water table is the major cause of the fissuring. The distribution and direction of the earth fissuring indicate that some other factors are also controlling the location of these fissures. The stratigraphy underlying the plain is among these factors. Current research has evaluated the effect of plain stratigraphy as an individual factor. Rockworks software has been used to show the three-dimensional stratigraphy of the area. The logs of boreholes and water wells located in the study area, have been used to correlate layers and draw a three-dimensional stratigraphy of the area. The fissures identified are marked on the three-dimensional model. The conclusions indicate a relationship between the location of earth fissuring and the various changes in stratigraphy over the area.

Résumé: Les fissures causées par les catastrophes naturelles à la surface de la terre peuvent être produits par les mécanismes différents. Dans la partie septentrionale des la plaine Mahyar située au sud Isfahan on a signalé. Durant les trente derniers années des fissures extensives qui ont endommagé maisons, fermes, canaux, et la majeure partie de la route principale Isfahan-shiraz qui est continuellement en réparation et on croit que ces fissures sont du uniquement à la baisse du niveau de la nappe phréatique, mais la distribution et la direction de ces fissures montrent que autres la facteurs peuvent contrôler leurs situations parmi les quels on peut mentionner la stratigraphie de la plaine. Les recherches présentées dans cet article vérifient les effets stratigraphie de la plaine qui peut être l'an des principaux facteurs. On a utilisé le système RockWorcks pour montrer la stratigraphie en trois dimensions de la région; pour cela on a utilisé les logs des forages et les puits qui sont situés dans cette région pour montrer la corrélation des lits et dessiner la stratigraphie en trois dimensions de la région; les fissures ont éfé identifié et situées sur le model de trois dimensions. La conclusion est très remarquable et montre la relation qui existe entre la situation des fissures et les changements de stratigraphie dans la région.

Keywords: 3D models, aquifers, clay, compaction, fractures, gravel, water table

INTRODUCTION

Northern Mahyar plain is located in the south of Isfahan, Iran. It is located in a semiarid region of Iran with an unconfined aquifer with an area of 158km^2. Development of surface fissures is one of the critical ground problems in the area. Fissuring has caused considerable damage to buildings and roads and agricultural activities have become redundent. Ajalloeian et al. (1998) and Talaie (2000) suggested that the lowering of groundwater level has resulted in fissuring of the plain. The water table drawdown was about 25.5m from 1981 to 1991 reported by Regional Water Board of Isfahan (RWBI). The fall in the water table during this time is considerable and if it continues to decrease, the rate of fissuring is expected to increase. In last few years, there has been little fluctuation in the water table, but fissuring has still occurred. This observation raises questions as to whether the reduction in water table is the only factor causing the fissures. Some other factors such as faults, aquifer heterogeneities, and bedrock knob protruding into the aquifer system and presence of weakness plain in aquifer system would also control progress of fissuring (Burbey 2002, Zhuping sheng et al. 2003).

This research attempts to understand the role of aquifer heterogeneity in the fissuring of the Mahyar plain. In this paper aquifer heterogeneities refer to an abrupt change in the thickness of beds within the aquifer. Such variations in thickness may result in rotation, vertical shearing and even horizontal extension at depth (Helm, 1994a). Therefore it is concluded that fissures initiated at depth then propagate to the surface. In contrast, classical theories of extensional strain caused entirely by bending at the land surface, as described above, require that a fissure begins at the land surface and migrates downwards for the duration of extensional bending (Burbey 2002). This paper is based upon Helm's theory. The theory explains that, the magnitude of vertical compaction is different on each side of a geometric heterogeneity. Localized differential vertical displacements in compaction intervals that contain a geometric abnormality migrate upward into the overlying, non-compacting interval and induce tilt and shear at the land surface. On the other hand, localized differential horizontal displacements may generate an extensional zone at depth and induce an opposite direction of rotation as well as fissures at the land surface (Zhuping sheng et al. 2003).

METHOD OF INVESTIGATION

A groundwater iso-drawdown curves map was prepared to determine what effect the reduction of the groundwater table would have on the creation and development of fissuring. Groundwater levels have been measured in boreholes that were drilled by RWBI from 1993. Then differences between watertable in 1993 and 2005 were calculated and the results were used to prepare groundwater iso-drawdown curves map using Rockworks software. During field investigations, geographical locations of fissures were determined using a GPS device. The fissures' locations are showed on a groundwater iso-drawdown curves map (Figure 1).

Figure 1 shows that a higher distribution of fissures is found in areas of higher drawdown. However it is suggested that the creation of the fissures is also influenced by other geological conditions such as stratigraphy thickness.

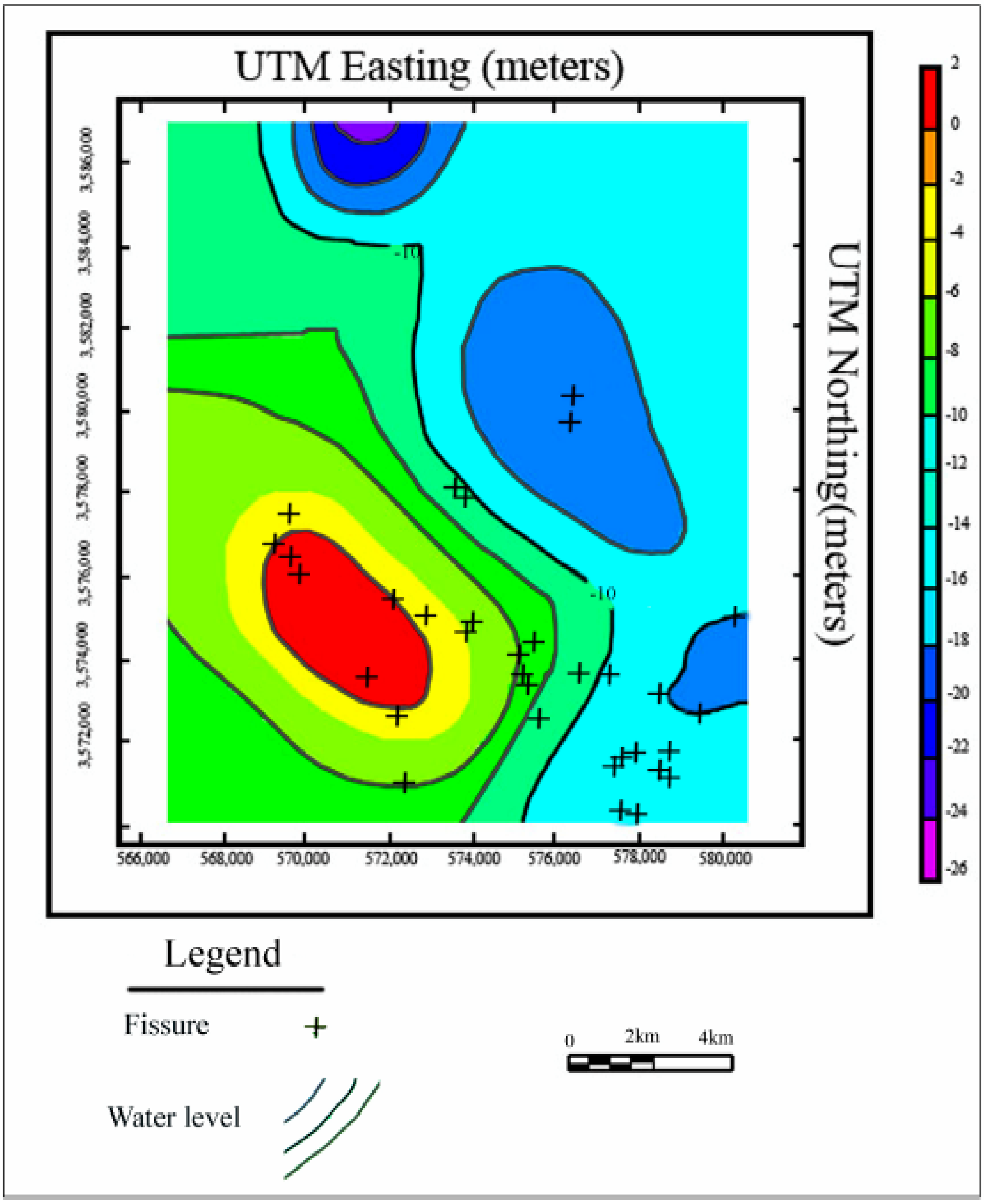

Figure 1. Fissures located on groundwater iso-drawdown

Some factors that help to propagate fissuring are faults and bedrock knolls, weakness planes and heterogeneities in the aquifer. The paper is focused on heterogeneity in aquifer. Heterogeneity is known as change in the properties or thickness of different layers. The presence of clay bearing strata is considered an important factor in this case. A number of drilling logs including 35 boreholes and agricultural wells were used to create a 3D geological ground model of the study area, using Rockworks software. The depth of the boreholes is over 150 meters. According to the Hookian (elastic) stress-strain constitutive relationship, the degree to which a porous material is compressed under a given stress depends on the coefficient of compressibility of the material. Subsidence displacements (and their relative magnitude between hydrogeologic units) in both the vertical and horizontal directions, therefore, are a function of aquifer compressibility (Helm 1994b; Burbey 1999). Geological units recorded in drilling logs were divided into clay and gravel units, where a layer containing more than 50 percent clay are shown as clay, and the others are shown as gravel. Also, in some places a mixture of cobble, sand and gravel is named as gravel. In this area clay is the compressible layer and plays a main role in consolidation, subsidence and fissuring. Therefore the other layers are not considered as important as clay. Figure 2 shows the 3D stratigraphic model of the area and the location of fissures indicated.

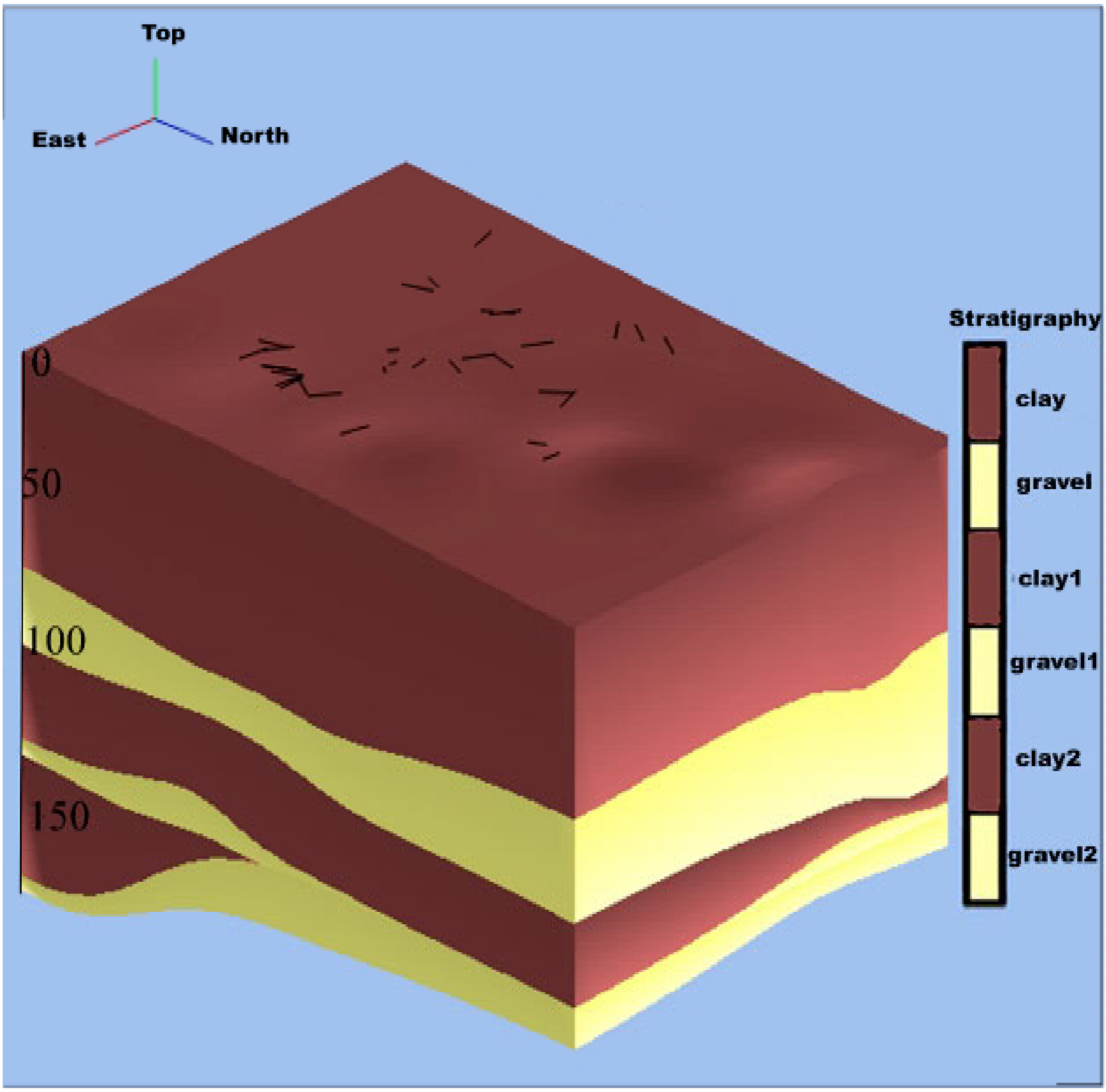

Figure 2. 3D stratigraphy of Mahyar plain

Clay, clay1 and clay2 are regarded as having similar hydraulic properties as the layers contain more than 50 percent clay. Gravel, gravel1 and gravel2 are also considered as hydraulically similar. The stratigraphic model shows that the area is constructed by fine and coarse grained materials alternatively. According to RWBI reports, the total thickness of the stratigraphy model is known as an unconfined aquifer. Figure 2 however, shows that the aquifer is not homogeneous in the study area. It shows the lithological heterogeneities within the aquifer. Because the clay2 layer is the most variable in thickness, and therefore most prone to differential settlements over the area, the fissures have been overlaid (Figure 3) onto this surface to show the special relationship between the unit thickness and occurrence of fissures. In the model shown in Figure 3 the azimuth and geographical location of the fissures are correct, but the lengths of the fissures are not the actual length.

In the model unit clay2 becomes markedly thicker towards the south. It is suggested that such dramatic differences in thickness result in differential vertical subsidence and then create tilt at the surface of the land and tensional stresses. When water is withdrawn, the effective stress (σ) on both side of clay2 (side with high thickness and the side with low thickness) increases, and consolidation occurs. But differences in thickness cause differences in consolidation magnitude. This results in a zone of tension or shear zone at the surface of clay. If the increase in stress is excessive, this shear zone will extend and migrate through the overlying layers to the surface.

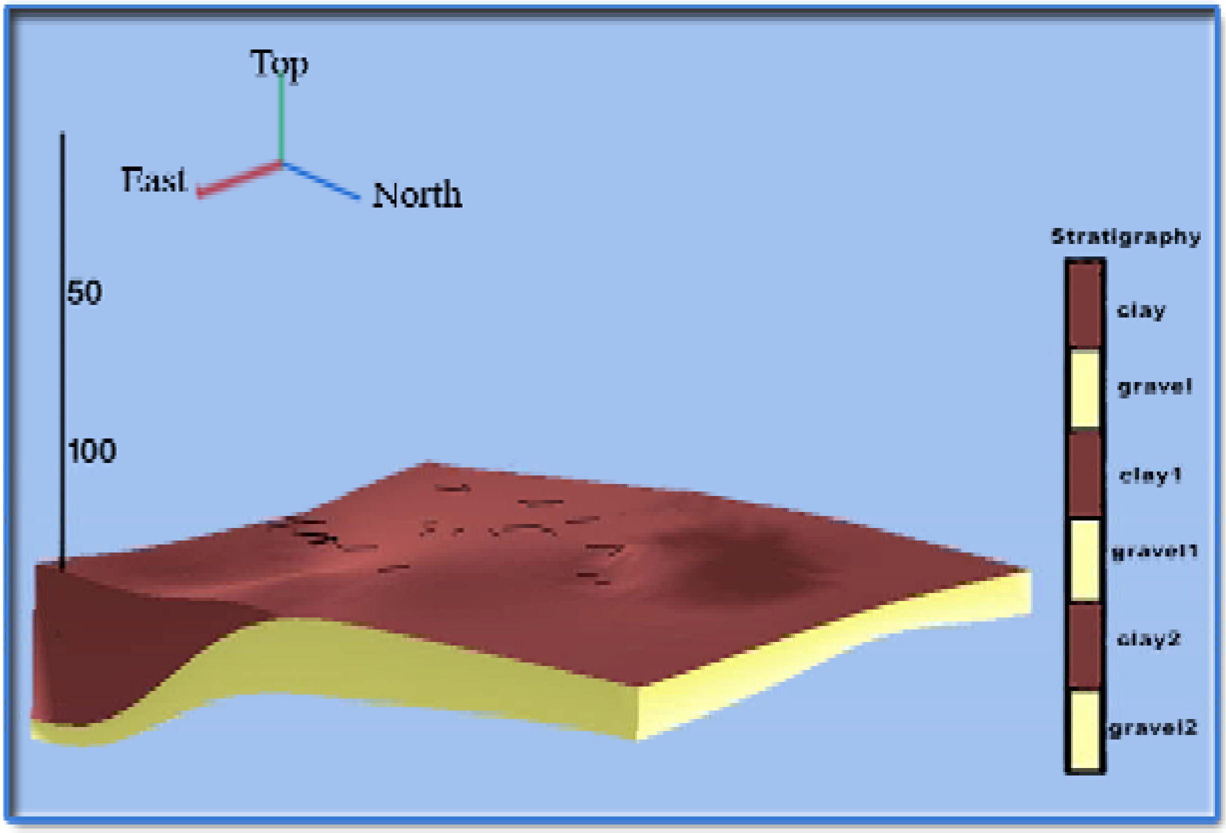

Figure 3. The surface of clay2 and fissures marked on it

CONCLUSION

Locations of fissures on the clay2 layer show that the location of fissures and the changes in thickness of stratigraphy correlate, thus probably aquifer heterogeneity or unusual geometry of stratigraphy layers are one of controlling factors for the location of fissures. However, the question of whether the layers ‘clay, clay1 or clay2’ are playing a main role in the location of the surface fissures will require the use of a numerical model.

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