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Hydrogeological Structure of the southern portion of the Anar fault, Central Iran

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Kardoost, A.[1], **Shahpasandzadeh, M.**[1]*, Keshavarz, S.[1], Abbasnejad, A.[2]
[1]Department of Earth Sciences, Graduate University of Advanced Technology, Kerman, Iran
[2]Department of Geology, Shahid Bahonar University, Kerman, Iran
(m.shahpasandzadeh@kgut.ac.ir)

Abstract

The hydraulic impacts of the faults range from barriers to conduit-barriers and conduits. The diversity of fault zone hydraulic behaviour can be explained by differences in fault zone structure. Hydrogeologic structure of faults such as the Anar fault is one of the most ambiguous issues of groundwater studies in arid to semi-arid region of the central Iran. This research investigates the hydrogeologic structure of the Anar fault cutting poorly lithified sediment. With an averaged net sedimentation rate of ~ 0.47 ± 0.11 mm/yr, the age of the aquifer could be constrained between 240 to 480 ka. The hydraulic conductivity of north segment of the fault is estimated ~ 1.38 x 10^{-4} ms^{-1}, whereas in the south fault segment is estimated ~ 2.54 x 10^{-4} ms^{-1}.

The macro-structure of Anar fault was investigated at outcrops of fault arrays cutting alluvial fan sediments of the Anar plain. Based upon this research, the fault zone should behave as conduit-barrier. The conduit-barrier behavior of the fault resulted from dominantly fault zone heterogeneities. The configuration and juxtaposition relationship of high and low hydraulic conductivity sediment is also an important factor in this fault zones, cutting sediment of contrasting competency. Similarly analysis of the hydraulic head either side of the southern portion of the Anar fault confirms the conduit-barriers behavior of the fault. In fact, the groundwater gradient across the Anar fault is from west and southwest toward east and northeast. Groundwater at the west of Anar fault, the recharge area, is much fresher than in the east, so that it abruptly becomes saline at the east. In addition, the depth of groundwater at the west of this fault is less that its eastern part. Thus, this fault behaves as a low combined conduit-barrier, because of fault zone heterogeneities due to either chemical precipitation or juxtaposition of high and low hydraulic conductivity sediment. Conduit-barrier behavior of the south segment of the Anar fault not only compartments the aquifer but also hinders fluid flow and allows preferential recharge into the aquifer.

Introduction

The subsurface flow model of faults, cutting poorly lithified sediment, constitute one of the greatest uncertainty in many fields of subsurface fluid research due to their wide range of potential hydraulic behaviour. The conduit, barrier or conduit-barrier behaviour of faults can impact groundwater resources (e.g. Caine *et al.*, 1996); For example, compartment of aquifers by fault barriers can limit the extent of accessible groundwater, or prevent the spread of contaminants. In contrast, fault conduits can influence groundwater recharge, or provide pathways for salt water intrusion into freshwater aquifers. An understanding of these processes is important for protecting groundwater supplies in modern societies (Wada *et al.*, 2010). Although there is a reasonable understanding of how faults impact fluid flow in crystalline or lithified rock, less is known about how faults in poorly lithified sediment impact groundwater flow. These sediments accommodate major aquifers in Iran used to deduce fault zone hydraulic conductivity structure.

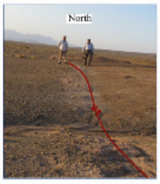
Located in an arid region, the central Iran is struggling with the recent droughts and a constant drop in groundwater levels due to irregular harvests. This condition has made the region vulnerable to social and environmental crises. Hydrogeological structure of faults such as the Anar fault is one of the most ambiguous issues in many groundwater studies (e.g.; Rawling et al., 2001; Caine et al., 1996). These researches illustrates the hydraulic behaviour of the southern portion of the Anar fault and identify the structure and deformation processes of the fault zone in poorly lithified alluvial sediment, which influence fluid-flow. In this research, the outcrop investigations of the sediments are used to deduce fault zone hydraulic conductivity structure.

The Anar Fault

The 200-km-long Anar strike-slip fault is known as a seismically active fault with a minimum slip rate estimate of 0.8 ± 0.1 mm/yr in the central Iran (Fig. 1; e.g. *Le Dortz et al., 2009; Foroutan et al., 2012*). In this research, we have focused on the southern portion of the fault, which runs along the Anar salt flat and through the populated city of Anar. The fault affected locally voluminous deposits of poorly lithified alluvial sediment, constituting the aquifer and confining units of the Anar plain (Figs. 2&3). With an averaged net sedimentation rate of ~ 0.47 ± 0.11 mm/yr *(Foroutan et al., 2012)*, the age of the aquifer could be poorly constrained between 240 to 480 ka. The aquifer is characterized dominantly by alluvial deposits, composed of coarse gravel alluvial conglomerates, inter-bedded with sand and clay layers.

Fig. 1. Satellite image of the NE-SW striking dextral Anar fault.

Fig. 2. Fault scarp of the Anar fault, north of Anar.



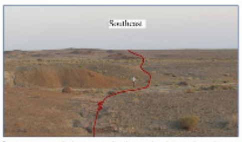


Fig. 3. Trace of the Anar fault as the boundary between the Pliocene-Pleistocene alluvial fan deposits and the argillaceous deposits.

Results

The fault zone structure was found to be different along the southern portion of the Anar fault. The mixed zones comprise of variably deformed sediment that accommodate the majority of strain. Specific structural elements in the mixed zones differ according to the lithology, in particular the rheology and stratigraphic relationships. The mixed zones are flanked by damage zones. The damage zones comprise antithetic or synthetic subsidiary faults that cut sometimes disaggregation bands that cut fine-grained sediment (Fig. 4). Our findings show the cemented fault zones could reduce fault zone hydraulic conductivity more than primary fault zone processes.

Although the most modest method of understanding fault zone hydrogeology is through analysis of hydrogeological data, analysis of the hydraulic head either side of the southern portion of the Anar fault infer the seal capacity of northern segment of the fault. In addition, the estimated hydraulic conductivity of fault zone in the north and south segments of the southern portion of the Anar fault are 1.38 x 10^{-4} ms^{-1} and 2.54 x 10^{-4} ms^{-1}, respectively.

Fig. 4. The Anar fault zone in the opened Paleoseismological trench, cutting Pliocene-Pleistocene alluvial fan deposits as the Anar plain aquifer, 35 km north of Anar.

south segments of the southern portion of the Anar fault are 1.38 x 10^{-4} ms^{-1} and 2.54 x 10^{-4} ms^{-1}, respectively. The gradient of groundwater at the south of Anar fault is from the west and southwest toward the east and northeast. Groundwater at the west of Anar fault, which is the recharge area, is much fresher than in the east, so that it abruptly becomes saline at the east. The depth of groundwater at the west of this fault is less that its eastern part. Thus, this fault behaves as a low combined conduit-barrier, because of carbonate chemical precipitation (especially aragonite), as well as juxtaposition of permeable and impermeable layers in the fault zone. Interestingly, the most of Qanats wells lies in the east of fault, because of sufficient accumulation of groundwater in the west respect to the east (Fig. 5). In another words, there was no need to continue excavation of wells to the west, when the excavated wells cross the fault zone.

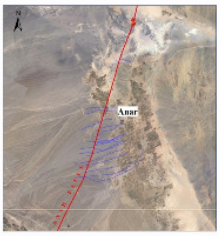


Fig. 5. Satellite image of the NE-SW striking dextral Anar fault, showing termination of the Qanats just west of the fault trace.

Conclusions

With an averaged net sedimentation rate of ~ 0.47 ± 0.11 mm/yr, the age of the Anar plain aquifer could be poorly constrained between 240 to 480 ka. The aquifer is characterized dominantly by alluvial deposits.

The structural elements of the Anar fault in the mixed zones differ according to the lithology, rheology and stratigraphic relationships. The damage zones comprise antithetic or synthetic subsidiary faults that cut fine-grained sediment.

According to this research, the cemented fault zones could reduce fault zone hydraulic conductivity more than primary fault zone processes. Based on hydrogeological parameters, the hydraulic conductivity of the southern portion of the Anar fault is estimated 1.38 x 10^{-4} ms^{-1} and 2.54 x 10^{-4} ms^{-1}, respectively .

The Anar fault behaves as a low combined conduit-barrier, because of carbonate chemical precipitation and juxtaposition of permeable and impermeable layers. The combined conduit-barrier behaviour not only compartment the aquifer but also hinder fluid flow and allow preferential recharge into aquifers, act as sources of fresh groundwater from west of the plain to the aquifers.

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