The interaction between water resources and faults: Case study of Lar valley in northeast Tehran

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Abstract-This research studies the interaction between the water resources and faults with the intention of identifying faults based on the effects of this inter-relation and their impacts on water resources. The research was conducted in the Lar valley located in the northeast of Tehran, the capital of Iran. The results indicate the influence of faults on 60% of Lar valley's rivers as well as on the quality of Sefidab River. The location of 57.5% of the springs was also influenced by the fault's actions and the change in the height of wellspring from 2500 to 3800 was attributed to the fault's impact. 32.5% of the springs were of karstic, while 54% were of contact and 46% of overflow type, originating from the limestone (karstic), sandstones, siltstones, shale, tuff and volcanic rocks as well as the quaternary sedimentations. The water quality of most springs is thought to be influenced by faults. The results of this research complement the previous methods and they can be applied in addition to other procedures in similar cases to identify faults having an impact on surface or ground water resources.

***Keywords*—** Fault impact on water resources; study of impacts; and identification of faults.

I. INTRODUCTION

Tectonics and the two important parameters of faults and folds affect the surface and ground water resources. The study of the evidence of tectonic impact on water resources can lead to the identification of the factors and their characteristics.

In this research the effect of faults on water resources, both surface and groundwater was analysed and the extent of impact on the quantity and quality of water resources in Lar valley in the northeast of Tehran, the capital of Iran was studied (Fig 1).

A number of issues were reviewed in this research, some of which are mentioned in this article.

In the year 1986, Keller claimed that faults have different impacts on alluvial fan, to the extent that an active fault with considerable deformation causes the placement of juvenile alluvial fan in the distance between the mountain and the plain, while an inactive fault causes the juvenile alluvial fan to appear far from the distance between the mountain and the plain (Fig 2).

It was stated in another research that the fault action on natural drainage systems during the generation of latitudinal valleys is such that the valley breaks the geological structure to align the valley axis with the axis of the geological structure (Oberlander 1992).

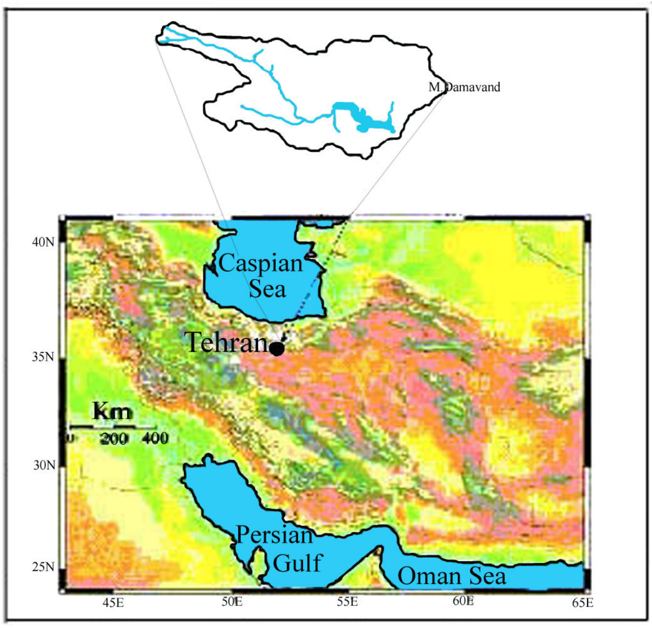

Figure 1- Situation of Lar valley, northeast of Tehran capital of Iran.

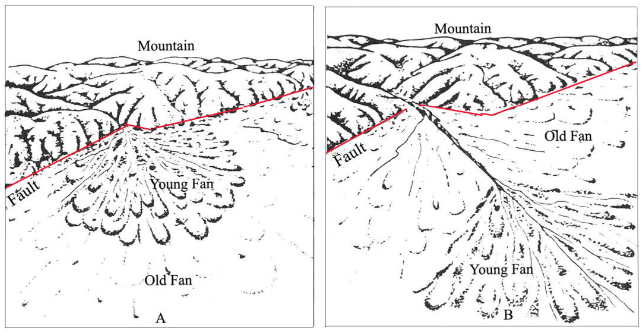

Figure 2- The alluvial fans impacted by fault. A is alluvial fan deposited adjustment to Mountain (active fault with rapid deformation). B is alluvial fan that deposited in Mountains down (Normal case) (After Keller 1986).

It is also said that the action of overthrust or reverse faults on river slope is such that in active faults the height of basin increases with the rapid deformation and the main river extends to the parallel of the fault, while the branches annexed to the main run perpendicular to the fault axis (Burbank and Anderson 2001). Bean has stated that in addition to the primary structures in place, the sediments in the earth crust such as stratifications, Lenz and changes in litho morphology, the secondary structures such as faults, fissures and folds have also a great impact on groundwater resources. The effect of faults on ground waters varies considerably with some acting as an obstacle and others on the contrary acting as a canal for ground waters (Bean 1967). In the tectonic zones, the permeability caused by breaks in fault axis and folds creates anomalies in groundwater regimes (Huntoon 1986). The vertical or horizontal changes in permeability caused by the action of faults are an important factor for the appearance of springs (Daneshvar 1971).From the 24 springs in the Tehran Plain, 5 are on the axis of the north Tehran overthrust fault, on the Kowsar fault and another on the Davoodieh fault (Engalence 1968).

Moreover numerous articles have been written on the impact of faults on the condition of ground waters in the karstic zones and other hard rocks, addressing their phenomenon. Some of these are mentioned below.

Modelling micro scale fluid flux within fault zone (Forster and Evans, 1988,), Hydrogeology of thrust faults (Forster and Evans, 1991), a theoretical model for thrust-induced deep groundwater expulsion (Ge and Garven 1994), Steady-state groundwater flow across idealized faults (Haneberge 1995), the influence of fluid flow in fault zones on seismicity pattern (Henderson and Maillot, 1997). Fluid flow in fault zones (Lopez, and smith, 1995).The influence of faults permeability on fluid flow (Matthai, and Roberts, 1996).Tectonics and hydrogeology of accretion prisms. (Moore 1989).Carbonate cements indicate channelled fluid flow along a zone of vertical faults (Sample , Ried, Tobin and Moore 1993).

At first the natural drainage system of Lar valley and its rivers and the impact of faults on these were studied. Moreover the three rivers of Lar, Delichay and Sefidab, which have hydrometric stations, were selected to study the surface water quality parameters. Then the location of 315 springs in Lar valley vis-a-vis their position to the faults, the location of the wellspring, their karstic characteristics, their type and the geological formation containing the spring in relation to the faults were studied. Furthermore the water quality at 9 spring outlets in the Lar valley and the surrounding areas were analyzed. Then faults influence on water quality of springs was studied.

The results of research indicate the effect of faults in Lar valley on the quantity and quality of the surface and ground resources as described below:

1- 60% of rivers in Lar valley are under the influence of the actions of the faults in different forms.

2- The quality of water in Sefidab river is influenced by faults.

3- 57.5% of the springs in Lar valley are along the faults axis (54% on thrust faults).

4- The water quality of some springs is influenced by faults.

5- The height of wellsprings varies between 2500 and 3800 meters and is thought to be the effect of faults.

6- 31% of the springs are of karstic type attributed to the geological formations of limestone (Lar formation), sandstones, siltstones and shale (Shemshak formation), Tuff and volcanic (Karj formation) as well as from the quaternary sediments, with the appearance of springs in the Shemshak and Karaj formations attributed to the action of faults.

7- 54% of the springs are of thrust fault type while 46% are of overflowing type (16% contact, 20% joint and opining, 10% seepage type) supposed to be under the influence of faults.

Based on the results, the identification of faults having an impact on water resources by taking into account evidences of faults impact on surface and ground waters through procedures applied in this research is possible. This is a new method that supplements the previous fault identification processes.

II. Study of Faults Impact on Surface Water

The surface water resources in the Lar valley include the rivers of Delichay, Sefidab, Vararood, Alum, Lar, Khoshkrood and Siah Plas (Fig 4). There are 3 hydrometric stations on Delichay, Sefidab and Lar. To study the impact of faults on rivers in Lar valley, the structural geology maps of the Valley (Fig 3) were correlated with the map of natural drainage system (Fig 4) and it was determined that the vertical model of the course of Sesang, Divasiab, Sefidrood, Vararood and Siah Plas was affected by the faults. The details of this impact on the mentioned rivers are as below:

Parts of the courses of Sesang River (9 km), Sefidab and Vararood (17 km), Delichay (2 km), Siah Plas and Lar rivers (15 km) as well as others are located on the faults axis. The studies have determined that around 60% of the Lar valley and their natural drainage system are influenced and controlled by faults.

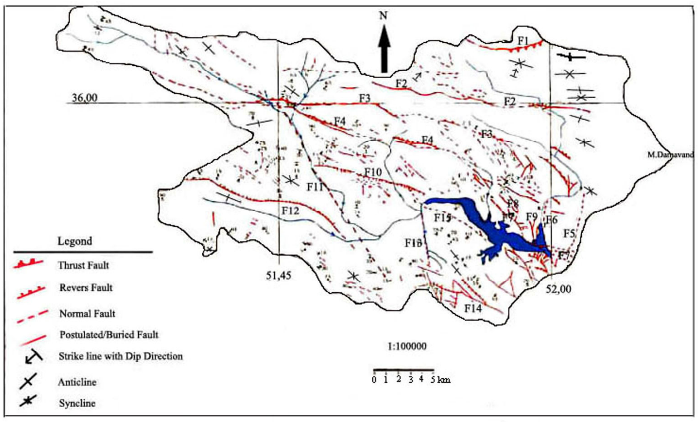

Figure 3-The map of Lar valley structural geology

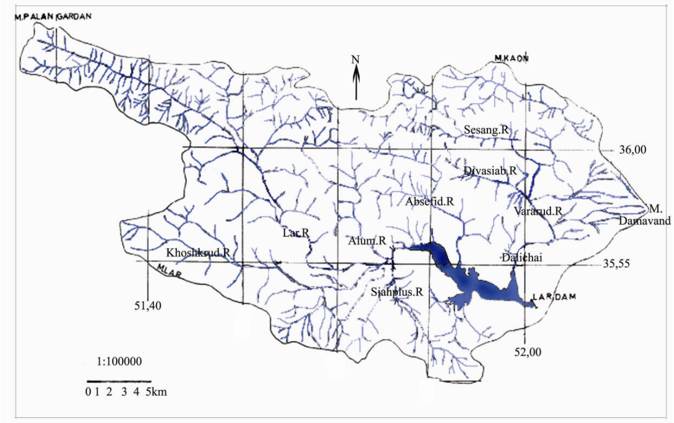

Figure 4- Hydrological map of Lar valley and its natural drainage system.

The results of chemical analysis of the three rivers of Lar, Delichay and Sefidab undertaken in the context of the study of faults impact on the quality of surface waters are presented in table 1.

Table 1-The surface water of Lar valley chemical analyze results

River name	Lar	Dalichai	Sefidab
K, Na	0.01, 0.18	0.09, 0.75	0.33, 1.0
Ca, Mg	1.55, 1.0	3.3, 2.0	4.1, 1.9
So_{4}, $_{CL}$	0.54, 0.18	3.03, 0.97	4.35, 1.78
$Hco_{3,}$	2.0	2.4	1.8
Type of water	Rich of $Caco_3$	Rich of $Caco_3$	Rich of Ca So_4
Effective factor	Limestone rocks	Limestone rocks	Faults

As shown in the table, the comparison of the water type and geological formation in the catchment basins of the same river has indicated that as the consequence of fault action the quality of water in Sefidab river is controlled by the geological formations, which have no surface evidence in the Lar valley. It can therefore be assumed that water is in contact with the said formations at depths through the faults resulting in a change in its quality.

III. Study of Faults Impact on Groundwater

The groundwater resources in Lar valley include 315 springs. The map of their dispersion (Fig 5) in the Lar catchment basin was correlated with the structural geology maps and the location of springs in relation to the faults axis, the number of equidistant springs, the interrelation of the springs and their distance from the fault axis were extracted the results shown in the table 2. As observed 36 springs are located on the axis of the selected faults, while 104 springs are in the surrounding areas, 51 springs on the hanging wall and 59 springs are on the

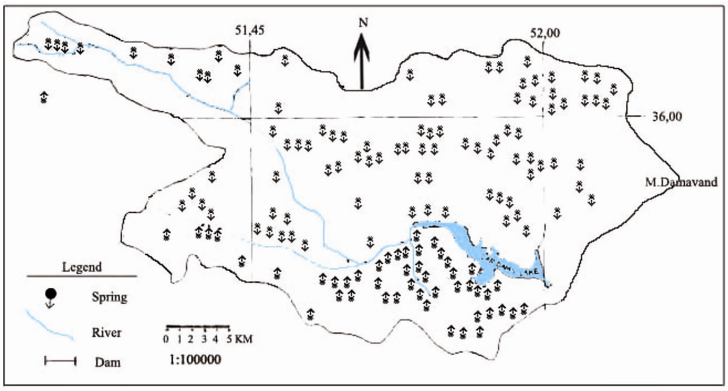

Figure 5- The map of Lar valley springs dispersion.

foot wall of the faults. The coefficient of integrity was calculated on the basis of distance in meters between springs and faults. The number of springs in the determined distance indicates that the appearance of springs around 4 faults as being significant and around 3 faults as somewhat significant while no relation was found around one fault. The table shows about 79% of Lar valley springs (250) affected by faults.

Table 2- Calculated equation of main faults and springs distance and its coefficient.

Equation, R	Main F	Max. and min .distance	Spring on Faults direct	Spring in fault around	Spring on hanging wall	Spring on footwall
Y= 0.3 x + 0.5 R= 0.77 and good	F1	20 m,0	4	1	--	5
Y= - 0.5 x + 2.33 R= 0.87and good	F2	15 m,0	2	6	--	8
Y= - 0.85 x + 7.8 R= 0.75 and good	F3	50 m,0	10	22	35	7
Y= 0.036 x + 3.2 R= 0.06 and average	F4	50 m,0	6	28	12	22
Y= - 0.5 x + 3 R= 0.5 and average	F11	15 m,0	2	6	--	--
Y= - 0.29 x + 3.96 R= 0.56 and average	F12	40 m,0	5	16	4	17
Y= - 0.514 x + 4.8 R= 0.75 and good	F13	30 m,0	5	13	--	--
Y= 0.114 x + 1.93 R= 0.15 and not good	F15	30 m,0	2	12	--	--
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In the next stage the heights of existing springs in Lar valley and around selected faults were measured as follows and it was determined that there are springs at heights of 2500 to 3800 m, indicating the existence of 10 aquifers of different height. The appearance of these aquifers is related to the impact of faults in addition to other factors such as type to rocks.

- Springs at the altitude of 3800 m
- Springs at altitudes of between 3500 to 3700 m
- Springs at altitudes of between 3000 to 3200 m
- Springs at altitudes of between 3100 to 3200 m
- Springs at the altitude of 3000 m
- Springs at altitudes of between 2600 to 2780 m
- Springs at altitudes of between 2700 to 3100 m
- Springs at altitudes of between 2500 to 2550 m
- Springs at altitudes of between 2750 to 2850 m
- Springs at the altitude of 2500 m

In the next step the results of chemical analysis of water from 9 springs selected in the Lar valley and surrounding areas were correlated in the Schuler Diagram (Fig 6).

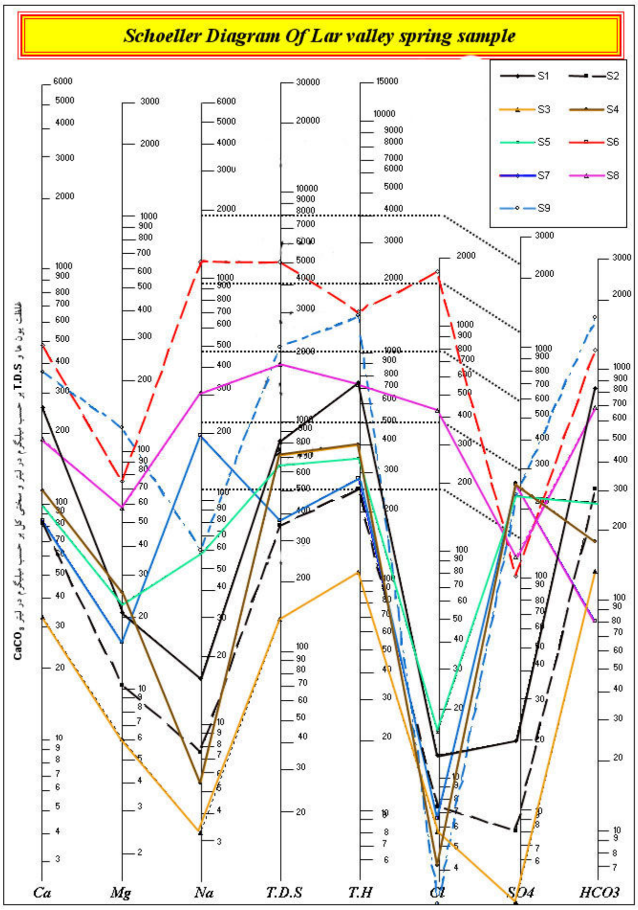

Figure 6-The Scholler diagram of Lar valley springs water. The number of samples is nine and many samples line are parallel and some cross each other.

Accordingly the water quality of 5 springs was found to be of carbonated calcic, 2 springs of sodium chloride and 3 springs were of sulphated soda and calcic type. Moreover the hardness condition of the water samples in Schuler diagram it became clear that some springs have a single source while others originate from separate sources. The existence of faults and fissures was assumed as the cause of water supply from different sources.

The results of Studies on karstic characteristic of the springs, their type and the geological formations containing the springs are presented in table 3.

IV. Results

The results of this study show the followings:

1- 60% of rivers in Lar valley are influenced by fault actions.

2- The water quality of Sefidab indicates the existence of geological formations that do not surface in the river basis or the Lar valley, and it is supposed that water is in contact with these formations through the faults.

3- The location of 57.5% of springs in Lar valley is on the axis of the faults, and the changes in altitude of the wellsprings are attributed to fault activity.

4- The water quality of a number of springs is affected by faults and the source of water in some springs is not common. It is supposed that faults have caused these springs to draw their water from different sources.

5- 31% of springs are of karstic type originating from the Jurassic and Cretaceous carbonated formations. The other springs originate from the hard formations of Jurassic, Eocene and the irregular sedimentations of quaternary. Their appearance in the hard formations is attributed to fault activity.

6- 54% of the springs are of contact type influenced by faults, while 46% of the springs are of overflow type.

The study's results allow the identification of faults and to complete the previous methods in this field.

Table3- The type, geological formation and karstic characteristic of Lar valley springs.

Type	Thrust faults spring	54%
	Contact springs	16%
	Joint ,opining spring	20%
	Seepage spring	10%
Geo-Formation	Limestone spring	31%
	Quaternary sediment	5%
	Tuff, Ash, volcanic, Sandstone and Siltstone	20%*
	Quaternary deposit	10%*
Karstic	98 Spring	31%
Un-Karstic	217 spring	64%

* Repetitive rate

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