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Reconnaissance Survey of Geothermal Resources in West Azarbaijan Province, NW-Iran

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ABSTRACT

West Azarbaijan Province (WAP) is located in the most northwestern part of Iran near Turkey and Iraq borders. This province is very rich in geothermal resources. According to many types of data such as geological, remote sensing, aeromagnetic, gravity and warm springs, 11 geothermal prospects were determined in WAP. In WAP, 41 warm springs exists with a temperature more than 25 ºC. Geothermal prospects are located around Maku, Shot, Khoy, Siahcheshmeh, Orumiyeh, Shahindezh and Takab cities. The hottest spring (Ghotur) in the WAP is located in the west of Khoy city and its temperature is 57.5 ºC.

1. INTRODUCTION

West Azarbaijan Province (WAP) is one of the 31 provinces of Iran. It is in the northwest of the country, bordering Turkey, Iraq and Nakhchivan Autonomous Republic, and the provinces of East Azarbaijan, Zanjan and Kurdistan (Figure 1). The province of West Azarbaijan covers an area of 43,660 km² including the Orumiyeh lake. In 2011 the province had a population of 3,080,576 inhabitants.

Figure 1. Location of West Azarbaijan Province in Iran

Due to the presence of some surface geothermal manifestations in WAP such as warm springs, young volcanic rocks, extensive travertine outcrops, etc., the Renewable Energy Department of Niroo Research Institute (NRI) conducted a Reconnaissance survey of geothermal resources in that province in order to determine geothermal prospects.

We used many types of data such as geology, warm springs, and remote sensing to define the geothermal prospects in WAP.

In our project, at first we gathered and evaluated relevant available data and then we generated some new data which were very useful for determining geothermal prospects in WAP. Finally we could recognize 11 geothermal prospects which are distributed in the North, Center and South of WAP. They are located around Maku, Chaldoran, Khoy, Salmās, Orumiyeh, Shahindezh and Takāb cities. In this paper we mention all data very briefly. They include geothermal surface manifestations, remote sensing results and integrated interpretation and the final results.

2. GEOLOGY

A geologic survey is usually the first work to be conducted "on the ground" and aims at detecting and characterizing the following (DiPippo, 2007):

- Tectonic and stratigraphic setting
- Recent faulting
- Distribution and age of young volcanic rocks
- Location and nature of thermal manifestations
- Hydrothermally-altered ground and rocks.

Due to the importance of geological data in a geothermal reconnaissance survey program we used 1:100,000 available geological maps which are generated by Geological Survey of Iran (GSI). The scale of the study is the same as the scale of the geological map. Since WAP is a large province; it isn't possible to deal with geology of the WAP in detail. Therefore, we used geological maps in order to determine and select geothermal surface manifestations in WAP such as young volcanic rock outcrops, Travertine deposit outcrops and faults. We also used geological data for generating a first conceptual model of each prospect which is not published in this paper due to the large number of prospects.

2.1. Young Volcanic Rocks

These rocks can provide the required heat for geothermal resources especially for high-temperature geothermal reservoirs. Young volcanic rocks in WAP are divided into two main groups, Quaternary rocks and Pliocene ones (Figure 2). It should be noted that Pliocene rocks are not very young but in some cases it is possible that volcanic rocks that belong to the late Pliocene can form some low temperature geothermal resources.

Quaternary volcanic rocks are located in the northern and central parts of WAP while Pliocene volcanic rocks exist in the southeastern part. Based on the geological maps, both groups of volcanic rocks are basaltic in composition. However there are some geothermal prospects in WAP whose heat source isn’t cooling of young volcanic rocks. For instance, in Silvana and Shahindezh, there are geothermal prospects there aren’t any outcrops of young volcanic rocks surrounding warm springs.

2.2. Travertine Deposits

Meteoric water, heated either around magma bodies or during deep circulation along faults, reacts with carbonate rocks and liberates CO_2. The hot waters are subsequently cooled as they mix with cooler groundwater and reach chemical equilibrium with the aquifer rocks at ~70 °C (Bargar, 1978). If the water reaches the ground surface through fractures, CO_2 escapes and the water becomes supersaturated with $CaCO_3$; precipitation of the carbonate forms travertine near or above the ground surface. Distinctive mounded travertine deposits form around these springs, which have temperatures ranging from ~30 to 100 °C. Travertine deposits are indicators of geothermal reservoir temperatures that may be too low to generate electricity but may have direct-use applications such as for greenhouses or hot-water heating for nearby communities, (Wohlets & Heiken, 1992).

Travertine deposits are outcropped in three separate regions of WAP, in the north, center and southeastern parts of the province (Figure 2). In the southeast of WAP, there are very extensive outcrops of travertine where some mining activity has developed. As it can be seen in Figure 2, there are extensive travertine outcrops around the cities of Shot and Takab; their area is about 26 and 100 km^2, respectively.

3. REMOTE SENSING

Remote sensing is a relatively inexpensive exploration tool, although the resolution is often not high enough to identify specific geothermal targets. Multispectral satellite data can provide a useful early picture of an area of interest. Geothermal exploration managers often use both ASTER data and landsat data (Jones et al, 2009).

Satellite images are useful tools in reconnaissance geothermal projects. They can provide some precious data about faults and hydrothermally altered areas especially in inaccessible and impassable areas. In the present study, we used ASTER satellite images in order to determine hydrothermally altered areas in WAP.

Argillic altered areas are shown in Figure 3. Although they are distributed in many parts of WAP, the most important altered area related to geothermal fluids are located in the north, center, south and southeastern of WAP. In order to control the altered areas, some field visits have been carried out in WAP (Figure 4). During the field checking, we collected some rock samples from altered areas. Then, some thin sections were taken from those samples. Microscopic studies were carried out on thin sections and finally it is found that the remote sensing data are very reliable. For example in Figure 5, there is a microscopic photo of a thin section of an altered rock.

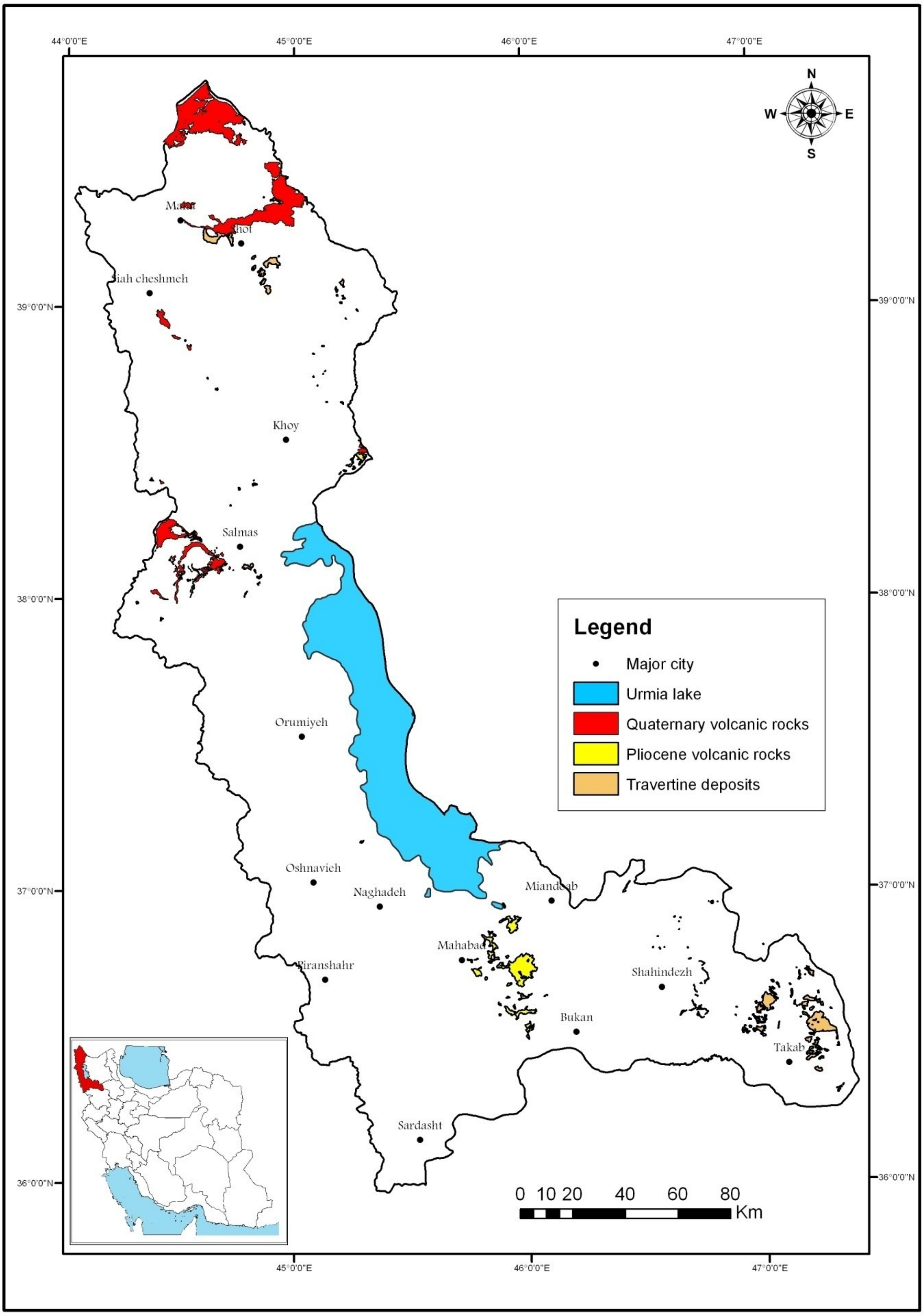

Figure 2. Young volcanic rocks and Travertine deposits in West Azarbaijan Province

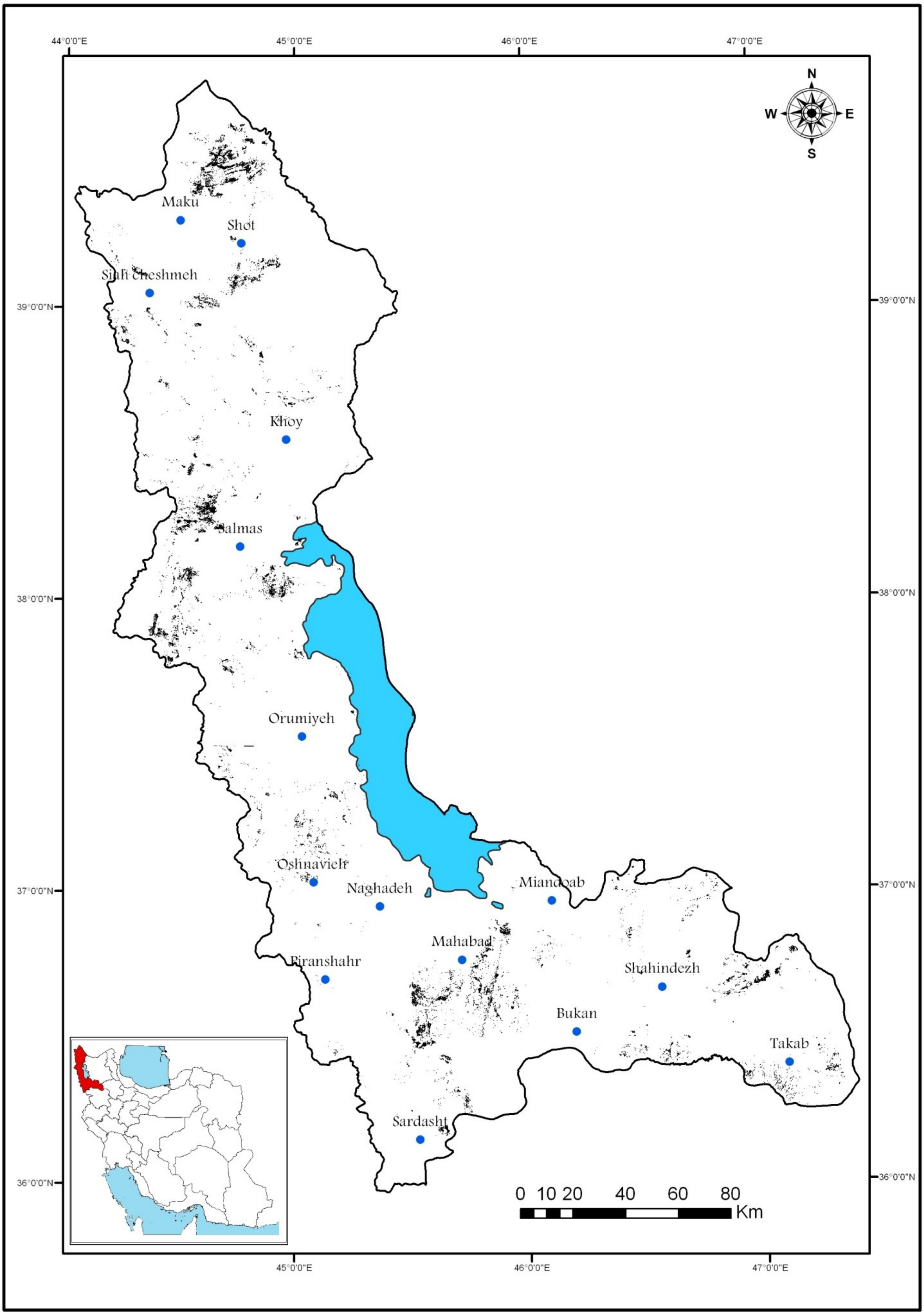

Figure 3. Argillic altered areas in West Azarbaijan Province

Figure 4. Field checking of extensive kaolinitic altered areas in West Azarbaijan Province (in Ghotur region, west of Khoy)

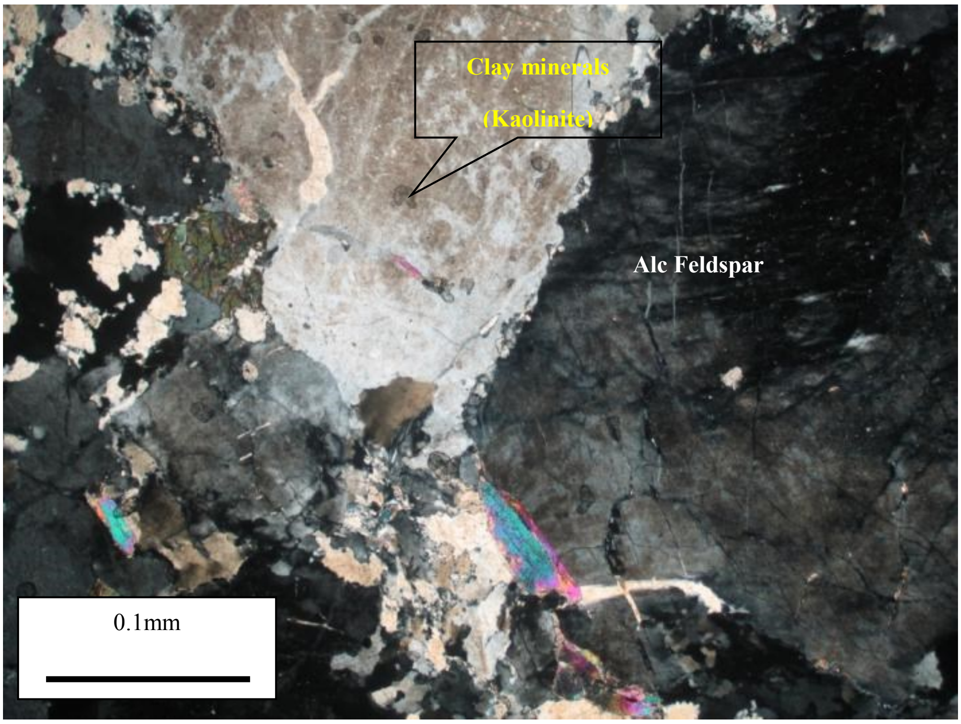

Figure 5. Microscopic photo of argillic alteration in metagranite rocks

4. WARM SPRINGS

In order to identify warm springs in WAP, we carried out many tasks. First, we searched for relevant papers, MSc and PhD dissertations, books and other data sources. We also used a databank of the West Azarbaijan Local Water Company. Then we searched in almost all counties of the province to determine unknown and undocumented warm springs. It should be mentioned that we considered those springs as warm spring whose temperature was more than 25°C. Finally, based on the obtained data we traveled to all counties of WAP in order to find and locate all the warm springs.

There are more than 40 warm springs in WAP which are located in Northern, Central and Southwestern parts of it (Figure 6). They are concentrated in 12 localities. They emerge around the cities of Maku, Shot, Chaldoran, Khoy, Orumieh, Shahindezh and Takab as shown in Figure 6. Also, their temperature range is from 29.6 (for the spring Istisu-e-Bala near the city of Siahcheshme) to 57.5°C (for the spring Ghotur in the west of Khoy city). Their pH varies from 6.34 to 7.57. In Table 1, other characteristics of WAP warm springs are listed. In Figure 7, two warm springs of WAP are shown.

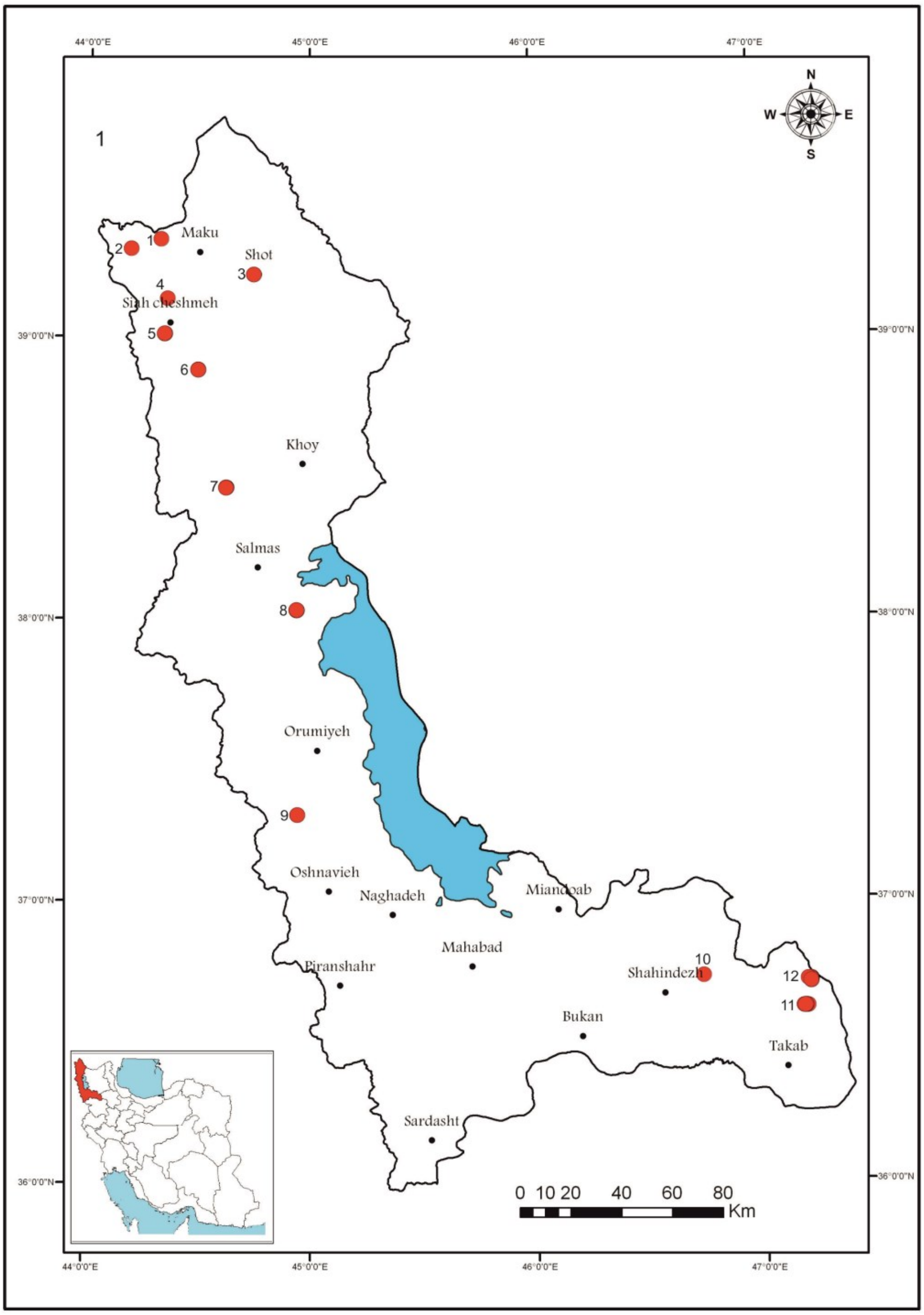

Figure 6. Warm Spring's location in West Azarbaijan Province

Table 1- General characteristics of West Azarbaijan province warm springs

No	Spring Name	Latitude	Longitude	T (˚C)	Flowrate (l/sec)	pH	Ec (µS/cm)
1	Bashkandi	441715.4	4355281.7	32	2	6.70	890
2	Arabdizaj	428349.7	4351752.6	27	0.25	6.73	1563
3	Shot	478011.6	4341346.9	33.2	1	6.42	2850
4	Chaldoran	442857.3	4318125.7	48	0.25	6.88	1401
5	Istisu-e- bala	444133.8	4331896.0	29.6	1	6.52	1742
6	Gharanjeh	456104.09	4304138.62	39.8	0.5	6.93	7381
7	Ghotur	467183.0	4257521.2	57.5	1	6.63	4480
8	Istisu	494756.7	4209247.6	40	0.5	7.34	1666
9	Haftabad	495075.2	4128625.8	32.3	2	6.34	2540
10	Ghezelghayeh	655225.0	4066062.0	29.7	2.5	6.68	7170
11	Ahmadabad	695369.0	4054516.9	38	3	6.59	1538
12	Gheinarjeh	697423.0	4064860.5	39	2	6.43	5920

Figure 7. Two warm springs in West Azarbaijan Province. Left Figure: Ahmadabad warm spring in NE of Takab; Right Figure: Haftabad warm spring in SW of Orumiyeh (see Figure 6 for city locations)

5. INTEGRATED INTERPRETATION

At the end, all data was analyzed using GIS. We superimposed all data layers in GIS and evaluated the relation of different data layers from a geothermal point of view. Definitely data on warm springs was the most important information; in the second place we considered young volcanic rocks, travertine deposits and altered areas. Finally, we could determine 11 geothermal prospects in WAP. In fact, according to our study, each prospect has its own warm spring(s) and possibly it is including some volcanic rocks, travertine deposits and altered areas too. All geothermal prospects of WAP are shown in Figure 8. As it can be seen in the figure, most of the prospects are located in the northern parts of the WAP. It is very clear that WAP is a rich province in the case of geothermal energy. In Table 2 some general data about WAP geothermal prospects are illustrated.

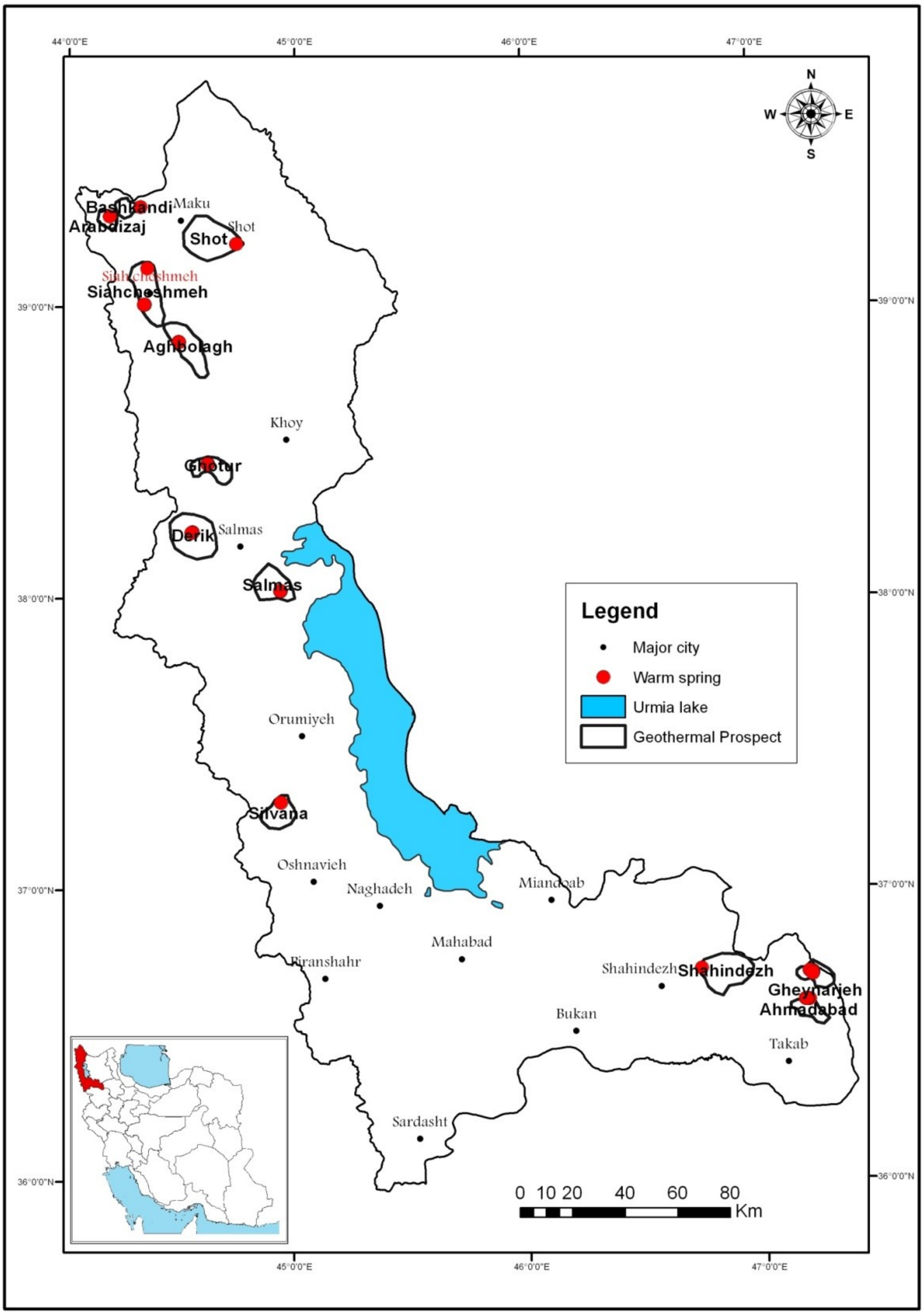

Figure 8. Geothermal prospects in West Azarbaijan province

Table 2. General information about West Azarbaijan Province Geothermal Prospects

No	Prospect name	County name	Area (Km^2)	Warm Springs Temperature Range (°C)
1	Bashkandi	Maku	48	31
2	Shot	Maku	247	30
3	Arabdizaj	Chaldoran	41	26
4	Siahcheshme	Chaldoran	190	28-35
5	Aghbolagh	Chaldoran	165	28-39
6	Ghotur	Khoy	101	48-57
7	Salmas	Salmas	144	35-42
8	Silvana	Orumiyeh	112	31-33
9	Shahindezh	Shahindezh	219	31-33
10	Gheynarjeh	Takab	90	28-39
11	Ahmadabad	Takab	76	26-40

6. CONCLUSIONS

According to the geothermal surface manifestations, there is a proper potential of geothermal resources in West Azarbaijan province. In West Azarbaijan province, 41 warm springs emerge from 12 locations and their temperatures vary from 26 to 57 °C. Young volcanic rocks mainly outcrop in the northern part of that Province. They are mostly outcropped around the cities of Maku, Siahcheshmeh and Salmas. Some geothermal prospects have different heat sources, based on available geological data. Geothermal prospects of West Azarbaijan Province were selected based on location of warm springs, young volcanic rocks outcrops, travertine deposits outcrops and altered areas. According to all available data, 11 geothermal prospects were determined in the province. There are more geothermal prospects in the northern parts of the province, than in the southern. Based on the available data, most of the determined geothermal prospects in the province are of low temperature. It is recommended to conduct a detailed exploration program in each prospect to delineate the geothermal reservoir nature, its characteristics and to generate the first conceptual model of the relevant reservoir. West Azarbaijan province is one of the coldest provinces of Iran, so in remote villages which do not have access to the national natural gas pipeline grid, geothermal fluid can heat the homes or other spaces in winter time. It is believed that Salmas, Aghbolagh and Ghotur geothermal prospects are suitable for power generation and heating purposes as well.

REFERENCES

Bargar, K. E.: Geology and Thermal history of Mammoth Hot Springs, Yellowstone National Park, Wyoming. U.S. Geol. Surv. Bull. 1444, (1978), 55 pp.

DiPippo, R.: Geothermal power plants. Principles, Applications, Case studies and Environmental Impact, Butterworth-Heinemann, Pub. Co. , (2007), 520pp.

Jones, k.l., Schulenburg, N.W., Kupferman, P.N., Bryant, G.P.: Hyperspectral remote sensing techniques for locating geothermal areas, (2009) in http://en.openei.org/wiki/Hyperspectral_Remote_Sensing_Techniques_For_Locating_Geothermal_Resources.

Wohletz, K., Grant H.: Volcanology and Geothermal Energy. Berkeley: University of California Press, (1992).

1: 250000 and 1:100000 geological maps of West Azarbaijan Province, Geological survey of Iran.