Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Preliminary Exploration of Geothermal Resources in Khorasan Province, NE-Iran

Javad Nouraliee

Niroo Research Institute, P.O.Box 14665-517, Tehran-Iran

Jnouraliee@nri.ac.ir

Keywords: Geothermal, Geology, Preliminary Exploration, Remote sensing.

ABSTRACT

Khorasan province, the biggest province of Iran, is located in the North-Easternmost part of the country. There are several hot and warm springs, hydrothermal altered regions, some volcanic craters which are the main surface manifestations of geothermal energy in Khorasan province.

Geothermal explorations in this region are included the following stages: geology, aeromagnetic surveying, remote sensing and geothermometery. According to the investigations, three potentially favorable areas were determined which all of them are located in the southern part of the province. Those are Ferdows, Naiband and Birjand areas. Their relevant areas are 3200, 2000 and 2400 km^2 respectively. Estimated reservoir temperatures of the selected regions are as follows; Ferdows (85ºC), Naiband (113ºC) and Birjand (90ºC) according to the Na-K, Na-K-Mg and Sio_2 geothermometers. All the geothermal prospect areas are located in the vicinity of the young volcanic rocks.

1. INTRODUCTION

Khorasan province (KP) is the largest province in Iran and is located at the Northeast of the country. Its area is more than 300,000 km^2, (Figure 1).

Due to presence of several volcanic craters and hot springs, KP is one of the important regions in Iran for exploration and exploitation of geothermal energy. Therefore, Renewable Energy Department of Niroo Research Institute (NRI) performed a preliminary exploration project which its results are presented briefly in this paper.

First, according to geology, volcanology, seismology and thermal water specifications, a relatively large region whose geothermal potential was more than the other parts of the KP, was selected for further study.

In the second stage the selected region was investigated by aeromagnetic surveying and remote sensing methods. As a result three favorable areas were chosen around the Naiband village, Ferdows and Birjand cities.

According to the geology (tectonic and volcanology) and hot spring distribution of the KP it can be found that almost all of the KP geothermal resources are convective hot-water dominated systems. Their heat source is recently solidified magmatic rocks. So, groundwater circulates downward in open fractures and faults and removes heat from deeper sections of the region. But the main question in this arid area is water source. More detailed investigations (especially isotopic studies) can determine that where does water penetrate to the geothermal resource?

2. VOLCANOLOGY

Young volcanic rocks are one of the most important heat sources of geothermal resources. So, their distribution throughout the province was studied.

The results show that there are some basaltic and andesitic rocks in the south of Aladagh mountain and Quchan city (in the northern part of the province) which belong to plio-pliestocene. Figure 2 shows the distribution of late Tertiary and Quaternary volcanic rocks in the KP. As it can be seen most of the young volcanic rocks are located in southern part of KP.

There are also some basic volcanic bodies related to the quaternary in the north of Kashmar city (Nabavi, 1971).

Along to the Naiband fault and south of Ferdows city, several young volcanic craters can be seen. Their volcanic rocks are basaltic in composition. Presence of hot springs and fumaroles reveals that these intrusive rocks are under cooling. In fact groundwater penetrates to the underground through the faults and after absorbing heat appears as a hot spring at the surface. There are more than 35 craters which are located in different distances from Ferdows city.

Around the southern end of Naiband fault, some young volcanic bodies (with 5000 to 50,000 years old) exist which are mostly basaltic (Nabavi, 1971).

3. TECTONICS

In terms of tectonic activity, KP is active. Evidences of these activities are Kopet Dagh foldings (in the north), several large faults and extensive seismic activity. Kopet Dagh foldings are located in the northern part of the province, which have NW-SE trend. They are more intensive in their southern margin.

Throughout the province, there are several major faults that have made sedimentary units border. Their movements also have made some deformations in different formations. The most important faults of KP are as follows: Miami, Kalmard, Troud, Naiband, Dorouneh, Nehbandan, Posht-e-badam and Hariroud.

It should be noted that none of them is completely in the province and only some sections of them are positioned in KP area. Figure 3 shows the main faults of Iran and KP.

4. SEISMICITY

Seismic activity study can lead us to active faults. Therefore, analysis of seismicity all over the KP can help scientists to localize active faults. Seismic activity of KP during 1964 – 2001 is shown in Figure 4.

So, the distribution of earthquake epicenters was studied. Hence it was found that seismicity around Shirvan, Bojnourd, Neyshabur, Mashhad, Espharayen and Jajarm cities were affected by NW-SE Kopet Dagh System (in the northern part of KP) (Heydari and Zare, 1995).

In KP central section, there is a major fault (named Dorouneh) which is very close to Kashmar and Torbat-e-heydarieh cities. It seems that they are located in a hazardous seismic region.

Other cities such as Torbat-e-jam, Khaf, Rashtkhar and Bardaskan are also in the vicinity of Dorouneh fault. To the south, Bonyabad-dasht-e-bayaz, Sarayan and Chahak fault plains can be seen. Qaen, Gonabad and Ferdows cities are positioned in this fault plain. There is another fault plain, where there are Esphandiar, Kalmard and Tabas earthquake fault inside it. Tabas fault strongly shocked all areas in 1979.

5. THERMAL SPRINGS

So far 31 thermal springs have been found in KP. Their location, and approximate temperature and flowrate are shown in Figure 5. These springs are near the following cities: Bojnourd, Quchan, Neyshabur, Kashmar, Ferdows, Qaen, Sabzevar, Birjand and Naiband village (Shahbeyk, 1993). Dig-e-rostam hot spring, whose temperature is about 75ºC and located near Naiband village, is the hottest spring in KP. Physical and chemical characteristics of thermal springs of south KP have been presented in Table 1.

As all available data about KP thermal springs were very old, so during this project, almost all of them were visited, sampled and checked again. The information obtained was used for geothermometry. According to the results of previous studies, such as volcanology, thermal springs, tectonic and seismicty, a relatively large area (about 80,000 km^2) in the southern half of KP was chosen for further exploration. The selected region is shown in Figure 4. The selected region has been investigated by two different exploration methods: Aeromagnetic surveying and remote sensing.

6. AEROMAGNETIC SURVEYING

In this part of the exploration, present aeromagnetic data from Geological Survey of Iran were used. Flight line distances in aeromagnetic maps was 7.5 km. The results were presented in two maps, total magnetic intensity map and aeromagnetic interpretation map. Magnetic anomalies are shown in Figure 6. Black arrows indicate those regions which coincide with other geothermal manifestations such as hot springs and hydrorthermal altered areas. Aeromagnetic data interpretation was performed based on geology rather than altered areas. In fact, these studies focused on those regions with low magnetic anomaly where located within a quaternary volcanic bodies and close to the known hot springs.

Interpretation of aeromagnetic data revealed that:

- There is a small negative anomaly in north of Ferdows city which is surrounded by high magnetic intensity rocks. Probably it is related to Ferdows warm spring. Also, to the south, there is another anomaly that is very large.

- In the north of Naiband village, there is an elongated anomaly that is aligned in N-S direction. It is surrounded by quaternary volcanic rocks. In the south of village is another anomaly that covers a large area, which contains a few hot springs (their temperatures varies from 30ºC to 75ºC).

- There is an anomaly in south-east of Birjand city, which extends in NW-SE direction and is positioned near Gondakan, Sarbisheh and Gezik warm springs. This anomaly also is very close to quaternary volcanic bodies.

7. REMOTE SENSING

In this part of the exploration, satellite images and data of the selected area were used. These data were included No. 1,4,5,6 and 7 bands of Landsat satellite. Study area was covered by 7 frames of Landsat images, which after many corrections were used to identify geothermal alteration anomalies. Satellite data were provided by Iran Remote Sensing Center (IRSC). In order to minimize the possible mistakes, results of these studies were controlled by available 1:250,000 geological maps. Figure 7 shows the distribution altered regions, which are believed to be related to geothermal resources. In order to interpret the remote sensing data, the following items were considered:

1. Those altered areas were related to sedimentary formations (such as shale, sandstone and limestone) have been omitted. For example such conditions exists in north of Gonabad city which is consisted of shaly formations.

2. Altered regions which were related to Quaternary and Tertiary volcanic bodies were regarded as the first and second priority for geothermal energy potential respectively.

3. Those altered regions which are within a Tertiary volcanic rocks were considered as an areas with reasonable geothermal potential.

Remote sensing study revealed that:

- In south of Ferdows, there are some altered regions in the vicinity of Quaternary volcanic craters and young andesitic rocks. In the north also, within Tertiary volcanic rocks, an altered region is found which presence of Ferdows hot spring inside it emphasize to the geothermal potential of the area. There is another altered region in the south of Ferdows, along Ferdows-Naiband road that is located in the Neogene-Quaternary volcanic rocks.

- In the north of Naiband village (about 60 km far from the village) there is a relatively large altered region within the Quaternary basaltic rocks that doesn't include any hot spring or other geothermal features. In the east, there is another altered area, which is parallel to the Naiband fault and elongated from north to south. It is surrounded by the Eocene volcanic rocks.

- Also in the south, a positive alteration anomaly was identified, which is related to Terriasic sedimentary rocks (mainly shale). They are very important because of two reasons; first, within this anomaly many dykes can be seen that intersect shales along the Naiband fault. Second, 5 hot springs (with temperatures more than 60ºC) were found in this anomaly.

- In east and southeast of Birjand, there are some large bodies of positive alteration anomaly, which are very close to Eocene to Quaternary andesitic, basaltic and dacitic volcanic rocks. In the east of Gezik village (east of Birjand) a large body of altered rocks can be seen in ophiolitic and

metamorphosed rocks. In this region alteration intensity is very high and the presence of Gezik hot spring marks it as a geothermally favorable region.

8. CONCLUSION

According to the results of different investigations, three regions were selected for further study. These regions are Ferdows, Naiband and Birjand. Figure 8 shows selected regions which are close to Ferdows and Birjand cities and Naiband village. Ferdows geothermal resource is very close to the city (about 3 km) and could be an excellent target for geothermal direct uses in the future. Ferdows city has 20000 inhabitants. Naiband region also has the same situation. Table 2 illustrates their specifications such as probable heat source, area, released heat energy (only from hot springs) and approximate reservoir temperature (based on Na-K, Na-K-Mg and SiO_2 geothermometry).

9. RECOMMENDATIONS

1. As Naiband village does not connect to national electricity network, so it will be a suitable idea to maintain its electricity needs by means of a small scale geothermal power plant (e.g. a binary geothermal power plant). Also, people of this region can utilize geothermal hot water for district heating in winter time.
2. Based on available data, there is no natural gas pipeline network in Ferdows city, therefore hot water of Ferdows geothermal reservoir can be used for district heating.
3. Due to sufficient potential of Birjand region, the inhabitants can heat their homes with geothermal fluid. This region includes Gezik, Nasroddin and Avaz villages and Sarbisheh town.
4. Furthermore, it is recommended to perform detailed geological, geochemical and geophysical explorations in order to obtain more knowledge about the nature, size and other features of Khorasan province geothermal resources.

REFERENCES

1. Heydari. M., Zare. H.,: A Preliminary study of Seismicity, Seismotectonic and Earthquake Fault Hazard in the Khorasan Province, International Institute of Earthquake Engineering and Seismology (IIEES), (in Persian), 1995.
2. Nabavi, M. H.: Review of the Geology of Iran, Geological survey of Iran, 1971.
3. Shahbeyk, A. : Mineral and Thermal springs of Iran, Geological survey of Iran, 1993.
4. www.seismo.um.ac.ir

Table 1: General characteristics of hot springs of Khorasan Province high-potential geothermal regions

City/Village	Hot spring	Longitude	Latitude	Elevation above sea level (m)	Temp. (ºC)	Flowrate (L/S)	pH
Ferdows	Ferdows	58º 12´	34º 8´	1500	45.5	5.2	6.69
	Farkhondeh	58º 16´	34º 8´	1575	19.2	5	8.45
Birjand	Gezik	60º 15	32º 54´	1348	34.1	15	7.9
	Gondakan	59º 59´	32º 33´	1744	34	16	6.22
	Sarbisheh	59º 48	32º 46´	2269	20.2	2.5	6.26
Naiband	Zardgah	57º 27´	32º 23´	1406	36.5	4	7.59
	Ashk-e-rostam	57º 30´	32º 16´	799	75.3	2	6.36
	Dig-e-rostam	57º 30	32º 16´	805	68.5	0.5	6.4
	Dig-e-rostam -east	57º 30´	32º 16´	807	65	0.5	6.4
	Ashk-e-rostam- southeast	57º 30	32º 16´	791	75.1	2	6.26

Hot spring	Electric		Chemical Analysis Results (mg/Kg)								
	µS/cm	mS/cm	TDS	Mg^{2+}	Ca^{2+}	K^{+}	Na^{+}	cl^{-}	HCo_3^{-}	So_4^{2-}	Sio_2
Ferdows	__	13.58	6600	77.3	464	19.6	1764	2907	268.4	980	33
Farkhondeh	__	6.19	4800	41.8	172	5.9	1467.6	1645	149	1248.5	11.08
Gezik	1396	__	730	30.2	27.2	2.3	183.9	126	217	226	15.33
Gondakan	__	7.44	4430	92.1	36	39.2	1551.5	936	2533	209	62.81
Sarbisheh	1955	__	1405	139	132	13.7	202.8	92	1391	86.4	39.88
Zardgah	1124	__	590	24	71.2	1.5	83.9	77	183	192.6	22.92
Ashk-e-	__	8.36	2600	39	188	27.4	685.1	922	290	533	51.51
Dig-e-	__	9.23	3065	40.8	220	43.1	792.4	1191	349	506	49.87
Dig-e-	__	3.80	3260	44.6	201.6	43.1	874.3	1311	303	526	49.38
Ashk-e-	__	8.85	2800	44.6	192.8	31.3	712.8	1021	315	533	49.97

Table 2: General characteristics of high-potential geothermal regions in Khorasan Province

Geothermal Regions	Area	Approximate Reservoir	Released heat energy	Heat Source
Ferdows	3200	85	1.08	Quaternary Volcanic
Naiband	2000	113	2.5	Doleritic rocks
Birjand	2400	90	4.3	Quaternary basaltic

Figure 1. Location of Khorasan Province in IRAN

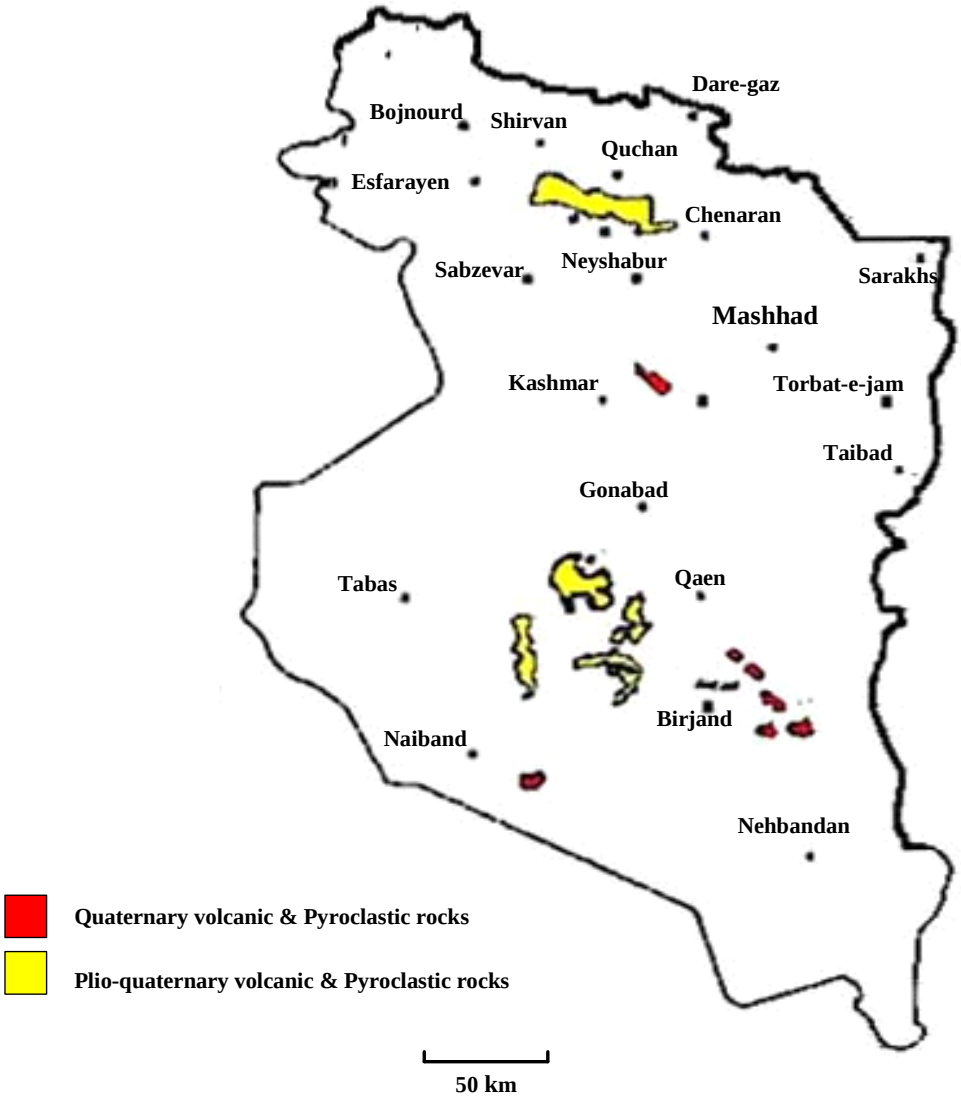


Figure 2. Distribution of young volcanic rocks in Khorasan Province

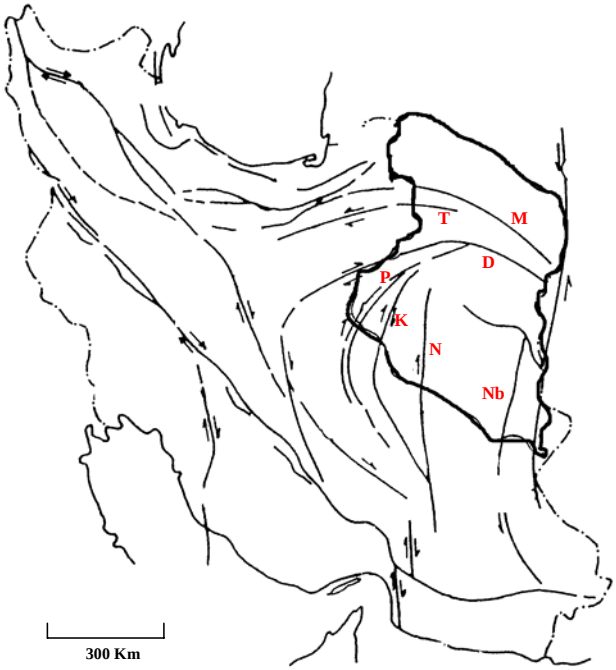


Figure 3. Major faults of Khorasan province

M (Miami f.), T (Toroud f.), D (Doruneh f.), P (Posht-e-badam f.), K (Kalmard f.), N (Naiband f.), Nb (Nehbandan f.)

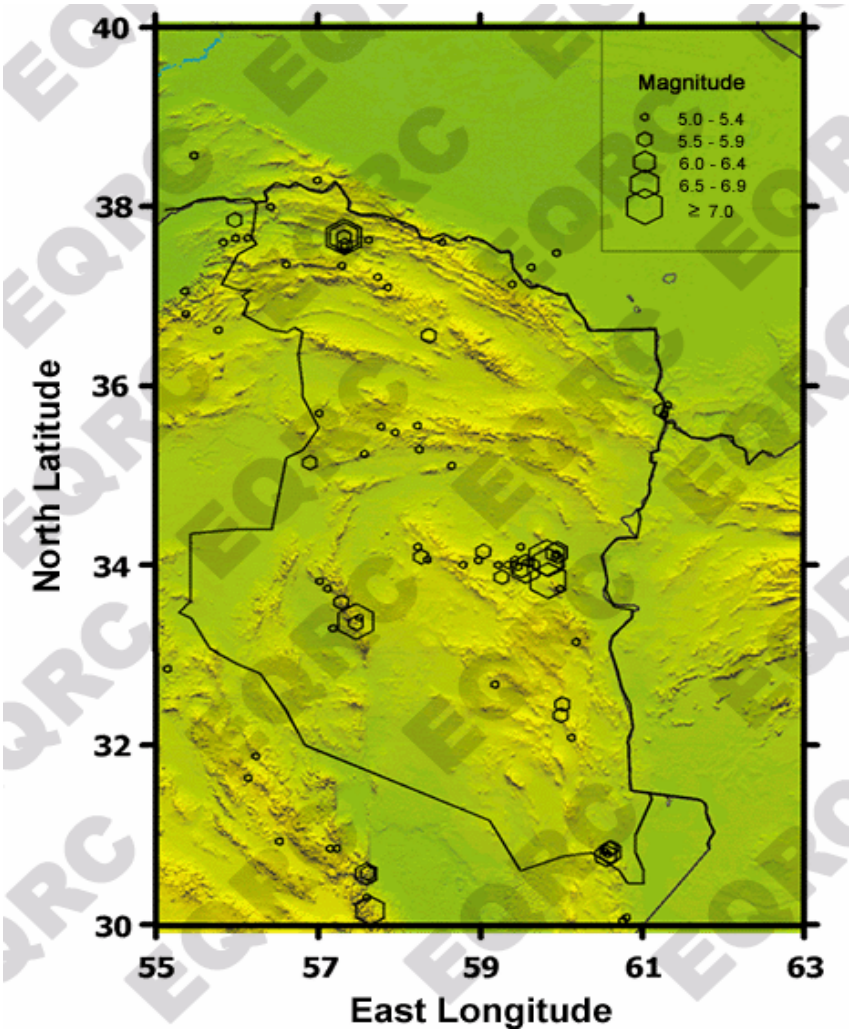


Figure 4. Seismicity of Khorasan province during 1964 - 2001

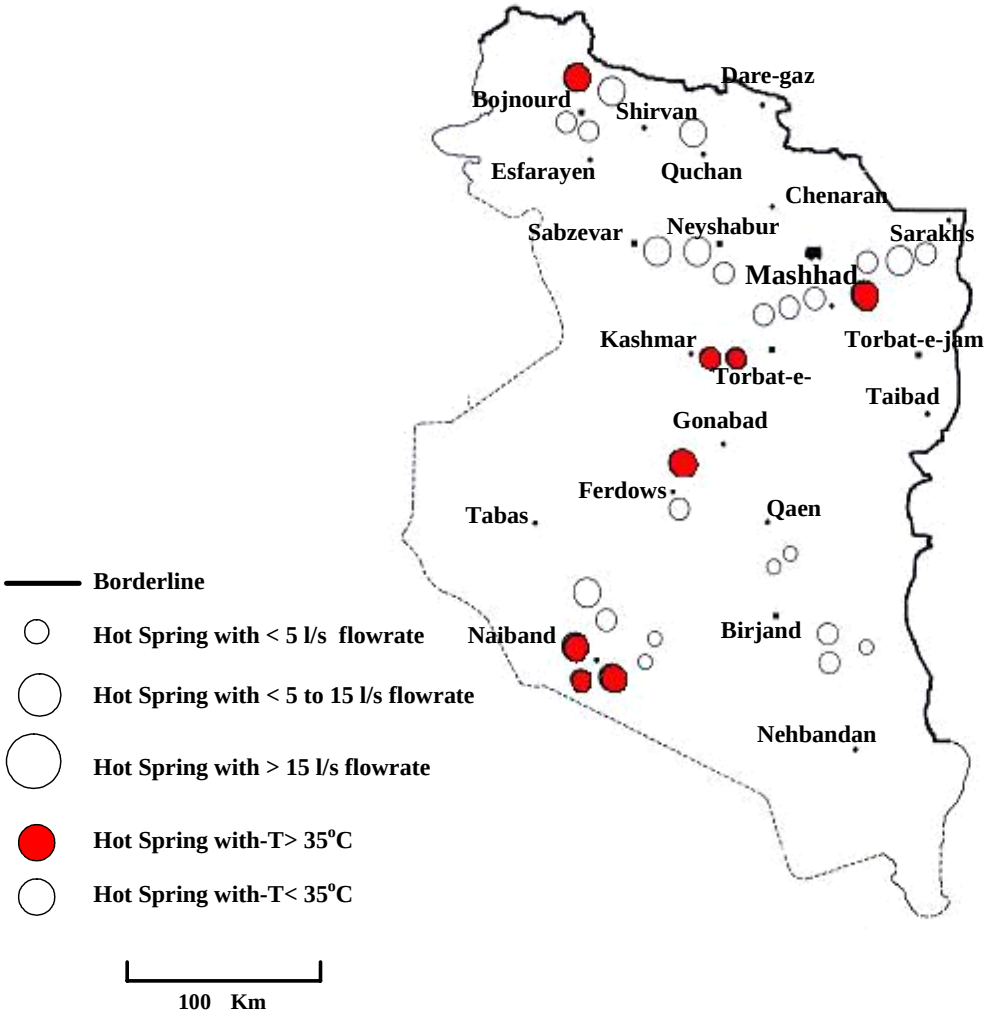
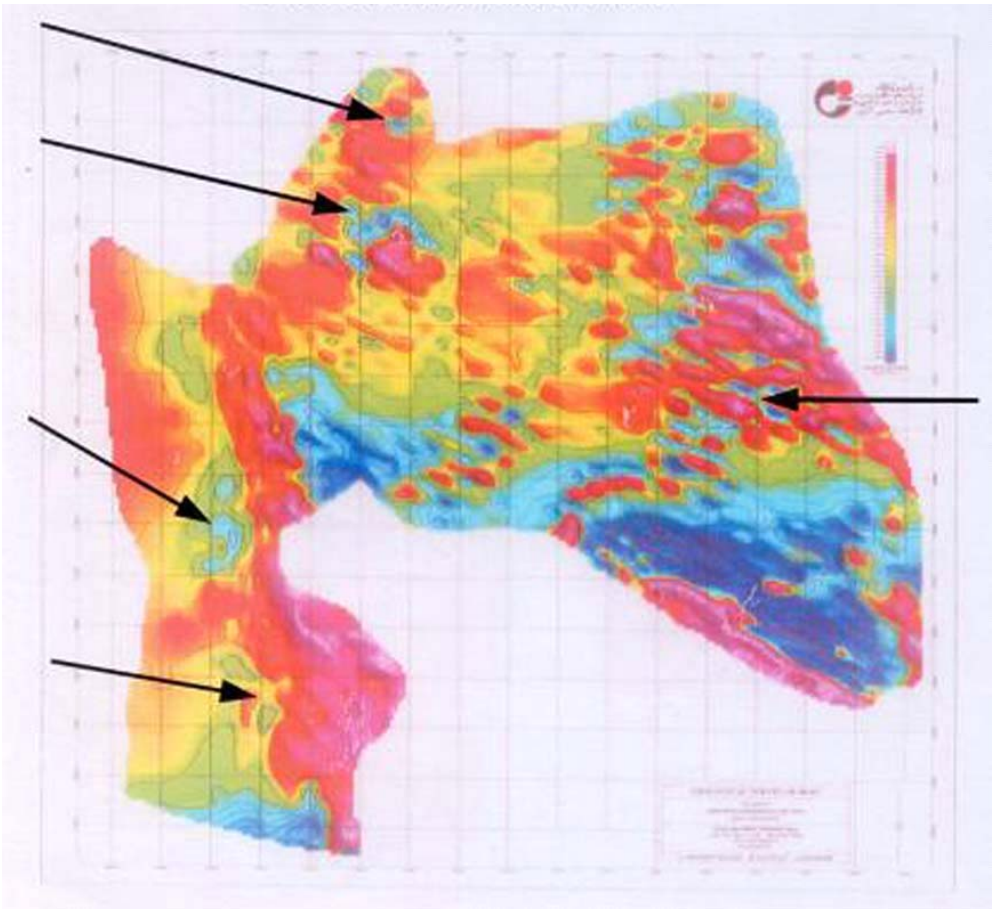


Figure 5. Hot Springs of Khorasan Province

Figure 6. Khorasan Province geothermal high potential region



50

Figure 7. Magnetic Anomalies of the Selected Geothermal Region in Khorasan Province

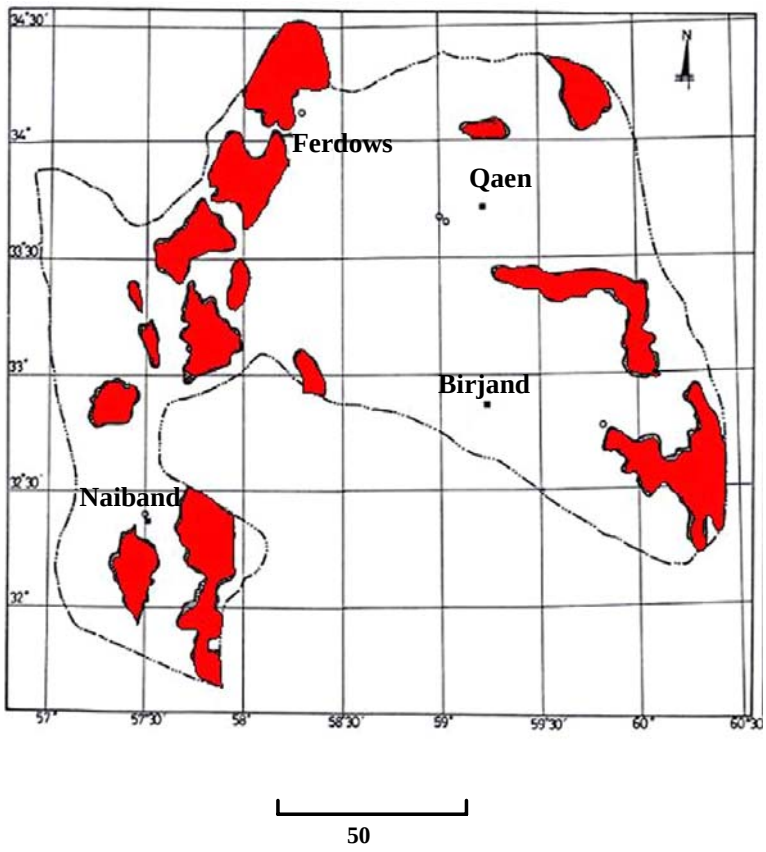


Figure 8. Altered Areas of the Selected Geothermal Region in Khorasan Province (based on remote sensing data)

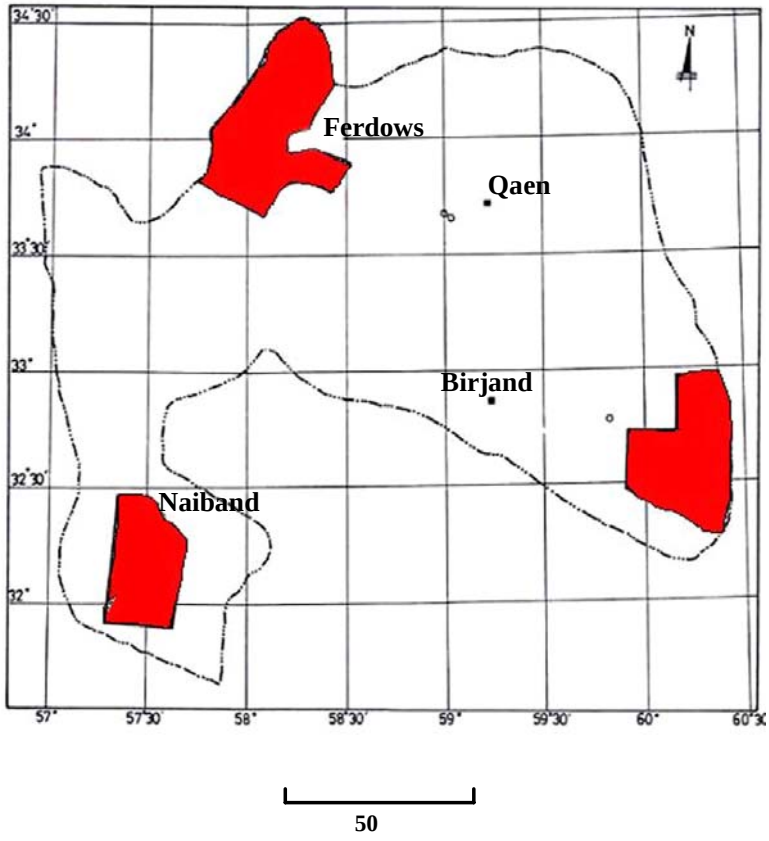


Figure 9. The most favorable geothermal areas in the southern part of Khorasan Porvince