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EXPLORATION AND GEOTHERMAL POWER IN AZARBAIJAN, IRAN (FROM SAVALAN TO KAMCHY VOLCANIC AREAS)

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Abstract- Geographical information system was used as a decision making tool to determine the spatial association between exploration evidence layers and environmental evidence layers in the Savalan geothermal field in northwestern Iran (Azarbaijan) for geothermal exploration well sitting. The ultimate purpose is to lower the cost of geothermal energy for electric power generation and direct uses.

Keywords: Exploration, Geothermal Energy, Geothermal Power.

I. INTRODUCTION

Many areas have accessible geothermal resources, especially countries along the Circum-Pacific "Ring of Fire" spreading centers, continental rift zones and other hot spots. Numerous active and extinct geothermal systemic in Azarbaijan Iran are closely related to late Cenozoic subaerial volcanism. Geothermal energy is one of the alternative energy sources that is being used in various ways, including for electric power generation and local heating systems. Geothermal Power in Iran is little used but growing.

There are known and potential locations near the north and north east of the Azarbaijan Iran that have been shown to contain volcanic fields and hot granites (e.g. Kantal region in border Araz River) at depth which hold good potential for development of geothermal energy. Exploratory geothermal wells have been drilled to test for the presence of high temperature geothermal reservoir rocks and such hot volcanic fields were detected. As result, project will eventuate in the coming years and more exploration is expected find new locations. Exploration involves finding vast volcanic fields with fracture systems that could generate electricity through water being injected. Circulated through the fractures and being returned to surface as steam.

Countries like the United States, Italy, Japan, New Zealand, Turkey, Mexico, Indonesia, China, Iceland, Kenya, Elsalvador, Nicaragua, and Russia are operating geothermal power plants. Azarbaijan Iran enjoys considerable potential to take advantage of renewable energies such as wind, solar and Geothermal.

In Azarbaijan Iran, most hydrothermal convection systems are developed in areas related to Plio-Quaternary volcanism, and these systems are associated with surface activity such as springs, fumaroles, hydrothermal alteration, and anomalously high surface temperatures, which can be the targets for remote-sensing. Many types of geothermal resources occur in Azarbaijan Iran [6].

II. GEOTHERMAL EXPLORATION

Geothermal exploration is the bridge between early-stage ideas for geothermal development and fully committed planning and start-up of geothermal production. In the broadest sense, geothermal exploration involves proving the viability of geothermal energy as a potential means of generating power and /or heat in a particular location. The knowledge obtained through exploration is the basis for an assessment of energy producing potential and the subsequent creation of engineering plans and construction cost estimates. The quality of the assessment depends on the quality of the available data. Accurate information from the exploration stage is crucial to assess not only the overall viability of energy production but the detailed physical challenges of drilling, operational expectations cost [1, 2, 10].

III. GEOTHERMAL STUDIES IN IRAN

Geothermal energy is one of the renewable energy sources that are being used in various ways, including for electric power generation and local heating systems. The geothermal studies in Iran started by the Iranian Ministry of Energy in 1975. Lineaments interpreted from remotely sensed imagery provide important information on subsurface fractures that may control the convective movement of geothermal fluids.

Many hydrothermal convection systems are situated at or near Plio-Quaternary volcanoes in Iran (Savalan, Sahand, Damavand and other regions) and photogeologic interpretation is quite helpful in volcano-stratigraphic studies of these areas. Molten or solidified magma beneath such areas generally is accepted as the heat source for the volcano - related geothermal systems.

Large scale circular features are observed in volcanic terrines from synoptic Landsat imagery. These features are known sometimes to be Quaternary calderas Figure 1. Other features are concealed partly by sediments or are obscured by dissected geomorphology. The Savalan area in the northern most part of Iran (Azarbaijan) was studied in order to: 1. clarify the geologic meaning of its large circular feature and 2. assess the geothermal potential of the area. The researchers concluded that the area was the center of early Pleistocene, large-scale volcanism and that the circular feature is a caldera which was formed by the eruption of voluminous acidic volcanic rocks (rhyolites to trachyandesites and tuffs) and was given the name of Savalan caldera. The Savalan area was selected as a geothermal exploration target.

A combination of several new types of data obtained in drilling and in assessment of geothermal resources assisted in interpreting the caldera structure. The electric power research center (EPRC) and Renewable Energy Organization of Iran (SUNA) were established to justify priorities of the above mentioned regions. As a result Khiav or Meshkinshar and Sarein area in Savalan region, were proposed for electric and direct use respectively. Savalan volcano is a point volcano and its coning is a strato-volcano type. This volcano, from geologogical point of view,is formed in the great Oligocene period. Its primal activity happened during Eocene time and the last activity in as during the end of Quaternary time.

There are several hot hydrothermal springs around the Savalan and other volcanoes in Iran especially in Azarbaijan Iran areas. In 1998 Kingston Morrison Ltd (KML) on behalf of SUNA completed a resistance survey consisting of D.C., TEM and MT measurements in Khiav (Meshkinshar). In this area location of three exploration wells were proposed the D.C. Schlumberger and tem and MT survey also performed in Sarein area for direct uses in the summer of 1998 [8].

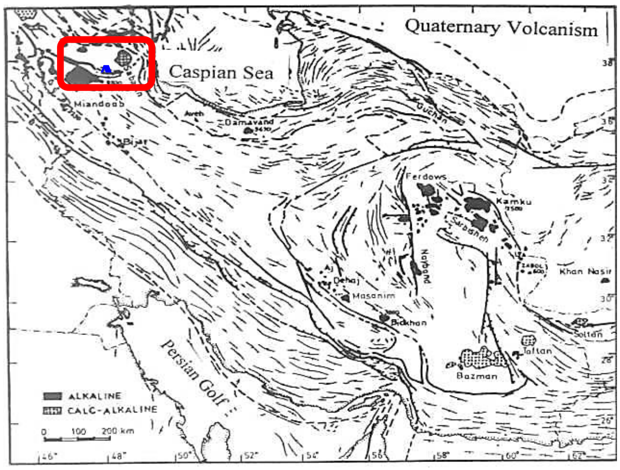

Figure f1. Map and geothermal distributions of hot springs in Iran: Savalan case studies [6]

Results indicate that Azarbaijan Iran has substantial geothermal potential the Ardebil, Sahand, Harzand - Zonouz, and NW of Azarbaijan Iran (Khoy-Maki region), and there are several hot water springs, the temperature of some of which reaches to 85°C. Company ENEL Nazionale per L'Energia Electrica of Italy (ENEL), suggests that Savalan, Sahand, Maki-Khoy and Sarein regions have promising prospects for electricity generation (Table 1) [4, 12].

Table 1. Different potentially geothermal regions investigated Azarbaijan Iran area and Damavand (Tehran) [5]

No	Region	Estimated Thermal energy ($\times 10^{18}$ J)	Estimated mean reservoir temperature (°C)	Reservoir Depth (m)	Region Area (Km^2)
1	Meshkinshar	14.84	240	2000-3000	500
2	Savalan	16.48	240	1300-2500	550
3	Sareine	16.65	140	500-1000	550
4	Sahand	7.6	160	1500-2500	11000
5	Khoy-Maki	30.40	170	2000-3000	6200
6	Damavand	5.11	190	2000-3000	550

IV. GEOLOGICAL SETTING

The studied areas represent the volcanism of the northwestern Iran, along a belt called the Alborz-Azarbaijan Iran. The principal mountain belts surrounding the south Caspian Basin are the eastern part of Greater Caucasus, the Talesh, Alborz and Kopet-Dagh. All involve major crustal shortening in response to the Arabia-Eurasia collision. The oldest rocks of this area belong to the Infracambrian (Late- Precambrian) which include purple micaceous shales and sandstone with intercalations of chertly dolomites at the base, and thick-bedded cherty dolomites at the top. The Paleozoic rocks are not exposed in the studied area. Among the Mesozoic rocks, the upper Cretaceous rocks are predominant. Different faces of Tertiary rocks appear at four places:

1- West of Caspian Sea: these rocks contain a sequence of volcano sedimentary deposits which includes tuffs, tuffaceous sandstones and volcanic intercalations.

2- The central plateau the Tertiary rocks contain a sequence of pyroxene Andesitic volcanic breccias, pyroxene andesite - basaltic lava flows and porphyritic andesite-latite lava flows.

3- During the Eocene, when extensive volcanic activity was taking place in most parts of Azarbaijan Iran, there was a subsiding sedimentary basin in the Moghan area, which was active until middle Miocene.

4- In response to the tectonic movements, after the end of Paleogene volcanism, a closed lagonal basin was formed in the south-western part of Ardebil area.

The Savalan volcano can be mentioned as the only example of Quaternary magmatic activity in the area under study, which has started the early Quaternary but is extinct at present [5].

V. HYDROTHERMAL ALTERATION AND GEOTHERMAL POTENTIAL INVESTIGATIONS IN KHIAV (MESHKINSHAHR) AND SAREIN AREAS

Recent years have seen a rapid growth in geothermal exploration and geological investigation of the Azarbaijan Iran areas resulting in the accumulation of vast amounts of valuable data. Geothermal development began in the early 1975 at Meshkinshahr and Sarein area in Azarbaijan Iran (Ardebil region). A hydrothermally altered area is a typical surface manifestation of geothermal activities and is, therefore, an important target for remote sensing techniques applied to geothermal areas. A 100-110 Km^2 area of hydrothermal alteration was interpreted from spot imagery with part of it within the Meshkinshahr prospect. At least in this area essentially all of the hydrothermal alteration is confined to the Pliocene-Quaternary formation. Within in Pliocene formation, the original volcanic lithology exerts a major control over the intensity of alteration (Ian Begie and others 2000).

The andesite lavas area generally weakly altered or fresh and are only strongly altered close to some fractures. Newer geochemical studies have contributed also to our understanding the genesis of magma in Azarbaijan Iran area. The tuffs and pyroclastic breccias are move permeable and are consequently strongly to intensity altered. The surface hydrothermal alteration in the NW Savalan area is relict and limited to the stratigraphically lower intervals of the Pliocene formation. The stratigraphically higher lavas, however, are all unaltered an may have been above the piezometric surface of the hydrothermal system the secondary minerals found in the weakly alters trachyandesite lavas in clued smectite, kaolinite, cristobalite, opal, chalcedony and opaques, However, some samples contain smectite, cristobalite, opal and Quartz, which indicates their alteration maybe associated with current thermal activity evident in the near surface [6, 9].

VI. REGIONAL VOLCANIC FRAMEWORK

Lineaments interpreted from remotely sensed imagery provide important information on subsurface fractures that may control the convective movement of geothermal fluids. Many hydrothermal convections systems are situated at or near Plio-Quaternary volcanoes in Azarbaijan Iran, and photogeologic interpretation is quite helpful in volcano-stragraphic studies of these areas. Molten or solidified magma beneath such areas generally is accepted as the heat source for the volcano- related geothermal systems. Larger - scale circular features are observed in volcanic terrain from synoptic landsat imagery.

These features are known sometimes to be Quaternary Caldera. The Savalan areas were studied in order to (1) clarify the geologic meaning of its large circular feature and (2) the geothermal potential of the area. The researchers concluded that the area was the center of early Pliocene to Pleistocene, large - scale volcanism and that the area circular feature is a caldera, which was formed by the eruption of voluminous acidictuff (dacitic and trachytic volcanic). The Savalan area was selected as a geothermal exploration target. A combination of several new types of data obtained in drilling and in the assessment of geothermal resources assisted interpreting the caldera structure. Geophysical exploration in Khiav (Meshkinshahr area). Geophysical techniques are used in northeast (Azarbaijan Iran, Savalan area) Iran to explore the geothermal energy. This will examine the principal geophysical techniques which are used to image the subsurface at deep (> 1 Km) medium (< 100 to 500 m) and shallow (< 20 m) depth of Investigation.

The NW Savalan geothermal prospect lies in the Moeil (Geynarja = boiling or steaming) valley on the western slopes of Savalan massive, approximately 16 Km southeast of the Khiav (Meshkinshahr) city (Youseif 2004). The NW Savalan geothermal fields were recognized satisfactory as a potential reservoir for power generation purpose. Pre-excavation investigation methods including such-as; seismic reflection, and refraction profiling, ground penetrating radar (GPR), electromagnetic and resistance survey and borehole geophysical logging gravimetric Survey in Savalan was Carried out by Ente Nazionale per L'Energia of Italy (ENEL 1983).

Drilling was started in late 2002 and three deep exploration wells were completed in 2004. Down hole temperature of approximately 240 ^oC has been recorded for two wells at the find depth of about 3200 m (SKM, 1998). Completion test and discharge evaluations of the wells were conducted successfully (Nourollahi, Yousefi, Ehara, Itoi 2008). Numerical modeling of the reservoir was accomplished and the capacity of the field was approved to install a 55 MW geothermal power plant. Seventeen more production and injection wells are planning to drill to supply the required steam for the planned power plant [6, 8].

VII. GEOPHYSICAL EXPLORATION IN SAREIN AREA

The small city of Sarein is famous for geothermal hot spring resources. In this area, gravity survey has been conducted by ENEL. (Fotohi, and Noorollahi 2000), and result of Electric power research center (EPRC) and SUNA justification MT, TEM and DC. Measurements have been carried out in an area of 100 Km^2. Results of the aforementioned investigation are under consideration. In general, geophysical exploration methods are fundamental tools in the search for geothermal resources, in the Sarein and Meskhinshahr areas for exploitation renewable energy in the Azarbaijan Iran. The semi aridity and high elevation of Azarbaijan Iran creates significant heating loads a winter nights. Where shallow geothermal resources are collocated with large heating demands, space and district heating is favorable and can compete with fossil fuel costs. The maximum temperature of local thermal springs is 84 ^oC. The geothermomentry has been attempted the investigation carried out by an Italian and best estimates are in excess of 85 ^oC in deep wells [6, 7].

VIII. CONCLUSIONS

In summary we see a broad spectrum of styles and ages of hot springs and geothermal energy in Azarbaijan Iran. This reflects the tectonic framework of the Azarbaijan Iran in the late Cenozoic. The diversity is due to local volcanic processes, the location of the hydrothermal system in relation to volcanic vent, and the subsequent uplift and erosion of the area. Surface detailed geothermal explorations have been carried out in the Savalan regions. Groundwater aquifers containing neutralized magmatic volatiles and the pattern of low resistances at depth imply that a vapor cored geothermal system may be present. Results of feasibility studies for two zones of high geothermal potential (32×l0^{18} Jules) in the Savalan region indicate the following priority: Meshkinshahr and Sarein areas. According to geothermometric evaluation, the average temperature of deep reservoirs is 140-250 °C. Therefore, Meshkinshahr area has the highest geothermal potential for electric generation whereas Sarein area for direct uses. Therefore, information about geothermal activity and hot springs provides an insight into evolution of this volcanic region.

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BIOGRAPHY

Ebadollah Ghanbari was born in Marand, Iran, in 1945. He received the B.Sc. degree from University of Tabriz, Tabriz, Iran in 1966, and the M.Sc. Ph.D. degrees from University of Paris VII and Sorbonne, Seismo Tectonics, France in 1972 and 1978, respectively. Currently, he is a Professor of Civil Engineering at University of Tabriz, Tabriz, Iran. He is also an academic member of International Association Structural/Tectonic Geologists (IASTG), International Association on the Genesis of Ore Deposits (IAGOD), International Association Quaternary (INQUA), International Association for Engineering Geology (IAEG), Association of Geophysics of Iran (AGIR), Association of Geology of Iran (AGIR), Association of Engineering of Mineralogy, Iran (AEMI), Iranian Commission of Large Dams (IRCOLD), Iranian Mineralogical Association (IRMA), and Iranian Seismological Association (IRSA).