Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Relationship Between Thermal Springs of Western Alborz Mountains and Regional Tectonics

Masoud Eshaghpour[1], Hasan Alizadeh Saloomahalleh[2]

Regional Water Company of Gilan Province, Iran[1], PNU University, Tehran Province, Iran[2]

isaacpour@gmail.com[1], h_alizadehs@pnu.ac.ir[2]

Keywords: Alborz Mountains, Iran, South Caspian plate, thermal springs, tectonics, Ramsar, geothermal fields

ABSTRACT

Alborz Mountain Range in northern Iran stretching from the borders of Azerbaijan and Armenia in the northwest to Kopedagh in north east of Iran. Its geology is linked with mysterious geology of South Caspian basin, central Iranian Plateau and Subduction of Arabian plate under Eurasia. Dormant quaternary volcanoes of Damavand and Sabalan are located not too far outside of west and east of the study area respectively and seem to be related to active tectonics of the study area. Thermal springs in Western Alborz Mountain range in eastern parts of Gilan Province and western parts of Mazandaran Province are related to active tectonic system. Hydrogeochemical characters of thermal springs in Gilan Province are not related to hydrothermal systems like those which are located around quaternary volcanoes of Iran. Changes in amount of discharge and location of these springs indicate their link with tectonic activity. In Eastern Parts (Ramsar Area) thermal springs flows from hillsides of Alborz Mountains very close to Caspian Sea with strong sulfur and radioactive emission. Alamkooh and Akapol are two recognized intrusives in eastern parts that can be a heat source. Dense forests and high amount of precipitation enforces the need for future researches to understand the exact heat source in Ramsar Area.

1. INTRODUCTION

There are some thermal springs in west of Alborz mountains that are not studied like other Iranian thermal springs specially those which are in contact with quaternary volcanoes. In this paper active tectonic of the area and its relationship with thermal behavior of thermal springs is discussed. Iran is underlined by an assemblage of microcontinents sandwiched between the converging Arabian and Eurasian cratons (McCall, 1998). Alborz Mountain Range in northern Iran stretching from the borders of Azerbaijan and Armenia in the northwest to Kopedagh Mountains in north east of Iran. This study is focused on western Alborz in east of Gilan Province and west of Mazandaran Province both located in South of Caspian Sea. Despite of geological relationships between Alborz Mountains and Iranian Azarbaijan, geographically Iranian Azarbaijan does not assume as a branch of Alborz Mountains, thus here Azarbaijan and Talesh areas (Figure 2) are not assumed as Western Alborz Mountains in this study, thus the study area is assumed as westernmost side of the Alborz Mountain range (Figure1).

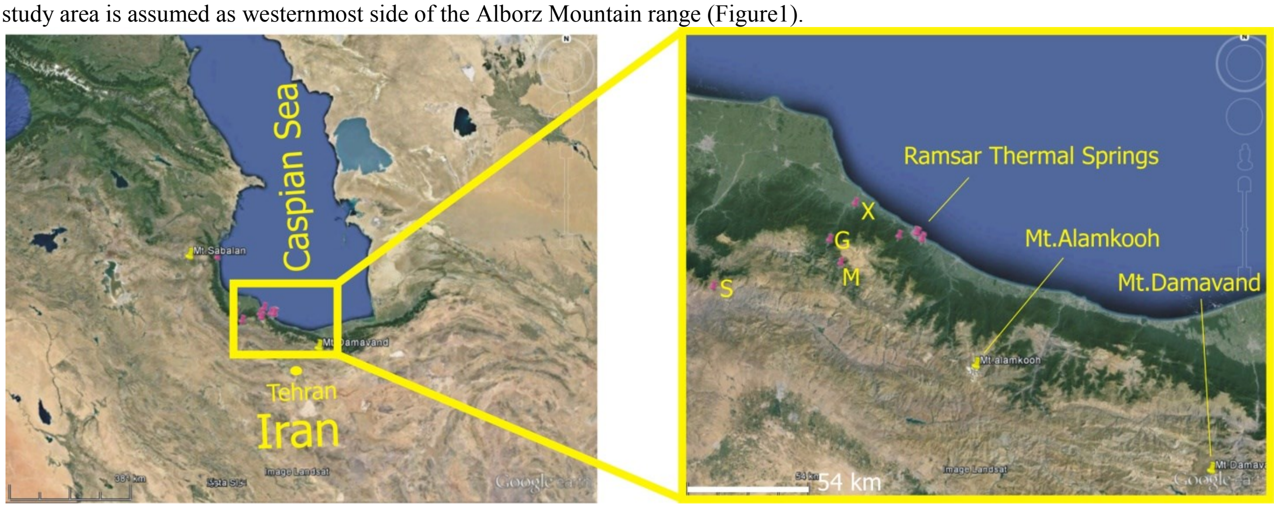

Figure 1: Location map of the study area. Thermal springs are shown with red icons. Ramsar springs in the east and thermal springs of Gilan Province, X: Khompate, G: Garmabdasht, M: Mayestan and S: Sangerood). Mt.Damavand volcano in the east and Mt.Sabalan volcano in the west are shown with yellow icons (Adapted from Google Earth Image Capture, 4/10/2013)

The study has an extraordinary climate specification in Middle East. In case all parts of Middle East suffer from drought especially in recent decades, the area like other southern Caspian lands, benefits the highest precipitation in all Middle East. Precipitation from west toward east decreases. It varies between 700-2300 mm per year and its average is 1000 mm/year. Average precipitation in Iran was last measured at 228 in 2011, according to the World Bank, indicating dramatically difference between north and south of Alborz Mountains that block and entrap humidity and clouds to affect central Iran. Thus groundwater resources like deep wells and Qantas are the main fresh water resources in central Iran while more than 100 main rivers originates from highlands of Alborz Mountains that all ends in the Caspian Sea. This makes surface water as the main source of fresh water. Wetland and lagoons are typical in the area. The name of Ramsar is also marked for "Ramsar Convention" that is a convention signed in Ramsar city in 1971 that intergovernmental treaty embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for sustainable use of all of the wetlands in their territories. Even 24 Iranian sites are registered regarding Ramsar Convention, no of them are located in the study area but 5 of them are located in sought Caspian plain.

2. BACKGROUND OF GEOTHERMAL INVESTIGATIONS IN IRAN

Geothermal investigation in Iran was carried out since 1974. A later investigation by ENEL (Italian power Generation Company) in 1976 under affiliation of ministry of power was the basis of all later studies and geothermal development plans. The study was focused on quaternary volcanoes for electricity production. As a result, some geothermal fields like Ramsar in north of Iran, Mahallat in central parts of Iran and Birjand in the eastern parts of the country were among all interesting areas that put away from preliminary investigations (Eshaghpour et al, 2010).

About 9 quaternary volcanoes are distinguished in Iran that illustrated in Figure 2 located in NW-SE direction parallel to main subduction zone of Arabian plate under central Iranian plateau where Zagros Mountains are located. Most of them are in close relationship with Orumiyyeh-Dokhtar (Urmieh-Dkhtar) magmatic arc (figure 2) that is behind Zagros fold belt. All quaternary volcanoes of Iran are dormant or inactive. The highest volcano of Asia (Mt.Damavand) is located in central Alborz area and Sabalan volcano is located in western sides of the range close to intersection of Alborz Mountains and Zagros Mountains. Researches and investigations later focused into the areas with better accessibility and basic structures that are located in north and north-western parts of the country (including Damavand, Sabalan and Sahand) refer to those which are located in east and south of the country (including Taftan, Bazman, Ernan, Aj and 2-3 unnamed volcanoes). Some reports have evidenced that the last volcanic eruption in Iran was occurred in Taftan volcano in south east of the country (Figure2) in Sistan & Baloochestan Province in amid 70's decade with small amounts of andesitic lava flows.

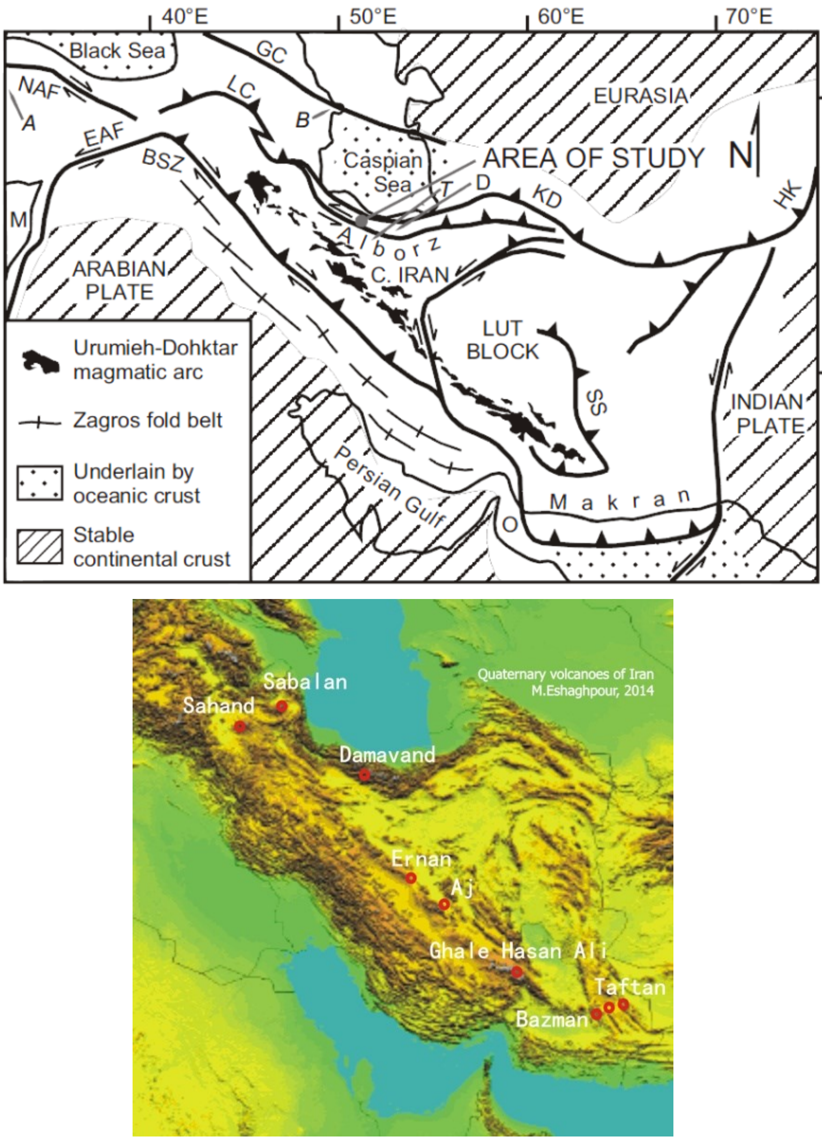

Figure 2: Left: Regional tectonic map of Iran and surrounding regions: A, Ankara; B, Baku; D, Damavand Volcano; E, East Anatolian Fault; GC, Greater Caucasus; HK, Hindu Kush; KD, Kopedagh; LC, Lesser Caucasus; M, Mediterranean Sea; NAF, North Anatolian Fault; O, Gulf of Oman; SS, Sistan suture; T, Tehran (After Alavi, 1994, Berberian et al, Axen et al, 2001), Right: Location map of quaternary volcanoes of Iran.

Saffarzadeh and Noorollahi (2005), Saffarzadeh et al (2010), Noorollahi and Yousefi (2010), Porkhial et al (2010) discussed promotions in investigations and development of geothermal researches in Iran specially in Sabalan geothermal field that is the most promising geothermal field Iran located in Northwest of Iran in Azarbaijan area that is tectonically the place where Zagros Mountains meets Alborz Mountains as a result of subduction of Arabian plate under Iran and Anatolia (Figure2).

3. GEOTHERMAL MANIFESTATIONS IN WESTERN ALBORZ MOUNTAINS

Thermal springs are the only geothermal manifestations in the study area. Like other thermal springs in Iran, their utilization is restricted by baleonological and touristic purposes especially between national inhabitants. These springs are not related to hydrothermal systems like those which are located around quaternary volcanoes. As most of the area is covered by dense forests, mining and exploration is prohibited by government to avoid its destruction, its geology is gloomy and doubtful. The study area can be divided to two branches of western and eastern parts.

3.1 Thermal springs in western parts

In Gilan Province, they have marked with X, G, M and S in figure1, representing Khompate, Garmabdasht, Mayestan and Sangerood thermal springs respectively. Their temperature varies between 19-32 ^{o}C. They are mostly carbonate types. Calcite deposition is common among them. Giggenbach triangle diagram was used to assess the degree of attainments of water-rock equilibrium. Thermal springs of Gilan Province in Giggenbach diagram are plotted near Mg ½ vertex indicating immaturity of waters (figure 3).

Mayestan spring (M in Figure 1) is the most important spring in western parts, discharges from highlands in Poolorood River sides and flows without any use into river despite restricted baleonological purposes. Its Average discharge is 5 l/s and EC=1730 µS/cm. After 1991 Manjil earthquake spring shifted 50m downward of main stream and its discharge increased significantly. Mayestan spring is the only spring in Gilan Province (west of the study area) that sulfur smells. According to a study by University of Gilan (Jozai, 2007) in measurement of Ra and other radionuclide inventories in Gilan Province springs, Mayestan Spring had the highest level. Travertine is deposited around the previous and recent locations. Garmabdasht Spring (G in Figure 1) discharging from Dorood formation consists of limestone and karst is developed around Garmabdasht springs. Big springs with moderate temperature (between 20-30 ^{o}C) drain the area. The area is also tectonized with recognized faults and very rough mountainous morphology. Khompate (X in Figure1) with a mean temperature of 16 ^{o}C is categorized as low Temperature spring with weak sulfur smell that is used by locals to bath especially during cold season of winter. Sangerood spring (S in Figure 1) means stony river is also deposited thick travertine terraces that partially are destroyed by mining and road construction during past decades unfortunately. At the moment Sangerood spring is flowing in both sides of the main road of the area that is located in a horizontal distance of about 5 km away from coal mine of Sangerood. Temperature in the surface is about 32^{o}C. CO_2 bubbles are visible in Sangerood spring. Local people believe that in four decades ago the discharge of the spring was strongly more than present. Present discharge of the spring is about 2 l/s that was increased after Manjil earthquake. According to Wilcox diagram, Sangerood water categorized as C4S1 type indicating high salinity hazard and low alkali hazard. Villagers believe that irrigation with this water is seriously harmful for olive trees (Eshaghpour et al, 2010).

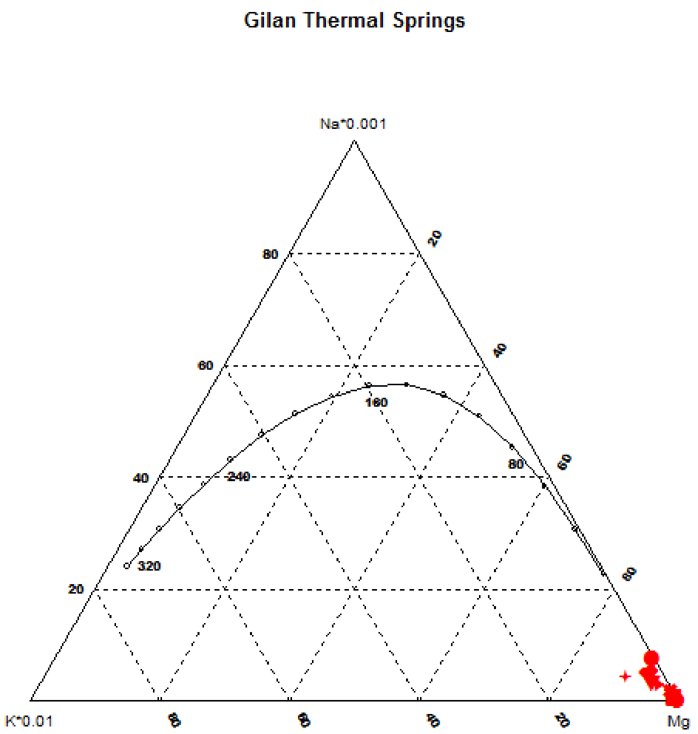

Figure 3: Thermal springs of Gilan Province are plotted in Giggenbach diagram.

3.2. Thermal springs in eastern parts

In Ramsar area there are about 8 thermal springs (Figure 1) that uses by tourists during the past centuries. Ramsar thermal and mineralized springs discharge along a local fault where hill sides of north of Alborz Mountains and coastal plain of Caspian Sea are separated (Figure 4). They are famous for their relatively high radioactive exposure and high chloride concentrations. The highest level of natural radiation emission is located near some thermal springs of Ramsar in north of Iran. It seems that radioactivity is connected to several hot springs along fault systems. Ramsar spas are close to Caspian Sea coast. Topography of the area indicates active fault system parallel to main trend of Alborz Mountain range.

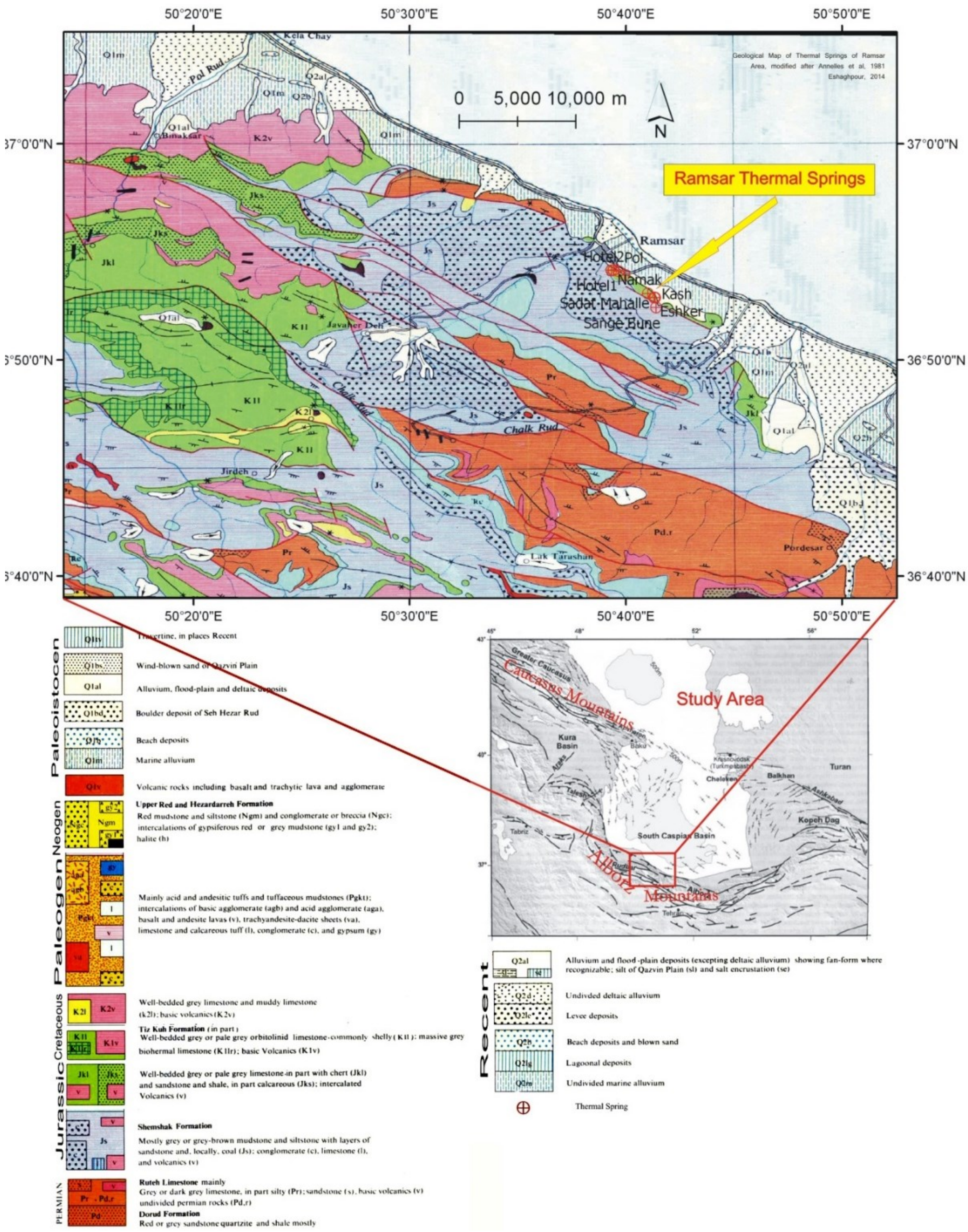

Figure 4: Geological map of Ramsar area (modified after Annelles et al, 1981). Small map is summarized of structural map of the area (adapted from Hinds et al 2001 and Jackson et al 2002)

Alamkooh one of the highest summits of Iran that is located in west of Mt.Damavand has a distance about 60 km in south east of Ramsar area hosts one the most famous intrusions in Iran (Figure 1). Electrical Conductivity of Ramsar hot springs varies between 1050-21600 µs/cm and pH varies between 5.5- 6.0. Temperature of the springs changes between 20-50^{o}C. Springs are sodium -chloride type. Geological map of the area is shown in Figure 4 but things far off seem to be too clear as rare geological and geochemical investigations has shown an indistinct view about the origin of these geothermal resources. According to existed geological map, Lithology of Ramsar area consists of grey limestone (Ruteh formation), dolometic limestone (Elika formation), Shale and sandstone (Shemshak formation), Highland Limestones (Tizkooh formation) and Deltaic and Alluvials in lowlands. Hot springs and mineralized waters are located mostly along a local fault. Closer distance to fault, results higher temperature. Travertine deposits exposure around of springs. These travertine deposits have the highest rate of radioactivity in the area. Groundwater level changes between depths of 22m under surface level to 1m close to the sea coast. Electrical Conductivity of Ramsar hot springs varies between 1050-21600 µS/cm and pH varies between 5.5- 6.0. Temperature of the springs is fluctuated between 20-50^{o}C. Most of the thermal springs are sodium -chloride type. They are mature and full equilibrium according to Giggenbach triangular diagram. Maturity of thermal springs and low pressure of CO_2 indicates deep circulation of waters and because of long contact time equilibrium between crustal rocks and thermal waters. Positive correlation between Cl and Mg shows that mixing of surface water in the thermal system is insignificant. The reservoir temperatures of Ramsar Springs evaluated with equal Na-K and Na-K-Ca geothrmometers and have range between 90 to 280º C (modified after Ansari et al, 2010). Tourist attractions and baleonological purposes are the only utilization of the springs. Because of suitable infrastructure and touristic attraction, Ramsar can be a pole of thermal spring for recreation in Middle East. Airport, Close distance between mountains and Sea (less than 3 km), good ways, natural resources (Forest, river), hotels and short distance to the capital are some potentially optimistic views about booming future.

The high background radiation in hot areas of Ramsar is primarily due to the presence of very high amounts of ^{226}Ra and its decay products, which were brought to the earth's surface by hot springs. Groundwater is heated by subsurface geologic activity and passes through relatively young and uraniferous igneous rocks. Radium is dissolved from the rocks by hot groundwater (Karam, 2002). When the groundwater reaches the surface at hot spring locations, travertine precipitates out of solution with dissolved radium substituting for calcium in the mineral. A secondary cause of high local radiation levels is travertine deposits with a high thorium concentration (Sohrabi 1990). Preliminary studies show no significant differences between residents in high background radiation areas (HBRAs) compared to those in normal background radiation areas (NBRAs) in the areas of life span, cancer incidence, or background levels of chromosomal abnormalities (Ghiassi-nejad et al., 2002).

4. REGIONAL GEOLOGY AND TECTONICS OF THE STUDY AREA

The study area is affected by South Caspian Sea plate and Alborz Mountains regionally. Also intrusions in adjacent area play great role in this geothermal system. Following geological units can be related to geothermal system.

4.1. Alborz mountain ranges

The narrow mountain ranges separated by wide lowlands of central Iran distinguish it topographically from the broad 2000 m orogenic plateau that encompasses parts of Turkey, Iraq, and western Iran. The northernmost of these ranges, the rugged Alborz Mountains, extend laterally 900 km around the south Caspian Sea and are located 200-500 km north of the Neo-Tethysian suture. Alborz has an average elevation of nearly 3000 m and includes three of the highest summits in Iran (Damavand volcano, 5670 m, Alamkooh, 4822 m; and Takht-e-Soleyman, 4659 m). Elevation decreases abruptly northwards over ~50-60 km to the Caspian Sea to 27 m below sea level. The south Caspian, site of intense oil exploration, is possibly the deepest sedimentary basin in the world with up to 20 km of Jurassic and younger sediments overlying mafic basement. Overall structural relief from the Alborz Mountains to the southernmost Caspian basement is ~25 km (Axen et al). Alborz Mountains is located in north of Iran and south of Caspian Sea. Its length and geological behavior is argued in different papers and books. In recent researches it has discussed as an orogenic belt between Iranian Plateau and South Caspian plate. Central Alborz accommodates ~5 mm/yr of shortening and ~4 mm/yr of left lateral strike-slip motion between Arabia and Eurasia plates (Vernant et al, 2004) onto strike slip and thrust faults. Toward east of study area, Central Alborz also hosts the dormant Damavand volcano.

4.2. Sought Caspian Sea tectonic

Satellite images, geomorphological factors, tectonic researches, deep wells and geophysical surveys especially seismic data gives an independent character to South Caspian area. South Caspian Basin is located between Eurasian plate and Central Iranian minor plate surrounded by high mountainous ranges in the north and south and a basin in the middle with 20 km thick sedimentary deposits above a basement with unusually thick oceanic crust or thinned but relatively High-velocity continental crust. It can be assumed even as a minor plate in boundary of Arabia and Eurasia plates. Seismic data gathered in Iran between 1964-98 indicates active tectonic around south Caspian plate and velocity field showing how the NNE motion of Arabian plate relative to Asia is absorbed in Iran (Jackson et al, 2002). The Caucasus Mountains were squeezed in between two plates in Cenozoic. In Eastern parts of South Caspian basin (Hollingsworth et al, 2008) explained how the westward extrusion of the South Caspian basin, relative to central Iran and Eurasia, occurs along right- and left-lateral fault systems in the northwest Kopedagh and east Alborz mountains, respectively. Regional shortening across these systems is not accommodated purely by strike slip, but is partitioned onto separate thrust and strike-slip thrust components. At present-day slip rates, the total right- and left-lateral offsets of ~35 km would be accommodated in ~10 m.y suggesting that the current kinematic pattern in this region, and the possible onset of subduction of the South Caspian block, may also date from this time, being minor plate of westward underthrusting under Talesh and Alborz mountains in northern part of Iran. Deformation and kinematics around the South Caspian Basin is proved by surface faulting, well-constrained earthquake, focal mechanisms and centroid depths and velocity. The basin itself behaves as a rigid block (Jackson et al, 2002). Knowledge of the deep crustal structure of the South Caspian basin has previously been limited to broad seismic velocity patterns provided by Deep Seismic Sounding (DSS) studies (Baranova, Kosminskaya, & Pavlenkova, 1991; Galperin, Kosminskaya, & Kraksina, 1962; Gegelyantz, Galperin, Kosminskaya, & Krafshina, 1958; Zonenshain et al., 1990; Zonenshain & Le Pichon, 1986), without the higher resolution provided by the seismic reflection methods. These early studies suggested that the South Caspian crust is composed of an upper sedimentary layer, with a mean compressional wave velocity of 3.5–4.0 km/s, and a lower oceanic ('basaltic') layer (Baranova et al., 1991; Galperin et al., 1962; Gegelyantz et al., 1958). More recent studies on the crustal structure of the South Caspian basin from teleseismic receiver function analysis (Jackson et al., 2002; Mangino & Priestley, 1998) suggested that the Moho [the seismically defined crust–mantle boundary (Jarchow & Thompson,1989)] beneath the South Caspian basin is an arch-like interface at the depth of 30 km, making for a much thinner crust than a 45–50 km, north of the Absheron Ridge, beneath the Central Caspian basin. A previous, relatively deep (12 s), seismic reflection profile of the South Caspian basin displays a detailed image of the stratigraphy of the sedimentary section, but unfortunately, for most part did not reach the crystalline basement (Nadirov, Bagirov, Tagiyev, & Lerche, 1997). However, despite the relatively large amount of earlier geophysical investigations of the South Caspian Sea region, the thickness and structural style of deformation of the sedimentary section as well as the crustal thickness and affinity remain equivocal. The new deep (20 s) seismic reflection data presented here provide evidence that the South Caspian basin may represent one of, if not, the thickest (26–28 km) accumulation of sediments in the world. These seismic data elucidate the shallow structural deformation, depth, and geometry of the detachment system as well as the definition of the sediment/crystalline boundary, providing new constraints to the previous studies (e.g. Allen, Vincent, Ismail-zadeh, Simmons, & Anderson, 2002; Baranova et al., 1991; Brunet et al., 2003; Jackson et al., 2002), and revealing new information especially at large depths. In addition, these data shed light on the affinity of the crust and the nature of the boundary between the South and Central Caspian basins across the Absheron Ridge which have recently been subject of controversy.

4.3. Active faults

As it described before in Ramsar area all thermal faults are exposure along a local fault that separate Jkl formation (Jurassic grey limestone) to Js formation (Jurassic sandstone and locally coal) and C formation (Jurassic conglomerate) (Figure 4). Totally Alborz mountain range is significantly steep with the flanks abruptly joining the plains that are along major thrust faults of Khazar fault in the north and Mosha, North Tehran and North Qazvin faults on south side. The range contains a thick sequence of Paleogene andesitic volcanics and intrusive rocks, and appears to have separated two independent marine sedimentary basins in the Neogene: the South Caspian Basin to the north and a Miocene (Qom Formation) basin in central Iran to the south (Stocklin 1974; Berberian & King 1981). All the well-constrained earthquake depths in the Alborz have less than 15 km depth and though there are a few are listed with more than 60 km depth that are all small and can't be confirmed. Most of the focal mechanisms in this belt show either reverse faulting or left-lateral strike-slip on faults parallel. Reverse faults and folds are known in the Alborz, though none are known to have ruptured at the surface in modern earthquakes (e.g. Berberian 1976; Berberian & Yeats 1999). Evidence for left-lateral strike-slip parallel to the belt is now substantial. Up to 80 km of left-lateral co-seismic surface ruptures formed in the 1990.06.20 (M,, 7.3) Rudbar-Tarom earthquake (Berberian et al. 1992) that are close to Sangerood thermal spring. In contrast, the 80 km of coseismic left-lateral ruptures that were observed following the 1990 Rudbar-Tarom earthquake in the western Alborz (Berberian et al. 1992) occurred on a fault system that was previously unknown and has a much more subtle expression in the geomorphology. The Rudbar-Tarom strike-slip fault is located in very high ground, mostly above 2000 m and close to the crest of the western Alborz. Only in a few places is it recognizable on air photographs or satellite images. As a result, the Rudbar-Tarom earthquake fault probably does not move often enough to exert much influence on the geomorphology (in contrast to the left-lateral faults further east), and that the fault would almost certainly have remained unrecognized were it not for the 1990 earthquake it is suspected that this contrast between the expression of the left-lateral faults in the eastern and western Alborz is significant, and return to this issue later (Jackson et al, 2002). Alborz accommodates the overall motion between the southern Caspian and central Iran, and seems to involve oblique left-lateral shortening. Once again, the earthquake slip vectors indicate that this is achieved by a spatial separation, or 'partitioning', of the strike-slip and reverse components on to subparallel faults with orthogonal slip vectors. There is abundant evidence for recent uplift in the Alborz, in the form of incised river terraces and coastal marine terraces, and it is very likely that the crust of Iran is being thrust over the South Caspian Basin (Berberian 1983). However, there is no convincing evidence in the earthquake focal depths for current subduction of the Caspian Sea crust into the mantle beneath the Alborz, as there is on the Apsheron-Balkhan sill (Jackson et al, 2002).

4.4. Damavand volcano

Damavand volcano is located in the central Alborz Mountains of northern Iran ~50 km north of Tehran, the capital of Iran. The volcanic edifice is one of the largest known on land (~400 km3). It reaches an elevation of 5670 m above sea level and is the highest peak in the Middle East (Shirzaei et al, 2011) and the highest volcano in the Asia. The volcano is constructed upon Paleogene–Neogene tuffs, lavas, and sediments, as well as Paleozoic–Mesozoic siliciclastic, carbonate, and evaporate sequences (Allenbach, 1966). The pre-Damavand units are deformed within an east-west–trending structural grain of large folds and major thrusts and/or strike-slip faults. These faults accommodate ~5 mm/yr north-south shortening and ~4 mm/yr left lateral west-east motion (Vernant et al., 2004), and have historically generated several destructive earthquakes.

4.5. Alamkooh and other intrusions

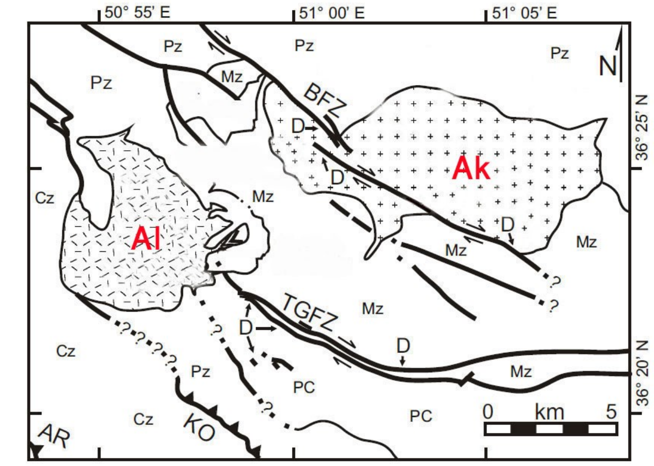

Figure 5: Map of Alamkooh region showing faults (Ak, Akapol pluton; Al, Alam Kuh pluton; BFZ, Barir fault zone; D, Dextral kinematic indicators on fault; KO, Kandevan "Overthrust"; AR, Alamut Rud thrust; TGFZ, Tang-e- Galu fault zone. Sedimentary country rock: Cz, Cenozoic; Mz, Mesozoic; Pz, Paleozoic; PC, Precambrian (modified after Annells et al. 1975, Vahdati- Daneshmand 1991, Lam & Axen unpublished)

Dating of thermal histories of granites in the central Alborz suggests rapid uplift of the range between about 6 and 4 Ma, nearly synchronous with subsidence in the South Caspian (Axen et al. 2001). Alamkooh intrusion is located near Alamkooh summit with batholith shape and its age is determined 3-5 Ma. Akapol is another intrusion with quartz monzonite and coarse to medium grained granodiorite in distance about 5 km northeast of Alamkooh granite intrusion (Figure 5). It is believed that monzonite of Akapol and granite of Alamkooh have the same age of Pliocene (Aghanabati, 2006).

5. DISCUSSION

Alamkooh and Akapol (Figure 4) are the closest recognized intrusive bodies to Ramsar thermal springs with a distance about 60 km in south east of Ramsar geothermal filed. Crystallization and thermal histories of two mentioned plutons were obtained by U/Pb, 40Ar/39Ar, and (U-Th)/He analyses of zircon, biotite, K-feldspar, and apatite. The Akapol granodiorite intruded at 56±2 Ma, cooled to ~150°C by ~40 Ma, and resided at that temperature until at least 25 Ma. The nearby Alam Kuh granite intruded at 6.8±0.1 Ma. It cooled rapidly to background temperatures (125-175°C) by 6 Ma. Persistence of ~150°C ambient conditions indicates tectonic stability for the Alam Kuh region from Late Eocene to Late Miocene time. Elevation-correlated (U-Th)/He ages from the Akapol suite indicate 0.7 km/m.y. exhumation between 6 and 4 Ma Moreover ~10 km of subsidence in the Caspian basin may be attributed to loading by the Alborz Mountains. Steep, dextral northwest-trending strike-slip faults in the Alam Kuh region cut the Akapol granodiorite and are truncated by the Alamkooh pluton. These results suggest that the change from Tertiary dextral strike-slip faulting to presently observe sinistral strike-slip may have occurred as late as 7 Ma, possibly due to the Late Neogene onset of continental collision. Crustal thickness under Iran decreases northeastward from ~55 km beneath the Zagros Mountains to 35-40 km under the Alborz, and finally to ~30 km in the south Caspian Sea (Dehghani and Makris, 1984). Strongly attenuated upper-mantle seismic velocities (Kadinsky-Cade et al., 1981) and Quaternary volcanism (Berberian and King, 1981) suggest the presence of shallow, anomalously hot, partially molten mantle asthenosphere beneath northern Iran. Gravity anomalies which indicate an insufficient crustal root beneath the Alborz (Dehghani and Makris, 1984) suggest that this anomalous mantle supports the elevation of the Alborz. However, the Alborz may be partially flexurally supported by the Caspian lithosphere. Although plate-circuit models show north or north-northwest convergence between Arabia and Eurasia (DeMets et al., 1990), seismicity indicates active deformation within the Alborz is partitioned between range-parallel sinistral faults and range-perpendicular thrusting (Preistley et al., 1994 and references therein). Hence, motion along the latter moves the western Alborz mountains northeastward over the Caspian. Catastrophic earthquakes, quaternary volcanoes, mountainous lands and elevated plateaus refer to lowlands and lakes are signs of tectonics activity in Alborz Mountains and adjacent areas. According to Priestley et al. (1994), the convergence between northern Iran and the South Caspian Sea is partitioned into a left-lateral strike–slip and pure thrust motion in the Alborz Mountains, resulting in the northward thrusting of the Iranian continental crust over the South Caspian Basin. Based on the same studies, two deeper (75 km) thrust earthquakes were localized further to the north-east. Thrust focal mechanisms in the Talesh Mountains, bordering the South Caspian Basin to the southwest, suggest thrusting of this region over the South Caspian basin from the west. Deep seismic reflection from the South Caspian Sea region in the vicinity of the Absheron Ridge suggest that the South Caspian basin is covered by a very thick (26–28 km) sedimentary cover, making it one of, if not, the thickest basin in the world. The thick (14–18 km) Cenozoic sedimentary section of the South Caspian basin as seen on the survey profiles seems to be dominated by a S-vergent fold and thrust system that appears to be rooted into an intra-sedimentary detachment dipping northward at a depth of ,14–20 km. Although slightly thicker than observed in other ocean basins, the apparent, 10 km thick crystalline crust is consistent with an oceanic affinity for this part of the basin. Active seismicity and gentle deepening of the crust from south to north are interpreted as evidence for northward subduction of the South Caspian oceanic lithosphere beneath the southern margin of Eurasia South Caspian lithosphere has a Subduction beneath the Eurasian continent at the Absheron Ridge.

Field surveys reveals that most of thermal springs in western parts (like Mayestan and Sangerood) have shifted locally and output discharge was changed after Manjil earthquake in 1990. Thermal springs of study area are in relationship with very active tectonic, active fault systems and young plutons. Effects of thermal behavior and chemistry of springs after earthquakes isn't unlikely and needs future monitoring. Thermal springs in western parts are not too mineralized and even are drinkable according to national standards, except Mayestan (M in Figure 1). Mayestan also is the only spring in western parts that sulfur smells and has the highest radioactive emission. Mayestan is the closest spring to Ramsar thermal springs, exactly behind the rough mountainous lands. Even Alamkooh and Akapol are the only recognized intrusives in the study area, it is possible that a significant intrusive is located under eroded soils and forests close to Ramsar area and active faults circulates high amount of precipitations along them and comes back to surface and deposits travertine and effect the area by heat and radioactive emission. This idea needs to be studied more on geological and hydrogeochemical investigations. Giggenbach triangle diagram was used to assess the degree of attainments of water-rock equilibrium of thermal springs in western parts of the study area. It reveals that the mentioned thermal springs are located near Mg ½ vertex indicating immaturity of water (Eshaghpour et al, 2010). It means that heat source is not connected to high temperature hydrothermal system. Eaerthquakes and strong motion of crust of crust and its active behavior can be a heat source for these springs. Ramsar hot springs are sodium-chloride and calcium-chloride type. They have strong smell of sulfur and high radioactive emission. The surface temperature of Thermal springs is between 19-65oC and SiO2 geothermometer estimates reservoir temperature between 86- 96 ^{o}C (Ansari et al, 2010).

There are rare and inconceivable papers regarding heat source of Ramsar thermal springs despite of their medical effects. Theories like uplift of sea water along deep faults or presence of connate waters (fossil waters) are not acceptable because of chemistry of waters and their hydrogeological characters. Changing in discharge and temperature of some thermal springs due to strong earthquake of Rudbar (Manjil earthquake) indicates the linkage between tectonic activity and heat source of the springs (Darvishzadeh, 1991).

6. CONCLUSIONS

Geothermal researches in Iran are focused in young volcanic areas. As a result some prosperous areas like Ramsar in western Alborz Mountains are eliminated to study and survey. Thermal springs are the only geothermal manifestations in the western Alborz Mountains. Geological and chemical behavior of thermal springs in the study area reveals that they are related to tectonics activity and earthquakes in western parts also to intrusives and local faults in western parts of the study area as sever tectonic activity in South Caspian plate and Alborz Mountains is proved. Being close to highest volcano of Asia (Mt. Damavand) and recognized intrusives also can be the heat source of thermal springs. It is possible that a significant intrusive is located under eroded soils and forests somewhere in depths of highlands in Ramsar area that by circulation of high rates of precipitations along local faults, thermal water comes to surface and expose their unique geochemical and radioactive characters.

REFERENCES

Aghanabati, S.: Geology of Iran, *Geological survey of Iran*, Dec (2006).

Alavi, M.: Tectonics of the Zagros orogenic belt of Iran, new data and interpretations, *Tectonophysics*, **v. 229**, (1994), 211-238.

Allenbach, P.: Geologie und petrographie des Damavand und seiner umgeurg, Zentral-Elburz, Iran, *Geologisches Institut*, ETH-Zurich, Mitteilung **Nr. 63**, (1966), 114 p.

Annelles, R.N, and Arthurton, R., and Bazley, R.A.B., and Davis, R.G., and Hamedi, M.A.R., and Rahimzadeh, F: Geological map of Ghazvin-Rasht area, Geological survey of Iran, (1981).

Ansari, M., and BahramAbadi, M., and Nazeri, M., and Ghorchibiki, K., and Abedsoltan, F.: The Characteristic and Classification of Thermal Spring in Ramsar area,North of Iran, *The 1 st International Applied Geological Congress*, Department of Geology, Islamic Azad University - Mashad Branch, Iran, 26-28 April (2010).

Axen, G., and Lam,P., and Grove, M., and Stockli, D., and Hassanzadeh, J.: Exhumation History of the Alam Kuh Area, Central Alborz Mountains, Northern Iran, Implications for Caspian subsidence and Collision-Related Tectonics.

Berberian, M., and King, G.C.P., 1981, Towards a paleogeography and tectonic evolution of Iran: *Canadian Journal of Earth Sciences*, **v. 18**, (1981), 210-265.

Berberian, M.,: The southern Caspian: a compressional depression floored by a trapped, modified oceanic crust, *Canad J. Earth Sci*., **20** (1983).

Darvishzadeh, A.: Geology of Iran, *Amirkabir publications*, (1991).

Dehghani, G.A., and Makris, J.: The gravity field and crustal structure of Iran: Neue Jahrbuch fur Geologische und Palaontische Abhandlungen, v. **168**, (1984), 215-229.

DeMets, C., and Gordon, R.G., and Argus, D.F., and Stein, S.: Current plate motions*: International Journal of Geophysics*, **v. 101**, (1990), 425-478.

Eshaghpour, M., and Alizadeh Saloomahalleh, H.: Hydrogeochemical Studies of Hot Springs in Gilan Province, N-Iran, *Proceedings*, World Geothermal Congress, Bali, Indonesia (2010).

Ghiassi-nejad, M., and Mortazavi, S. M. J., and Cameron, J. R., and Niroomand-rad, A., and Karam, P. A: Very high background radiation areas of Ramsar, Iran: Preliminary biological studies, *Health Physics*, **Volume 82**, Number 1, January (2002).

Google Earth Image Capture, www.google.com.

Hollingsworth, J., and Jackson, J., and Walker, R., and Nazari, H.: Extrusion tectonics and subduction in the eastern South Caspian region since 10 Ma, *Geology*, **V.36**, October 2008).

Jackson, J., and Priestley, K., and Allen, M., and Berberian, M.: Active tectonics of the South Caspian Basin, *Geophys*. J. Int.**148**, (2002), 214-245

Jozai, S.: Measurement of Ra and other radionuclide inventories in spring waters of North Alborz, *Master thesis*, University of Gilan (Guilan), (2007).

Karam, K.: The high background radiation area in Ramsar Iran, geology, norm, biology, LNT, and possible regulations, NY 14642, *WM '02 Conference*, Tucson, AZ, February 24-28 (2002).

Kadinsky-Cade, K., and Barazangi, M., and Oliver, J., and Isacks, B.: Lateral variations of high-frequency seismic wave propagation at regional distances across the Turkish and Iranian plateaus, *Journal of Geophysical Research*, **v. 86**, (1981), 9377-9396.

McCall, G.J.H.: The geotectonic history of the Makran and adjacent areas of southern Iran, *Journal of Asian Earth Sciences*, **v. 15**, (1998), 517-531.

Noorollahi, Y., and Yousefi, H.: Geothermal Energy Resources and Applications in Iran, *Proceedings*, World Geothermal Congress, Bali, Indonesia, (2010).

Porkhial, S., et al.: Geothermal Energy in Iran, *Proceedings*, World Geothermal Congress, Bali, Indonesia (2010).

Priestley, K., and Baker, C., and Jackson, J.: Implications of earthquake focal mechanism data for the active tectonics of the South Caspian basin and surrounding regions, *Geophysical Journal International*, **118**, (1994), 111–141.

Saffarzadeh, A., and Noorollahi, Y.: Geothermal Development in Iran, A Country Update, *Proceedings*, World Geothermal Congress, Antalya, Turkey, (2005).

Saffarzadeh, A., et al.: Geothermal Energy Developments in Iran, *Proceedings*, World Geothermal Congress, Bali, Indonesia, (2010).

Shirzaei , M ., et al: Gravity-driven deformation of Damavand volcano, Iran, detected through InSAR time series, *Geology*,; **v. 39**; no. 3; March (2011), 251–254.

Sohrabi., M: Recent radiological studies of high level natural radiation areas of Ramsar, *Proceeding* of International Conference on High Levels of Natural Radiation, Ramsar, Iran. Vienna: IAEA, (1990).

Stocklin, J.: Northern Iran: Alborz mountains, in Mesozoic- Cenozoic Orogenic Belts: Data for Orogenic Studies, ed. Spencer, A., *Geol.* Soc. Spec. Publ. London, **Vol. 4**, (1974), 213-234.

Vernant, P., and Nilforoushan, F., and Chery, J., and Bayer, R., and Djamour, Y., and Masson, F., and Nankali, H., and Ritz, J.F., and Sedighi, M., and Tavakoli, F.: Deciphering oblique shortening of central Alborz in Iran using geodetic data: *Earth and Planetary Science Letters*, **v. 223**, doi: 10.1016/j.epsl.2004.04.017 (2004), 177–185.

Vernant, P., and Nilforoushan, F., and Hatzfeld, D., and Abbassi, M., and Vigny, C., and Masson, F., and Nankali, H., and Martinod, J., and Ashtiani, A., and Bayer, K.C., and Tavakoli, F., and Chery, J.: Present-day crustal deformation and plate kinematics in the Middle East constrained by GPS measurements in Iran and Northern Oman: *Geophys*. J. Int., **v. 157**, (2004), 381–398.