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THE GEOTHERMAL OCCURRENCE OF KAPISTRI, IERAPETRA AREA, CRETE

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Abstract

The geothermal occurence is located close to the Kapistri village, Ierapetra town, prefecture of Lassithi. In some water wells temperature of about 25°C in a depth of 100 - 150 m below surface, were measured. The calculated geothermal gradient is thus double in size compared to normal gradient.

The geological environment is composed of platy limestones of the autochthonous series of Crete on which units of phyllite – quartzite series as well as Pindos and Tripoli zones are overthrusted. Granite intrusion occurs in the carbonates with distinct contact metamorphism, in the Kapistri area. Intense tectonic activity is observed in the wider area of the Ierapetra graben with main fault direction N – S, E – W, NW – SE, and NE – SW.

The elevated geothermal gradient, the intense faulting of the area and the existence of deep circulated water indicates the development of a deeper geothermal field.

Key words: *Geothermal Energy and gradient, heat flow.*

Περίληψη

Η γεωθερμική εμφάνιση εντοπίζεται κοντά στο χωριό Καπίστρι,στην ευρύτερη περιοχή της πόλης της Ιεράπετρας στο νομό Λασηθίου της Κρήτης. Σε μερικές υδρογεωτρήσεις μετρήθηκαν θερμοκρασίες περί τους 25°C σε βάθος 100 – 150 μ.από την επιφάνεια. Η γεωθερμική βαθμίδα που υπολογίστηκε είναι διπλάσια της κανονικής.

Η Περιοχή καλύπτεται από πλακώδεις ασβεστολίθους της αυτόχθονης σειράς της Κρήτης πάνω στην οποία είναι επωθημένες μονάδες της φυλλιτικής – χαλαζιτικής σειράς και των ζωνών Πίνδου και Τριπόλεως. Εντός των ασβεστολίθων έχουν διεισδύσει μαγματικά πετρώματα (γρανιτοειδή) που έχουν προκαλέσει μεταμόρφωση επαφής και ρηγμάτωση κοντά στο Καπίστρι. Έντονη τεκτονική δραστηριότητα παρατηρείται στην ευρύτερη λεκάνη Ιεράπετρας με κύριες διευθύνσεις των ρηγμάτων Β – Ν, Α – Δ, ΒΔ – ΝΑ και ΒΑ – ΝΔ.

Η αυξημένη γεωθερμική βαθμίδα, η έντονη ρηγμάτωση της περιοχής και η γεωχημική ένδειξη για την παρουσία νερού που κυκλοφορεί σε μεγάλο βάθος δείχνουν την πιθανή ανάπτυξη ενός βαθύτερου γεωθρμικού πεδίου.

Λέξεις κλειδιά: *Γεωθερμική ενέργεια και βαθμίδα, θερμική ροή.*

1. Introduction

The Kapistri village is located in the wider area of Ierapetra, Lassithi prefecture in east Crete Island (Figure 1). Its distance from Ierapetra town is 5.5 to 6 km. The geothermal occurrence was located during reconnaissance prospecting in the frame of a relative research program of IGME (general geothermal reconnaissance in Greece). The relief of the area is hilly to plain with olive trees and greenhouses cultivations.

The location and development of geothermal field will contribute to the further development of greenhouses decreasing the heating cost which is necessary for the winter months. Moreover it will contribute to the mitigation of CO_2 emissions.

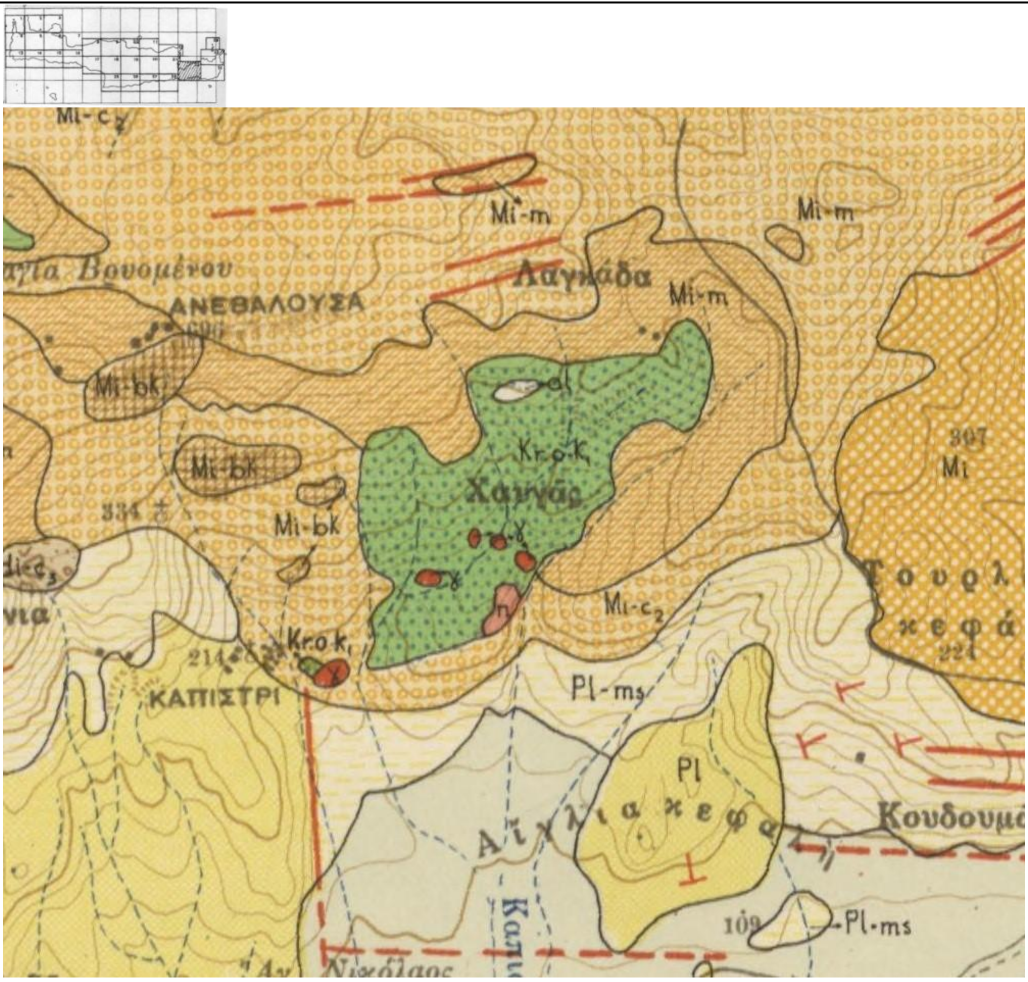

Figure 1 - Geology of the Kapistri area (al= recent alluvial deposits, di-c3= fluviatile terrace, Pl= Pliocene formations undivided, Pl-ms= marls, Mi= undivided Miocene formations, Mi-c2=basal conglomerate, Mi-m= marls, Mi-bk=limestones, kr o k1= Cretaceous coarse grained limestones, π=peridotites, γ=granitoids), from Papastamatiou J., 1959.

2. Geological Setting

According to the geological map of the area (map sheet Ierapetra, scale 1:50.000, Papastamatiou J., 1959) it is located in the west part of Ierapetra graben (Figure 1).

The geological basement consists of platy limestones of the autochthonous series of Crete on which the following series have been overthrusted:

- The nappe of phyllitic – quartzitic series
- The nappe of Tripoli geotectonic zone, and

- The nappe of the internal Hellenides zones (Pindos zone).

The Upper Cretaceous platy limestones have been intruded by acid magmatic rocks (mainly granitoids), which caused recrystallization of carbonates by contact metamorphism. The magmatic rocks outcrop more to the north close to the sea coast.

During the middle Miocene time the deposition of younger sediments started and continued to Pliocene and Holocene. The Tertiary sediments consist of clastic rocks, marls and marly limestones. The Quaternary sediments consist of sand and conglomerates. During the Holocene alluvial sediments were deposited (Lambrakis, N., 1987).

The structural geology of the area is marked by the Ierapetra graben with NE – SW direction and by four faults directions, i.e. N – S, E – W, NE – SW and NW – SE. Although there is a reactivation of the faults during different periods, it is observed that the N – S and E- W faults are older than the other two directions. The big fault of Kavoussi – Vainia has very large throw and determines the east margin of Ierapetra graben.

3. Geothermal Data

The intrusion and solidification of the magma into the limestones caused contact metamorphism as well as zones of intense faulting which constitute as channels of secondary water circulation. The Kapistri narrow area has been suffered of intense tectonic movements resulted in remarkable faults observed both in the limestones and in their contact with the younger sediments.

In the following figure (Figure 2) the main faults close to Kapistri and the sampled water boreholes are shown. Five boreholes were located, two of which do not yield any water. The temperature of all of the boreholes was measured and from two of them water samples were taken.

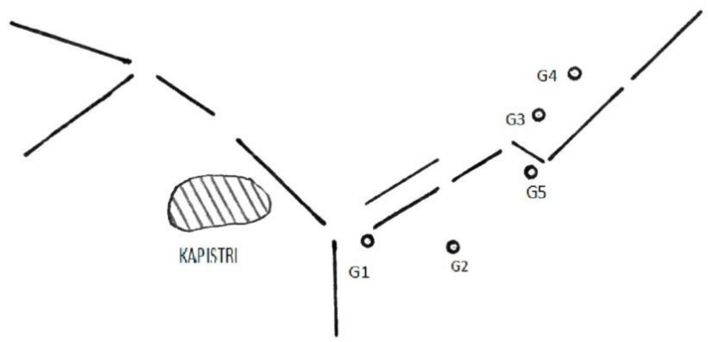

Figure 2 - Sketch map of observed faults and the measured boreholes (approx. scale 1:25000).

In the following Table1 the temperature recorded in each borehole is presented. The temperature in dry boreholes was measured down the hole and in the remaining the water temperature was measured in the outflow.

The mean annual temperature of Ierapetra area is 19.8^{o}C. Considering that the Kapistri is located in an altitude of 150 – 200 m.a.s.l. and that the atmospheric temperature gradient is 0.006^{o}C/m the mean annual temperature is 1^{o}C less than that of Ierapetra, namely 18.8^{o}C. Taking into account that the mean normal terrestrial geothermal gradient is 3.3^{o}C per 100 m. we can estimate that the expected temperature, in a depth of 100 m., will be about 22^{o}C. This value, compared to the meas ured temperatures of 22 – 25^{o}C it is evident that a thermal anomaly exists in the area. This local geothermal gradient is almost double of the normal gradient and gives enough geothermal interest in the area.

Table 1 – Measurements of temperature in boreholes.

Borehole	Depth in m	Temperature in ^{o}C	Comments
G1	110	25	
G2	100	23	No water
G3	142	23.2	
G4	170	22	6pt
G5	100	20	No water

Another important observation is that the highest temperature was measured in the borehole G1 which lies in the intersection of two main fault directions (Figure 2). It shows an upwards circulation of warm water. It is well known that faults can operate as surfaces of flow of rain water to depth where it is heated, becomes lighter and rises towards the surface again through faults.

In the wider area there are main faults reaching big depth and assisting the water circulation too deep in the earth where they are heated, by geothermal gradient, and they rise up to the surface creating thermal anomalies. During its up rise the warm water mixes with near surface cold aquifers and loses some heat. Water mixing and heat loss is evident from the chemical composition of analyzed water samples.

3.1 Water Geochemistry

Two samples of water were collected in the outflow of the boreholes G1 and G3. The samples were analyzed for the 17 elements and the physical parameters as shown in the Table 2.

Table 2 – Results of chemical analyses of water.

Element	Borehole G1 (mg/l)	Borehole G3 (mg/l)
pH	7.85	7.6
Conduct.	1022	705
Ca	73.74	76.15
Mg	32.1	27.72
Na	131.1	55.20
K	3.91	2.35
HCO3	305.7	334.30
Cl	212.7	88.62
SO4	45.62	24.01
NO3	<3	18.60
Trace	**(In ppm)**	**(In ppm)**
SiO2	17.14	13.40
Fe	0.04	0.03
B	0.11	0.05
F	0.01	<0.01
Li	0.01	<0.01

Element	Borehole G1 (mg/l)	Borehole G3 (mg/l)
Sr	0.59	0.35
As	0	0

Observing and comparing the analyses of the two samples one can see that the water of borehole G1, which presents the higher temperature and is located closer to the fault intersection than the borehole G3, contains more salts (as shown by the conductivities) and has higher concentration of the elements characterizing the geothermal water (Na, K, Cl, SO_4, SiO_2, B, Li, Sr). The position of the water samples in the diagram Langelier – Ludwig (1942), (Figure 3) indicates that the sample of borehole G1 has a deeper origin compared to the sample of borehole G3. This sample contains more alkali elements and Cl ions and less alkali earths and carbonic acidic elements compared to their concentration in surface aquifers.

From the correlation diagrams of the elements Na with Cl and Na with Ca (Figures 5, 6) it is clear this differentiation of the two water samples as regards their origin. The enrichment of the water sample G1 in Na and Cl and in Ca and HCO_3 of the sample G3 determines the different circulation of these waters. Namely the water from borehole G1 seems that it has circulated for longer time and has come to contact with no carbonate rocks, in deeper level containing low Ca. In contrast the water of borehole G3 seems to circulate in carbonate rocks containing mainly Ca and sited close to the or on the surface. This conclusion is supported also from the diagram of Ca – Mg (Figure 4) on which it is observed the higher content in Mg and lower in Ca of the sample from the borehole G1compared with the water from borehole G3.

4. Conclusions

The geological setting of the Kapistri area (limestones with granite intrusions) as well as the intense faulting are favorable geothermal factors that can cause deep water circulation and result in heat transfer. The temperature measurements indicate a computed geothermal gradient twice the size of normal gradient. It is a fact which shows a significant geothermal interest for the area.

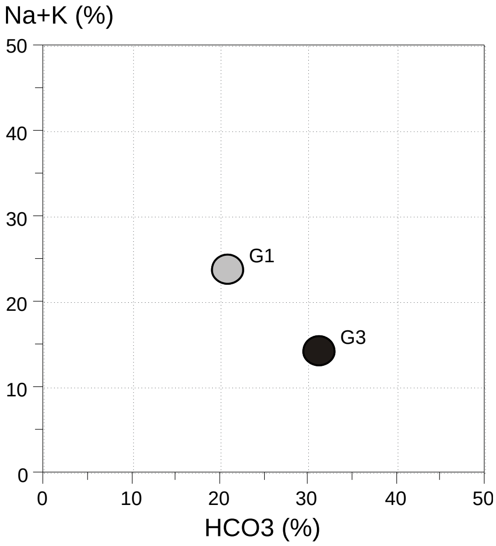

Figure 3 - Diagram Langelier – Ludwig.

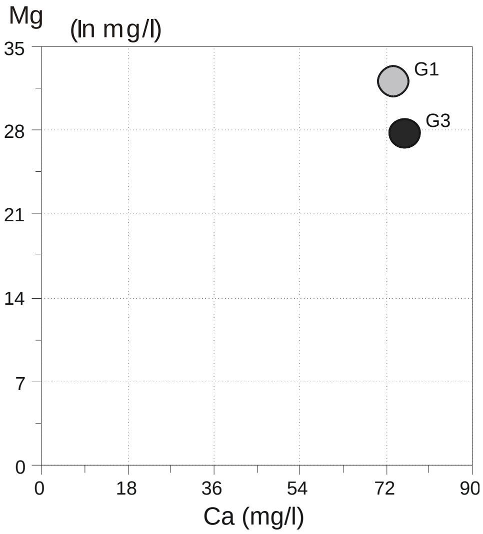

Figure 4 - Diagram Mg – Ca.

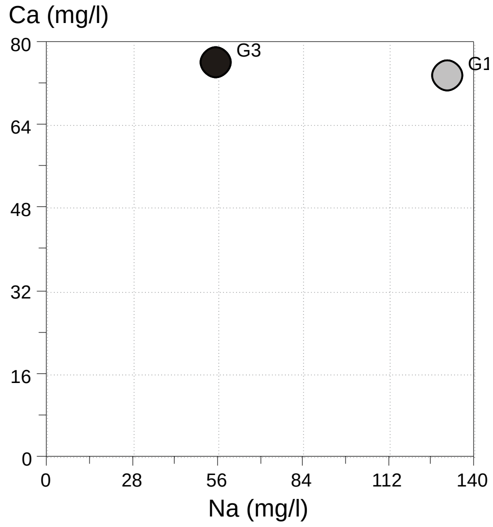

Figure 5 - Diagram Ca – Na.

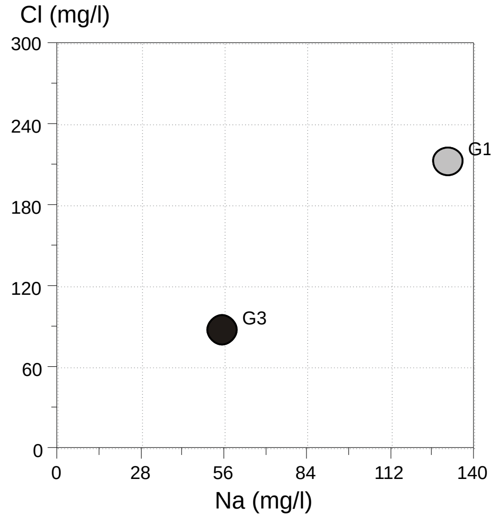

Figure 6 - Diagram Na – Cl.

The chemical composition of the warm water sample leads to the conclusion that, in addition to the near surface aquifer, there is another one occurring in deeper level with different geochemistry and higher content in soluble salts. This aquifer, as it is evident from its chemical composition, has come in contact with no carbonate rocks for a long time while its dissolving capability (in which the high salt content is due) may be the result of a higher than measured temperature, too.

From the above mentioned we conclude that in the area there are the necessary conditions to support the geothermal interest for exploring for geothermal fluids with higher temperature than the known 25^{o}C. Therefore it is proposed that a systematic geothermal exploration program must be applied. In a first phase this program should have as a target the detailed identification of the thermal anomaly with the collection of geological, geochemical and temperature data. An indicative phased exploration program must contain the following works:

- Geological reconnaissance in the wider area with the aim to find the distribution and separation of the formations with geothermal criteria, such as permeable formations, storage formations and cap rock.
- Search for altered rocks and their relation with geothermal manifestation.
- Temperature measurements in the wider area in order to determine the extent of thermal anomaly and its relation with faults.
- Water sampling for determining the chemical composition and the study of circulation mechanism.
- Processing and evaluating of the resulted data in order to continue for deep exploration.

5. References

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