**TUBITAK PROJECT 111090**

***Title of the project:***

# Determination of fault activity and geothermal origin by soil and groundwater degassing: the extension of Dead Sea Fault Zone (DSFZ) in the Amik Basin (Hatay) and its relation with Karasu Fault Zone (KFZ) and origin of thermal waters in Amik Basin


## Abstract

The application of fluids and gas geochemistry studies applied to better understand the fluids/gas/faults relationships (such as delination of buried fault zones, monitoring of seismic activity, identification of the origin of geothermal waters) has been favored in recent years. Satisfied results have been obtained by the application of geochemical techniques (e.g. gas and water chemical and isotope composition; soil degassing measurements) to constrain the origin, the components and the behaviour of the fluids circulating over active fault zones and seismic-prone areas. To carry out geochemical studies, Amik Basin in the Hatay Region was selected as a study area because the area experienced catastrophic earthquakes in the historical times (for example Karasu earthquake, 1822 August 13, M = 7.4 and Amik earthquake 1872 April 3, M = 7.2). In addition, manifestations of thermal water and probable natural degassing in the Amik Basin, Reyhanlı and Karasu Valley are indication of the presence of aquifers providing active circulation of fluids in depth in the study area.

Aim of  this project: 1) the soil-degassing evaluation over the Amik Basin, and 2) detailed investigations of the geochemical features of the thermal and cold waters existing from the southern border of the Amik Basin to the northern sector of Karasu Fault Zone. The geochemical investigations will include chemical (major and minor)  and isotopic analyses of both waters and the dissolved gases. The project will merge new and different investigation techniques to get several results using a pure geochemical approach. The main targets are the identification of buried faults and the evaluation of the geothermal features of the circulating fluids. We will achieve thosee targets by the evaluation of the origin, circulation and interactions of the fluids with the host rocks including the latest basaltic outcrops. The relationships of thermal waters with the latest volcanic activity outcropping along the Karasu Fault Zone will be constrained by the investigation of thermal waters discharging at the SE and NW part of the Amik Plain. The results of these investigations will be used to define the tectonic lines and their relationships with volcanism, gas discharges, heat source of thermal activity. Since the tectonic structures cross a very large seismic-prone area moving from the Dead sea toward the NAFZ, the results will not be limited to Turkey but they will be shared with other middle east countries, mainly Syria, where the activities of DSFZ were also observed.



**Keywords:**

Dead Sea Fault Zone, Amik Basin, helium, radon, gas geochemistry, geothermal potential


## Rationale

As highlighted  in recent researches, fluids geochemistry has an important role in determination of active tectonic lines, monitoring of seismic activity and in constraining the origin of thermal fluids including their relation with the tectonic setting. Although some important researches about the extension of sinistral S-N elongated DSFZ (Dead Sea Fault Zone) in the Amik Plain have been carried out (Rojay vd., 2001; Akyüz vd., 2006; Altunel vd., 2009; Karabacak vd., 2010), the exact location of this fault, its Northwards elongation, and other tectonic structures crossing the Plain are still unclear. Moreover, the SW extension of the Karasu Fault, connecting the DSFZ and SAFZ (South Anatolian Fault Zone) and the relationships of the thermal waters discharging in the Amik Plain with the volcanic rocks outcropping along the Kırıkhan-Reyhanlı corridor the Karasu Fault and other active faults (Kop, 1996) are still open and debeated questions. This proposal aims (i) to trace the extension of the DSFZ until the Karasu Fault, (ii) to better understand the thermal waters/active fault relationships and (iii) to recongize other structures (if any) parallel related to the DSFZ. The fluids geochemistry will reveal possible magmatic or mantle origin of gases, the origin of thermal waters, their interactions and relationship with active faults. The latter information will also contribute to assess the geothermal potential of the region.

## Scope

The DSFZ is a large tectonic structure crossing Jordan, Israel, Syria and Turkey following a nearly N-S direction. As the DSFZ is one of the most active structures of the whole region, the scope of the project is to characterize the Turkish-Syrian section of the fault as its contributions to reduce natural disasters of geologic origin. The presence of thermal waters at some areas located along the fault , increases the validity the project as it is also a source of information for geothermal potential evaluation purposes.To reach this target, a geochemical approach will be followed

The DSFZ is one of the most active tectonic structures of the region crossing Jordan, Israel and Syria following a nearly N S direction. The DSFZ goes along the Asi river in the Amik Plain of Turkey (fig. 1). A geochemical approach will be adopted for the determination of the northern extension of the DSFZ and the SW extension of KFZ by soil-degassing measurement of $CO_2$, Rn and $CH_4$. Since the SW side of the Amik Basin includes a number of thermal water discharge locations potentially related with the Kırıkhan-Reyhanlı corridor and thermal waters are also discharged along the WNW-ESE trending faults extending outside the country located to the South of the Reyhanli town and SE of the Amik Plain (Reyhanli dextral Fault; Şaroğlu vd. 1987) information related to the geothermal potential of the area can be additional results of the geochemical approach of the project. Soil degassing measurements coupled with water geochemistry studies will be carried out in the west-middle West of Amik Plain, close to the boundary of Syrian. This study will include the Reyhanlı Hamam (Hamamat) thermal spring (t= 37 $^oC$), Borniyaz mineralized water well (t=25 $^oC$), Kırıkhan Ilıpınar spring, Reyhanlı- Yenişehir ve Cüdeyde cold water springs and Kırıkhan-Reyhanlı hot water wells (Fig.1 and Table 1).

Within the scope of this study, the continuation of DSFZ to the Karasu Fault, the extension of the Karasu Fault in SW direction, the relation of volcanics outcropping along the Karasu Fault with geothermal activity and the origin of thermal waters will be determined by carbon and helium isotope composition of the dissolved gases and isotope composition ($\delta^{18}O$, $\delta^2H$ ve $^3H$), major, minor and trace ion analyses in water.

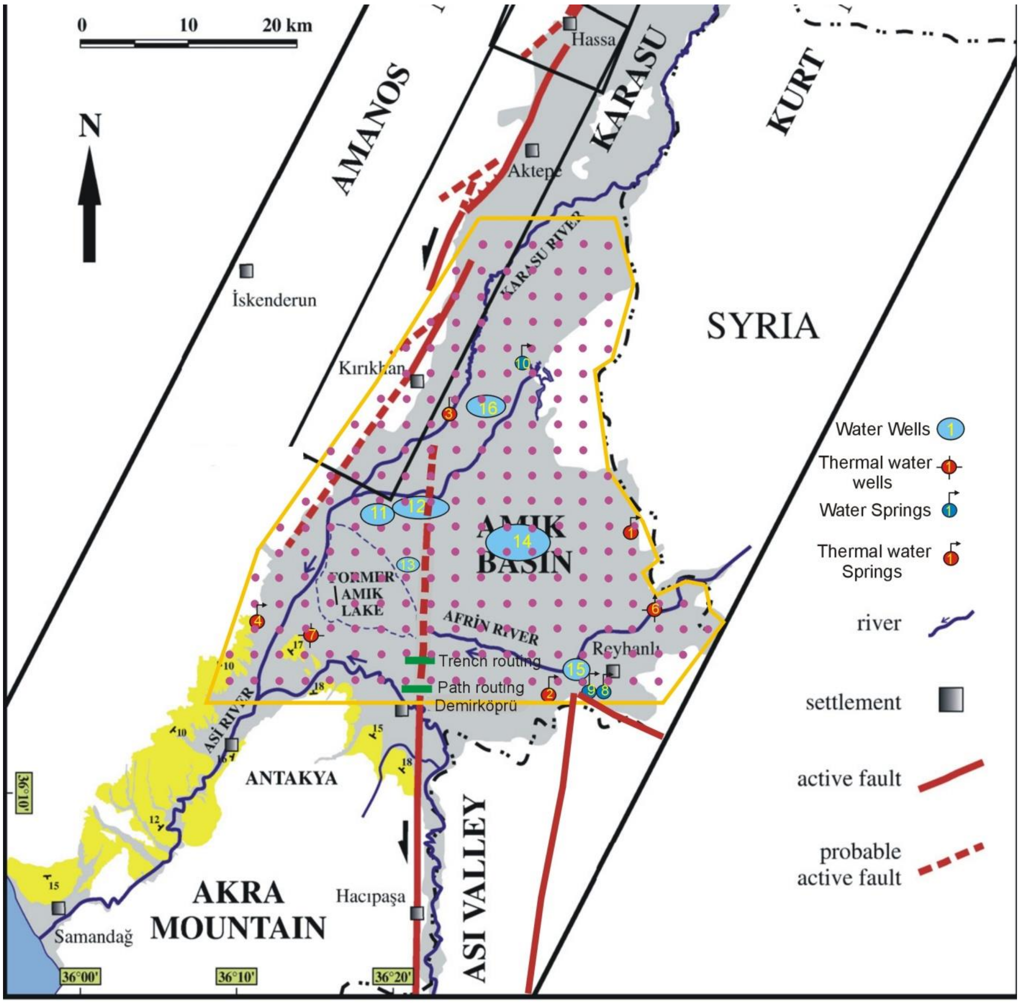


Fig. 1 Proposed sampling and measuring grid points around the Amik Basin area

| | Number | Water temperature (°C) |
|---|---|---|
| **Thermal water springs** | | |
| Hamam | 1 | 37 |
| Ilıcapınar | 2 | 23 |
| Ilıpınar | 3 | 25 |
| Karali | 4 | ? |
| **Thermal water wells** | | |
| Borniyaz | 6 | 25 |
| Otoman Palace | 7 | 43 |
| Thermal boreholes in Kırıkhan | 8 | 25 |
| **Cold water springs** | | |
| Yenişehir | 9 | 14 |
| Çayır | 10 | 10 |
| Gölbaşı | 11 | 12 |
| **Cold water wells** | | |
| 408 Evler | 12 | 17 |
| Kazkelli | 13 | 16 |
| 408 Evler II | 14 | 18 |
| Kumlu/Kumlu DÜÇ/Uzunkavak | 15 | 20 |
| Reyhanlı DÜÇ | 16 | 18 |

Table 1. Cold and thermal springs and wells in the Amik Basin

# Methods

The project will be developed using geochemical technologies. In the following, methods and techniques adopted for both the fieldwork and laboratory analyses are described:

Soil $CO_2$, radon and helium gas flux anomaly mesaurement is known as an useful method to locate active and buried faults under alluvium cover. There are numerous studies showing that high He and $CO_2$ and/or Rn contents are good indicators of fault degassing. Moreover, soil and groundwater gas geochemistry studies also play an important role in geothermal potential studies in hydrothermal areas. Measurment of gas discharges can easily discriminate permeable and/or impermeable zones. It is for sure that this kind of study should be integrated with other geophysical/geologic data.

## Fieldwork

The fieldwork will provide the information about the soil-degassing activity ($CO_2$, Rn and $CH_4$) and allow the collection of samples to be analyzed in the laboratory.

The fieldwork will be developed using GIS-type software to allow the correct location of the sampling sites and the nodes of the degassing grid measurements on georeferenced maps.

This project proposal comprises the following methods for investigations aimed to measure the natural degassing rate from selected areas and to collect gas and water samples:

1- Soil degassing measurements will be carried out over an almost regular grid (side of 2.5km) accross the areas where buried faults are supposed to exist. The measurements will be repeated two times a year, especially at locations where initial gas emmisions are high, so as to be able to monitor its relations with the seasonal variations and microseismicity.

2- The spacing of profiles are proposed as 2.5 km, and could be reduced to 1 km where Table 2. Measurement and Analysis Methods in the project gas anomalies can be observed. Furthermore, dissolved gases and chemical and isotope composition of groundwaters taken from shallow/deep wells and springs from the studied areas will be analyzed in order to understand possible relations with buried fault zones.

Soil-$CO_2$ gas flux will be measured by a portable instrument composed of a chamber connected to an Infrared spectrometer (WEST Systems, Italy). A small, pocket size, computer (PDA) manage the instrument, showing the result(s) of measurement in real time. The fluxmeter is equipped with the LICOR LI-820 the most accurate and reliable portable carbon dioxide detector. The LI-820 is a double beam infrared sensor compensated for temperature variation in the range from -10 to 45°C and for atmospheric pressure variation in the range 660-1060 HPa. Accuracy 2% repeatability ±5ppm. The full scale range can be set to 1000, 2000, 5000 or 20000 ppmV of carbon dioxide. The characteristics of precision refer to the sensor set to a full scale range of 20000 ppmV. If a very high sensitivity is required the detector can be set to 1000 or 2000 ppm full scale value. The instrument, which is in the shape of a closed semi-circle of 30 cm diameter, has a height of 20 cm and resembles a reversed pot. When it is mounted on the measured surface, the measurement is made by driving in the edges of the pot into the soil so as to provide airtight. In the mainframe of the the project the instrument will be donated by the Italian partner

| materials to be analyzed | Type of Analyses | Parameter | Number of sample or measurements/ Period | *Total of the sample or measure ments | Applied Methods | Measurement Location | |
|---|---|---|---|---|---|---|---|
| | | | | | | In Field | in Lab |
| WATER | A- Physical Analysis | Temperature (°C) ,pH,Eh (Redox Potential), EC,DO,Salinity, Alkalinity, GWL | 50/4 | 200 | Multi parameter measurement device, YSI 556 model, Alkalinity kit | In both locations | |
| WATER | B- Chemical Analysis | Ca, Mg, Na, K, Cl, $SO_4$, $HCO_3$, $CO_3$ | 50/4 | 200 | $Ca^{2+}$, $Mg^{2+}$, $Na^+$ ve $K^+$ analysis are measured with atomic absorption spectrometer, $SO_4^{2-}$ is measured by spectrophotometer, alkalinity is measured by standard titration technique, $Cl^-$ anion is measured by silver-nitrate titration technique | --- | H.U. Water Chemistry Laboratory (Ankara) |
| | | Heavy metals (Cu, Zn, Pb, Cd), pollution parameters ($NO_2$, $NO_3$, $NH_3$) and total Fe, B, Br, As, F, I, $SiO_2$ such as the other parameters | 50/4 | 200 | | --- | NTU (TAIWAN) and INGV (ITALY) |
| WATER | C- İsotopic Analysis | $^3H$ | 50/2 | 100 | Tritium measurements are made by Liquid scintillation technique. | --- | H.U. Water Chemistry Laboratory (Ankara) |
| | | $\delta^{18}O$, $\delta^2H$ | 50/2 | 100 | Oxygen-18 and Deuterium ısotope analysis are made by mass spectrometer, | | NTU (TAIWAN) and INGV (ITALY) |
| SOİL GAS +WATER | | $^{13}C/^{12}C$, $\delta^{13}C_{CO2}$ | 50/4 | 200 | $CO_2$ İsotope Analyzer (LGR), Iso$CO_2$ CRDS (Picarro) | | |
| | | $^3He/^4He$, $^4He/^{20}Ne$, $^{40}Ar/^{36}Ar$ | 50/4 | 200 | Micromass 5400 Noble Gases Mass Spectrometer; GVI5400TFT mass spectrometer; GVI Argus MS | | |
| SOİL | D- Radioactivity Analysis in Soil | $^{238}U$, $^{232}Th$, $^{40}K$ | 10/1 | 10 | Gama Spectrometer | --- | NTU (TAIWAN) |
| SOİL GAS +WATER | E-Gas Analysis | Rn | (200+50)/2 | 500 | Ionization chamber (GEO-RTM 2128 and Alphaguard PQ2000PRO) | On the Field | --- |
| | | $CO_2$, $CH_4$ | (200+50)/2 | 500 | IR spectrometer (WEST LI-820) | On the Field | --- |
| | | Helium ($^4He$) | (200+50)/2 | 500 | Helium Leak Detector (Alcatel ASM 102S) | On the Field | --- |
| | | Ar, $N_2$, $CO_2$, $CH_4$, $^4He$ | (50+50)/2 | 200 | Micro GC and Noble Gas MS | On the Field | NTU (TAIWAN) and INGV (ITALY) |

*Sampling and measurement periods were chosen for four periods between July 2011 and June 2013 in wet and dry spells (there will be no gas measurements just before and after rain, herein wet period means cold season). Sampling will be carried out in four periods within two years and the number of sampling is approximate. Total number of sampling and measurement can be increased or decreased to a reasonable amount according to results of measured values.

gas anomalies can be observed. Furthermore, dissolved gases and chemical and isotope composition of groundwaters taken from shallow/deep wells and springs from the studied areas will be analyzed in order to understand possible relations with buried fault zones.

3- Soil-$CO_2$ gas flux will be measured by a portable instrument composed of a chamber connected to an Infrared spectrometer (WEST Systems, Italy). A small, pocket size, computer (PDA) manage the instrument, showing the result(s) of measurement in real time. The fluxmeter is equipped with the LICOR LI-820 the most accurate and reliable portable carbon dioxide detector. The LI-820 is a double beam infrared sensor compensated for temperature variation in the range from -10 to 45°C and for atmospheric pressure variation in the range 660-1060 HPa. Accuracy 2% repeatability ±5ppm. The full scale range can be set to 1000, 2000, 5000 or 20000 ppmV of carbon dioxide. The characteristics of precision refer to the sensor set to a full scale range of 20000 ppmV. If a very high sensitivity is required the detector can be set to 1000 or 2000 ppm full scale value. The instrument, which is in the shape of a closed semi-circle of 30 cm diameter, has a height of 20 cm and resembles a reversed pot. When it is mounted on the measured surface, the measurement is made by driving in the edges of the pot into the soil so as to provide airtight. In the mainframe of the the project the instrument will be donated by the Italian partner INGV.

4- Measurements of Radon in soils and dissolved in waters will be done in-situ or in the lab within 24h using gas samples collected in tubes. Water radon concentrations will be determined using a radon detector (RTM2100, SARAD) equipped with an internal pump. Radon gas is stripped from a water sample of ca. 380 ml by a pump (3 liter min-1) in a closed loop. Radon measurements in water and soils will be carried out by a GEO-RTM 2128 gamma spectrometer (SARAD, Germany) purchased from a previous project.
5- High Rn gas values might also emanate from the U-Th enrichment within the clay materials accumulated along the fractures of the fault zones, apart from the probable burried active fault zones. In such cases, [$^4$He] and $^3$He/ $^4$He ratios are needed in order to find out whether the increase in Rn gas is related with the active faults in great depths and also to determine whether the increase of soil Rn originates from the U-Th enrichment.
6- The collected gas samples will be sent to the laboratories of INGV and NTU soon after sampling. He concentration will be measured by using the Alcatel instrument which will be provided from the proposed project. Also, three samples from each profile of the Rn measured soils will be taken to measure $^{238}$U, $^{232}$Th and $^{40}$K. The isotopic composition will be measured for He, Ar, $CH_4$, $H_2S$, $CO_2$ and $N_2$.
7- Since analyses of gas concentrations and isotopic ratios will be made by using gas cromotography and mass spectrometry both at NTU and INGV, an accurate intercalibration of the $^3$He/$^4$He and $^{13}$C/$^{12}$C ratios with respect to international standards will be contemporary performed at both the INGV (Italy) and NTU (Taiwan) laboratories.

**Sampling and analytical procedures of gases:**

***1-Soil degassing and soil gases***

A wide area of more than 200 km$^2$ including all the sampling sites, will be investigated for soil $CO_2$, Rn and $CH_4$ degassing. The measurements will be carried out at an almost regular grid with node distance of 2.5 km following two different techniques: the dynamic concentration (active method) and the accumulation chamber (passive method). Both of the measuring methods have been applied over a large variety of degassing systems (i.e Chiodini et al., 1999; 2000; Italiano et al., 2009). The two methods have limits in their applicability as a function of the soil degassing intensity (Carapezza and Granieri, 2004). The active method (Gurrieri and Valenza, 1988), measures the $CO_2$ concentration in a gas mixture driven by a constant flow-rate pumping to a spectrometer. The gas is pumped through a pipe of a section of 2.5 cm$^2$ inserted at a depth of about 50-60 cm in the soil. The right $CO_2$ concentration value of the analysed gas mixture (soil $CO_2$ and air) is taken when it reaches the steady state (constant value).

The passive method, also known as the closed chamber method, is based on the measurement of the increase of the $CO_2$ concentration in an accumulation chamber of known volume, placed on the soil. The method provides a flux following the equation (1):

$$(1) \qquad H dc_t/dt = \Phi_t (1 - c_t)$$

where H is the height of the accumulation chamber, $dc_t/dt$ is the $CO_2$ concentration increase within the chamber as a function of the time, $\Phi_t$ is the total $CO_2$ entering the chamber, $c_t$ is the $CO_2$ concentration at time *t*.

On the field, the gas mixture within the accumulation chamber is continuously detected by a spectrometer and the $CO_2$ concentration is recorded on a palmtop computer, where the variation in concentration *vs* time is shown. A computer code provides the flux value with no specific assumption. The uncertainty of both the methods (in the range of ±10%) was estimated by repeated measurements on the same site.

Gas samples from the soil-degassing will be taken for lab analyses when $CO_2$ or $CH_4$ display very high content (above 2-3 %).

***2-Dissolved gases***

Apart from soil gases, gases will be collected mainly from gas bubbling in waters. The gases will be sampled taken care to avoid any atmospheric contamination. An inverted funnel will be placed on top the bubbling driving the gas towards a pyrex bottle of about 50 ml with two valves at both ends. The bottle is washed by the gas coming from the funnel and the sample will be taken closing the two valves after a volume of at least one of order magnitude higher than that of the sampling bottle has been passed through.

The dissolved gases will be extracted in the laboratory from water samples stored in 240ml glass bottles sealed in the field by silicon/rubber septa using special pliers. All of the samples have to be collected taking care to avoid even the tiniest bubbles to prevent atmospheric contamination. Chemical analyses will be carried out on the gas phase extracted after the attainment of the equilibrium (at constant temperature) between the water sample and a known volume of host, high purity gas (argon), injected inside the sampling bottle (see Sugisaki and Taki, 1987 and Capasso and Inguaggiato, 1998 for details). The analytical determinations will be carried out by gas chromatography using a Perkin Elmer 8500 equipped with double-detector (TCD-FID) using argon as carrier gas.

The dissolved gases will be analyzed also for their helium isotope composition. The analyses will be carried out on gas fractions extracted following the same procedure as for the gas chromatography. The system includes a two-stage purification line and a cryogenic pump with charcoal trap. The gas sample first passes through the first-stage purification line to remove the active gases (including $H_2O$ , $CO_2$ , $N_2$, $O_2$, $H_2$, hydrocarbons, and sulfur gases etc.) and heavy noble gases (Ar, Kr, and Xe). The sample is then allowed to enter the second-stage purification line for further purification. It includes a Ti-sponge furnace, charcoal trap with liquid nitrogen, and SEAS Ti-Zr getters. At this stage all the active gases should be totally removed and, the purified gas is trapped into a cryogenic pump at 15°K. Lastly, helium and neon are released by step-wisely increasing temperature to 34 and 70°K, respectively, to be sequentially admitted into the mass spectrometry (Micromass 5400 noble-gas mass spectrometer with dual collectors) for the determination of isotopic compositions. Air is routinely run as a standard for calibration. In general, the total errors on the ratios are less than 2 and 5% in one sigma standard deviation, respectively, for $^3He/^4He$ and $^4He/^{20}Ne$. Details of the procedures are found in Yang et al. (2005).

The isotopic analyses of the purified helium fraction will be performed by a static vacuum mass spectrometer (GVI5400TFT) that allows for the simultaneous detection of $^3He$ and $^4He$-ion beams, thereby keeping the $^3He/^4He$ measurement error to very low values. Typical uncertainties in low-$^3He$ samples (R/Ra values below 0.1) are within ±5%.

The isotopic composition of all the dissolved inorganic carbon (TDIC) will be carried out by mass spectrometer following a specific procedure based on the chemical and physical stripping of $CO_2$. The stripped gas is purified by means standard procedures. The samples will be measured using a Finnigan Delta Plus mass spectrometer and the results expressed in δ ‰ vs. V-PDB standard. The standard deviation of $^{13}C/^{12}C$ ratio is ± 0.2‰.

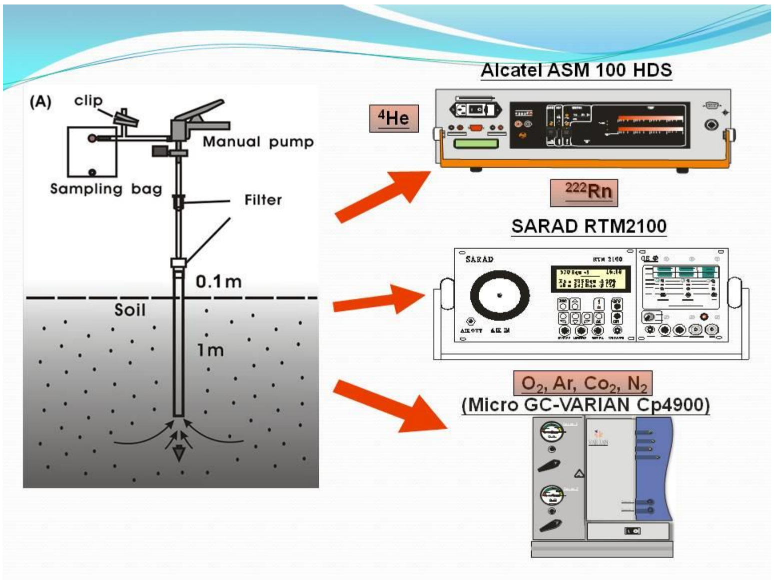


Fig. 2 Soil-gas measurement model

**Sampling and analytical procedures of water samples**

Water samples will be collected in order to carry out both chemical and isotopic analyses. Six different samples will be collected at each site: one as-is sample (50 ml) for stable isotope ($\delta D$-$\delta^{18}O$) composition; one filtered sample (100 ml) for anion analyses; one filtered sample acidified for cation analyses (100ml) one more sample will be taken by falcon-type bottles (50 ml) for trace element analyses; two more samples will be taken for tritium (500ml) and radon analyses (380ml).

On the field, pH, Eh, temperature and electrical conductivity (EC) will be measured directly at the sampling sites, while $HCO_3^-$ content will be measured by titration with 0.1N HCl and the dissolved oxygen will be measured by a temperature-compensated YSI multi-parameter probe on flowing waters. Samples will be stored in clean polyetilene bottles rinsed with the water to be sampled. Major cations and trace elements will be measured on samples filtered at 45 □ and stabilized by ultrapure $HNO_3$ for cation analysis. Major constituents were determined by a Dionex DX 120 ion chromatograph, and trace elements by a Jobin Yvon ICP-OES Ultima Due. 2-□□errors are within 2 and 5 %, respectively.

Isotope determinations (D/H and $^{18}O/^{16}O$) on water samples will be performed by equilibration technique for oxygen and water reduction (hydrogen production by using granular Zn). Measurements will be carried out using a Finnigan Delta Plus mass spectrometer and AP 2003 automatic preparation system coupled with an IRMS. Analytical precision is better than 0.2‰ for $\delta^{18}O$ and 1‰ for $\delta D$.

## Anticipated Results and Achievements

These surveys will not only help us to check the efficiency of our soil gas measurement technique in one of the most active tectonic regions of the world but also in demarking the fault zones in the study area.

This further issue can be useful for inter-comparison studies of collected geochemical soil-gas data of Amik Basin (Hatay/Turkey), Ghab Basin (Syria) along the earthquake-prone area of DSFZ and highly seismic regions in the world. The results obtained from the project will provide the basic information to develop a geochemical monitoring of the area carried out by both periodical sampling and automatic stations. The continuous monitoring of the region will

Table 3. Workpackage No vs. Time

| Workpackage No | Months | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| WP 1 | T U M G | | | T A G L O G | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| WP 2 | | | | | | | T U M G | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| WP 3 | | | | | | | | | | | | | SUGAJAG | | | | | | | | | | | | | | | | | | | | | | | |
| WP 4 | | | | | | | | | | | | | | | | | | | T U M G | | | | | | | | | | | | | | | | | |
| WP 5 | | | | | | | | | | | | | | | | | | | | | | | | | SUGAJAG T AG JETAG | | | | | | | | | | | |
| WP 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | T U M G | | | | | |

Table 4. Research Groups of the project

| | Name of Group | Abbreviation | Responsibles |
|---|---|---|---|
| | All groups | (TÜMG) | All members of the projects |
| 1- | Tectonics Research Group | (TAG) | B. ROJAY, A. OZACAR,V. KARABACAK T.F. YANG, V. WALIA |
| 2- | Water and Gas Geochemistry Research Group | (SUGAJAG) | G. YUCE, H. T. YALÇIN, T. F. YANG, F. ITALIANO, V. WALIA |
| 3- | Laboratory Measurements Groups | (LÖG) | F. ITALIANO, T. F. YANG |
| 4- | Geothermal Research Group | (JAG) | H. T. YALÇIN, G. YÜCE, F. ITALIANO, T.F. YANG |

help to set up geochemical models aimed at a better understanding the relationships between fluids during the development of seismogenic processes related to the regional activity of the fault systems under study.

This will create an opening for further cooperations to carry out different kind of geological/geophysical/geochemical work over other basins along the DSFZ, which is a known living laboratory worldwide for various geoscientific researches.

Undergraduate & master degree students may get to be trained to use the geochemical techniques, and to understand the mechanisms of soil-gas migration in fault systems of different seismic regions.

**Table 5.** Main work packages (WP), periods, members and definitions of the work within the frame of the project

| WP Nr | Short name of the WP | Period | Responsibles | Details of intended study in WP |
|---|---|---|---|---|
| **(1) Preparation and instrument calibration works** | Project preparation meeting | **March 2012--Aug 2012** | Project Leader and all members of the project | ➢ Consent on project area definition, apparatus purchase, work plan, timetable, eradication of possible delays and difficulties, coordination of research groups (TABLE 3) |
| | Purchase of instruments and disposals<br>Confirming insitu sampling and measurement locations<br>Calibration of field equipment<br>1st interim report | | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI)<br>Volkan KARABACAK (Consultant )<br>Arda OZACAR (Consultant )<br>Francesco ITALIANO (Consultant )<br>Frank T. YANG (Consultant )<br>Vivek WALIA ( Consultant )<br>Fellowship student | ➢ Achievement of related 1/25000 scaled topographic maps<br>➢ Following active tectonic lines and coordination between active tectonic and gas measurements groups<br>➢ Location nodes on map using GPS receiver<br>➢ Calibration of He leak detector<br>➢ Calibration of Micro GC 490<br>➢ Calibration of noble gas MS<br>➢ Calibration of Radon detector<br>➢ Assessment of accordance between realization of WP percentage and expenditures, and discussion of subsequent WP |
| **(2) Field and Lab works** | Insitu measurements and sampling (summer and winter periods)<br>Evaluation of field measurements<br>Project evaluation meeting<br>2nd interim report | **Sep 2012-Feb 2013** | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI)<br>Volkan KARABACAK (Consultant )<br>Arda OZACAR (Consultant )<br>Francesco ITALIANO (Consultant )<br>Frank T. YANG (Consultant )<br>Vivek WALIA ( Consultant )<br>Fellowship student | ➢ Insitu physical parameter measurement of waters<br>➢ Soil and water gas measurements and cold/hot water gas/water chem/isotope sampling<br>➢ Sampling of soil and rock for $^{238}U$, $^{232}Th$, $^{40}K$ analyses<br>➢ Sampling and gas measurement with He Leak Detector<br>➢ CO2 and radon measurement with Gas flow meter and Radon instrument<br>➢ $CH_4$, $H_2S$, Ar, $N_2$, $N_2O$, $O_2$, C2, C3 measurement with Micro GC 490<br>➢ Dispatch of collected samples for analyses<br>➢ Lab measurement of other gases by noble gas mass spectrometer<br>➢ Assessment of accordance between realization of WP percentage and project outcomes, and discussion of delays and difficulties ,if any, and subsequent WP evaluation<br>➢ Pre-evaluation of MSc thesis from Project |
| **(3) Office, Field and Lab Works** | Determination of second measurement locations in the light of first field and lab results<br>3rd interim report | **March 2013- Aug 2013** | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI) | ➢ Achievement of micro and macro seismicity data of study area<br>➢ Input water, gas and isotope geochem data to GIS<br>➢ Drawing and interpretation of areal distribution of gas concentrations<br>➢ Soil and water gas measurements and cold/hot water gas/water chem/isotope sampling<br>➢ Sampling and gas measurement with He Leak Detector<br>➢ CO2 and radon measurement with Gas flow meter and Radon instrument<br>➢ $CH_4$, $H_2S$, Ar, $N_2$, $N_2O$, $O_2$, C2, C3 measurement with Micro GC 490<br>➢ Dispatch of collected second period samples for analyses |

Table 5 cont'd

| WP Nr | Short Name of WP | Period | Responsibles | Details of intended study in WP |
|---|---|---|---|---|
| **(4) Field and Lab Works** | Field measurement and sampling<br>Graphical and statistical evaluation of data<br>Evaluation of geothermal potential<br>Project evaluation meeting<br>4th interim report | **Sep 2013- Feb 2014** | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI)<br>Volkan KARABACAK (Consultant )<br>Arda OZACAR (Consultant )<br>Francesco ITALIANO (Consultant )<br>Frank T. YANG (Consultant )<br>Vivek WALIA ( Consultant )<br>Fellowship student | ➢ Achievement of micro and macro seismicity data of study area<br>➢ Evaluation of origin and interaction of water, gas and isotope analysis results<br>➢ Transfer of water, gas and isotope results into GIS<br>➢ Evaluation of geothermal potential<br>➢ Active tectonic evaluation (volcanism-active tectonism)<br>➢ Graphical and statistical evaluation and interpretation of all data<br>➢ Assessment of accordance between realization of WP percentage, expenditures and project outcomes, and discussion of delays and difficulties ,if any, and subsequent WP evaluation |
| **(5) Evaluation of all field and lab works and preparation for project finalization** | (Missing) Field measurement and sampling<br>Graphical and statistical evaluation of data<br>Evaluation from the geothermal potential and eathquake-fluid-gas geochem changes points of view<br>Project evaluation meeting<br>5th interim report | **March 2014--Aug 2014** | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI)<br>Volkan KARABACAK (Consultant )<br>Arda OZACAR (Consultant )<br>Francesco ITALIANO (Consultant )<br>Frank T. YANG (Consultant )<br>Vivek WALIA ( Consultant )<br>Fellowship student | ➢ Evaluation of seismicity with results of analyses, and determination of possible changes with seismicity<br>➢ Transfer of all measurement results into GIS<br>➢ Evaluation of origin and interaction of water, gas and isotope analysis results<br>➢ Evaluation of geothermal potential – geothermometric evaluation<br>➢ Active tectonic evaluation (volcanism-active tectonism)<br>➢ Completing missing or unfinished analyses<br>➢ Integrated evaluation of project data<br>➢ Group meeting for project report and scientific paper preparation |
| **(6) Preparation scientific paper and presentation and introducing of project final report** | Check of Project data<br>Final Report | **Sep 2014- Feb 2015** | Galip YÜCE (CI)<br>Tolga H. YALCIN (PI)<br>Bora ROJAY (PI)<br>Volkan KARABACAK (Consultant )<br>Arda OZACAR (Consultant )<br>Francesco ITALIANO (Consultant )<br>Frank T. YANG (Consultant )<br>Vivek WALIA ( Consultant ) | ➢ Evaluation of origin and interaction of water, gas and isotope analysis results<br>➢ Transfer of all data into maps, statistical evaluation of all data and finalize interpretations<br>➢ Share of important results with other institutions<br>➢ Preparation of proceedings and papers<br>➢ Submit of final project report to TÜBİTAK |

Table 6. Fieldwork days of each person in the project

| Work Package No | Period | Fieldwork days of each persons in the project | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Galip YÜCE (Chief Investigator)** | **Bora ROJAY (Principal Investigator)** | **Volkan KARABACAK (Consultant)** | **H. Tolga YALCIN (PI)** | **Francesco ITALIANO (Consultant) (1)** | **T. Frank YANG (Consultant) (2)** | **Vivek WALIA (Consultant) (3)** | **Arda OZACAR (Consultant)** | **(Scholar)** | **(Scholar) Graduate Student** | **(Scholar) Graduate Student** |
| (1) | March 2012-Aug 2012 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | - | - |
| (2) | Sep 2012-Feb 2013 | 15 | - | - | 10 | 10 | 10 | 10 | 10 | 15 | - | - |
| (3) | March 2013- Aug 2013 | 10 | 10 | 10 | 10 | - | - | - | 5 | - | 10 | 10 |
| (4) | Sep 2013-Feb 2014 | 15 | 10 | 10 | 15 | 8 | 8 | 8 | 5 | - | 15 | 15 |
| (5) | March 2014- Aug 2014 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 5 | - | 10 | 10 |
| Total fieldwork and meeting days | | 60 | 40 | 40 | 55 | 35 | 35 | 35 | 10 | 25 | 25 | 35 |

## BUDGET OF THE PROJECT:

**<u>The total fund is demanded from TUBITAK : </u>= 351 551 TL (almost 177 550€, it is very close to the upper limit- 180 000 €)**

### CONTRIBUTION ANALYZE OF FOREIGN PARTNERS TO THE PROJECT

Analyses Prices-

Payment for analyses service if contributions were not existed.

Unit price per sample

| Quantity | FRANCESCO (INGV) | H.Ü | TPAO | TAEK |
|---|---|---|---|---|
| Major ions: | 75€ x 1,97 = **147 TL** | 130 x KDV (%1.18) = **153 TL** | | |
| Minor and trace elements | 110€ x 1,97=**217 TL** | 130 x KDV = **153 TL** | | |
| Tritium | 180 € x 1,97= **355 TL** | 160 x KDV= **189 TL** | | **550 TL** |
| $^{13}C/^{12}C$ | 25 € x 1,97= **50 TL** | | **200 TL** | |
| $^{18}O$ ve $^{2}H$ isotope analyses | 90 € x 1,97= **177 TL** | | **300 TL** | |
| Gaz analyses | 80 € x 1,97= **158 TL** | | **225 TL** | |
| Noble gas Analyses | 400 € x 1,97= **788 TL** | | | |
| $NH_4$ analyses | 30 € x 1,97= **59 TL** | | | |
| $^{13}C$ (TDIC) analyses | 30 € x 1,97= **59 TL** | | | |
| Sr izotopes | 280 € x 1,97=**552 TL** | | | |
| $^{238}U$, $^{232}Th$, $^{40}K$ analyses | | | | **360 TL** |

Contributions of Taiwanese and Italian Consultants to the TUBITAK project

| | *Analysis price<br>FRANCESCO+HÜ+TPAO+TAEK | Quantity | Total price (TL) |
|---|---|---|---|
| Minor and trace elements | **153 TL** | 200 | 30 600 |
| $^{13}C/^{12}C$ | **50 TL** | 200 | 10 000 |
| $^{18}O$ ve $^{2}H$ isotope analyses | **177 TL** | 100 | 17 700 |
| Gas analyses | **158 TL** | 200 | 31 600 |
| Noble gas Analyses | **788 TL** | 200 | 157 600 |
| $NH_4$ analyses | **59 TL** | | |
| $^{13}C$ (TDIC) analyses | **59 TL** | | |
| Sr isotopes | **552 TL** | | |
| $^{238}U$, $^{232}Th$, $^{40}K$ analyses | **360TL** | 10 | 3 600 |
| **TOTAL** | | | **251 100** |

* Calculated by taking the lowest prices into account

Total contribution of Italian-INGV and Taiwan-NTU partners ca. :
Taiwanese side: 127 350 TL
Italian side : 123 750 TL
+
----------------------
**251 100 TL (126 818 €)***

**RESPONSIBILITIES OF ALL MEMBERS IN THE PROJECT**

| | |
|---|---|
| Name, surname and title | Galip YÜCE Assoc. Prof. |
| Task in the project | Coordinator |
| Responsibility in the project | Coordinating of project, Planning of studies packages, Organizing of project meetings, Organizing of field studies, Evaluation and discussion of project data, Control of project teams, Supplying of equipments, Preparing of annual and final reports, Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | H. Tolga Yalçın Assoc. Prof. |
| Task in the project | P. Researcher |
| Contribution ratio | % 60 |
| Responsibility in the project | Hydrogeochemical and isotopic measurements sampling, Evaluation and discussion of water, gas and isotope analyses, Calculating of geotermometers for geothermal potentials, Preparing of annual and final reports, Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Bora Rojay Assoc. Prof. |
| Task in the project | P. Researcher |
| Contribution ratio | % 40 |
| Responsibility in the project | Determining of fault features in project area<br>Evaluation of active faults in project area<br>Geological evaluations in project area<br>Discussion of relationship between DSFZ and Karasu Fault<br>Evaluation of relationship between active fault branches and gas measurements<br>Discussion of relationship between tectonic and volcanism in project area<br>Preparing of annual and final reports<br>Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Volkan KARABACAK Assoc. Prof. |
| Task in the project | Consultant |
| Contribution ratio | % 30 |

| | |
|---|---|
| Responsibility in the project | Determining of buried fault features in project area, Discussion of relationship between DSFZ and Karasu Fault under Amik Basin, Evaluation of active fault branches with instrumental methods, Shallow geophysical studies, Discussion of relationship between tectonic and gas measurements in project area, Preparing of annual and final reports, Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | T. Frank YANG Prof. |
| Task in the project | Consultant |
| Responsibility in the project | Gas geochemistry studies, He detector and micro GC calibration and measurements, Evaluating of hydrocarbon gas measurements, Analyses of 238U, 232Th, 40K in NTU laboratories, Discussion of relationship between tectonic and volcanism in project area, Inert gas measurement and evaluations, Preparing of annual and final reports, Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Vivek WALIA Dr. |
| Task in the project | Consultant |
| Responsibility in the project | Preparing of gas concentration maps , soil gas measurements, Determination of defective gas measurements, Discussion of relationship between tectonic and gas measurements in project area, Planning of Radon Gas measurements, Supporting to geophysical studies, Preparing of annual and final reports, Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Francesco ITALIANO Dr. |
| Task in the project | Consultant |
| Responsibility in the project | Planning and coordinating of gas and water geochemistry studies<br>Inputting data of measurement points in the field to GIS<br>$CO_2$ and $CH_4$ soil gas measurments<br>Gas, isotope and rare element analyses in INGV laboratories<br>Preparing of annual and final reports<br>Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Arda ÖZACAR Assist.Prof. |
| Task in the project | Consultant |
| Responsibility in the project | Stress analyses and micro/macro earthquakes occured in the study area and their relations with active tecnotic movements |

| | |
|---|---|
| Name, surname and title | Quota for scholarship student |
| Task in the project | Scholarship student |
| Responsibility in the project | Supporting on all field studies<br>Official services and transform all data to computer programs<br>Drawing of maps<br>Preparing of annual and final reports<br>Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Quota for scholarship student |
| Task in the project | Scholarship student |
| Responsibility in the project | Supporting on all field studies<br>Official services and transform all data to computer programs<br>Drawing of maps<br>Preparing of annual and final reports<br>Preparing of scientific products |

| | |
|---|---|
| Name, surname and title | Quota for scholarship student |
| Task in the project | Scholarship student |
| Responsibility in the project | Supporting on all field studies<br>Official services and transform all data to computer programs<br>Drawing of maps<br>Preparing of annual and final reports<br>Preparing of scientific products |