## Resume on FIELD CAMP results from the area of Ciomadu volcano area

The most recently extinct volcano of the East Carpathians igneous range - **Ciomadul**, for which combined U–Th and (U–Th)/He zircon, as well as radiocarbon dating has indicated that it had last erupted about 32 kyrs ago (Harangi et al., 2015), was chosen to be the main base of the SEG/TGS Filed Camp 2015, Romania.

The volcano external slopes host a multitude of mineral groundwater discharges, which can provide significant information on the current status of the still active inflows of magma-derived fluids.

Most published hydrogeological and hydrochemical data concerning the mineral water discharges from this location are several decades old. Consequently, some of the described groundwater outflows have disappeared, while new wells and artificially dug pools have been commissioned meanwhile (Figure 1).

The ESG-Project consequently aimed to update the corresponding body of information, while concomitantly attempting to acquire, by means of geophysical techniques (electrical prospection, electromagnetic method and magnetometry), and chemical analyses of groundwater samples, a coherent overall image of the local hydrogeological setting.

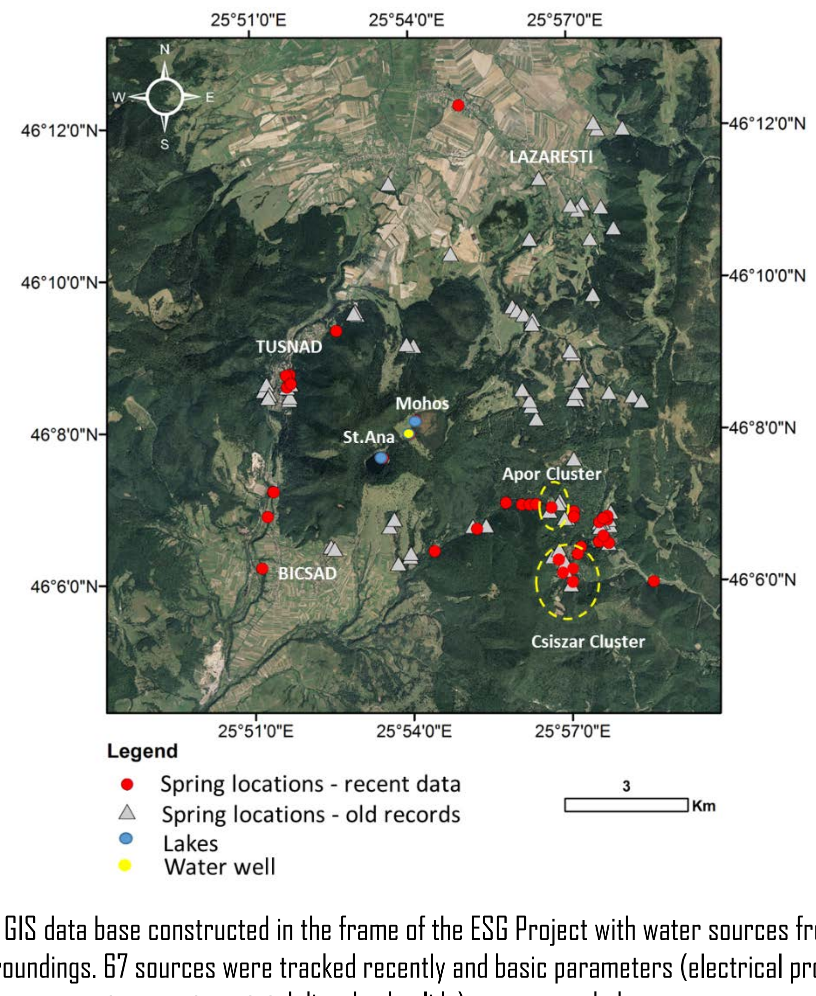


Figure 1 - The GIS data base constructed in the frame of the ESG Project with water sources from Balvanyos-Tusnad area and its surroundings. 67 sources were tracked recently and basic parameters (electrical properties, pH and temperature, total dissolved solids) were recorded

# Geophysical prospection

- **AIMS:** Several perimeters for geophysical measurements were chosen with the aim to demonstrate to students the capacity of the involved methods to identify fracture zones, to see the groundwater effect on electrical data and to differentiate between the water types without using the invasive methods.

**Other objectives:**

- Advanced utilization of geophysical equipment (system calibration, functions checking, programing the operating device, inputs for reducing the inaccuracies in measurements, recognition of most-common problems during acquisition and solving the problem, downloading the data, solving the errors)
- Proper choice of the geophysical method according to the objectives and petrophysical parameters of interest
- To identify the optimum profiles location based on theoretical basics learned at university, local tectonics and hydrogeological information provided by the Field Camp tutors
- Appropriate choice of the electric array and electrode distance, considering the size of the targets and planned depth of investigation
- Configuration of the equipment and command – files generation for less common used arrays and multielectrode hybrid arrays
- Lows and goals of the applied geophysical methods in particular cases
- Team working benefits in geophysics

- **Methods:** Electrical Resistivity Method- ERT (Electrical Tomography) & VES (Vertical Soundings)
  ELECTROMAGNETIC METHOD (near-surface applications)
  MAGNETOMETRY

During the Field Camp we've mapped **67 water outflows.** It was revealed that the electrical conductivity of groundwater is extremely variable in the area of Ciomadu Mt, ranging from 54μS/cm (pH=3.75) to 47900 μS/cm (pH = 6.6), thus being one of the most challenging area for a geophysicist to find drinkable water.

For groundwater resource mapping by means of geophysical techniques, the first stage is to track the geological formations or structures which are able to host water. This includes mapping of porous and permeable rocks and locating the low permeability or impermeable layers (clay, solid rock) which confine or delimitate the water-bearing structures. Electrical properties of rocks and groundwater can be assessed with different methods and survey techniques (quasi DC electrical current, alternative electrical current ranging from low to high frequency). The electric and electromagnetic methods rely on the distinctive electrical property of the water (usually electrically conductive) and the electrical contrast generated between the rocks with high water content and the adjacent rocks.

During the field camp we gathered data from different locations for getting the correct answer of our general question "**how the groundwater resources are seen in geophysical data**". The first steps were to look for locations with natural springs as well as tapped outflows, to perform geophysical measurements in different geological settings and then to look at the data in comparison with water chemical characteristics and geological maps.

Temperature is a factor which influences the electrical properties of the mineralized water. Despite the fact that Harghita Mountains also hosts the strongest heat-flow anomaly in Romania, most of the natural outflows were classified as "tepid waters" (15-23°C), only few basins with acid water showing higher values during the summer time (Homos 1–Figure 2), as influenced by the external temperature regime. Among the located sources, the highest discharge temperature (28.5$^0$C) has been recorded for SNAM borehole (Foraj SNAM- figure 2), whose water upflows from ~ 300m. Such results were useful to evaluate the necessary temperature correction when estimating groundwater electrical properties at higher depths.

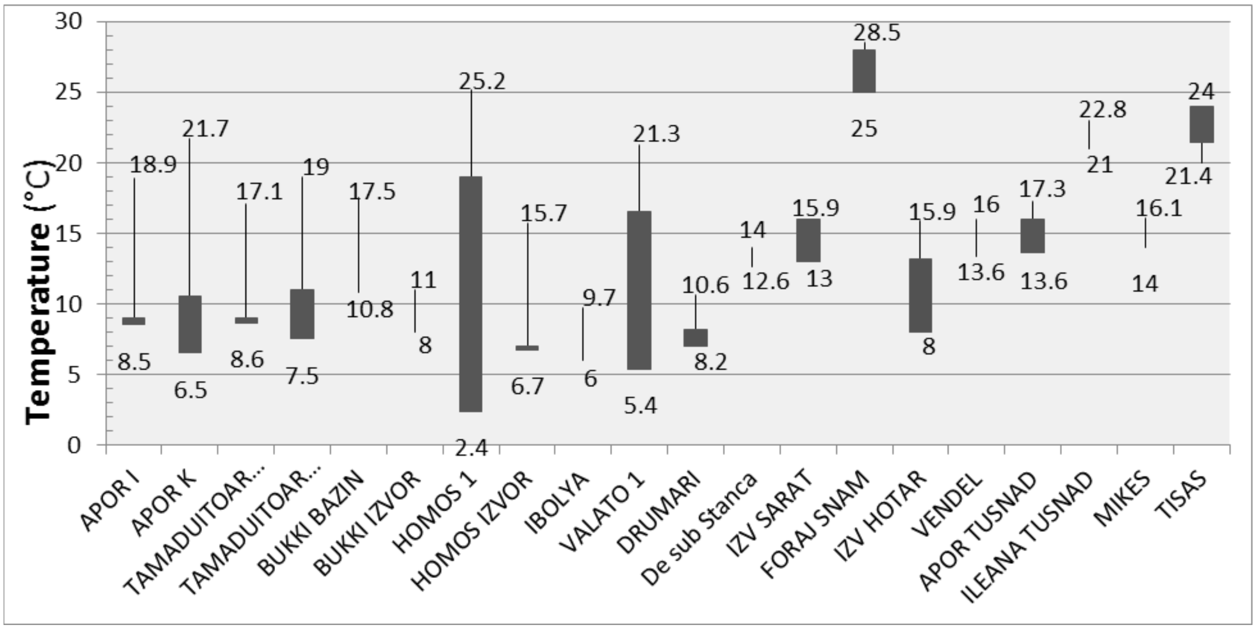


**Figure 2** - Variation ranges recorded within the time-interval May - October 2015

The groundwater samples analyzed by us showed a wide interval of variation in terms of electrical resistivity: minimum of 0.47 Ωm – and maximum 106.38 Ωm (Table 1).

The highest value belongs to the uppermost aquifer having identified so far within the Ciomadul volcanic structure, on the western rim of Mohoş crater, close to the saddle with St. Ana crater (Figure 1). Here, a domestic well dug at about 1060 m elevation allowed to notice the aquifer, which is positioned about 10 m higher than the water surface of the peat-bog which presently occupies the Mohoş crater bottom. Inside the swamp we were also able to take water samples from 2 "water windows", which display very low mineralized acid water (179-189 Ωm).

Data from Mohoş Peat-Bog and its surroundings were compared with electrical properties of St. Ana Lake which occupies the homonym crater bottom. The straight line distance between the mentioned domestic well and the nearest shore of St. Ana Lake is less than 1 km. Here, instead we got the highest electrical resistivity of all water samples (**714.89**Ω**m**).

The electrical resistivity data (electrical tomography) performed in the "twin" craters of Ciomadu volcano indicates that the involved phreatic aquifer observed in the domestic well is supplying the Mohoş swamp.

The ERT & VES measurements performed in the St. Ana volcanic crater area, showed no evidence of an aquifer and the water lake electrical properties suggest that its supply is derived exclusively from rain water. It is also worth noticing that near St. Ana Lake we got the maximum value of $^{222}Rn$ found in soil (65.03 kBq/m$^3$) from the investigated FIELD CAMP area.

**Table nr. 1** –Example of results with variation of electrical properties of water sources and pH

| Source code | Temperature (T°) | Conductivity (µS/cm) | pH | Electrical Resistivity ρ(Ωm) |
|---|---|---|---|---|
| Apor- A | 15.2 | 1240 | 4.05 | 8.06 |
| Apor- B | 19.1 | 16260 | 1.58 | 0.62 |
| Apor- C | 18 | 21200 | 1.48 | 0.47 |
| Apor- D | 16.9 | 14660 | 1.63 | 0.68 |
| Apor- 1 | 16.6 | 1357 | 3.58 | 7.37 |
| Apor- 4 | 18.4 | 2853 | 2.41 | 3.51 |
| Apor- 5 | 16.6 | 4720 | 2.3 | 2.12 |
| Apor- 6 | 17.45 | 7580 | 1.94 | 1.32 |
| Apor- I | 18.9 | 678 | 3.61 | 14.75 |
| Apor- J | 18.7 | 648 | 3.63 | 15.43 |
| Apor- K | 21 | 4430 | 2.17 | 2.26 |
| Apor- L | 19.5 | 9060 | 1.87 | 1.10 |
| Bazin Mare | 16.6 | 3250 | 2.86 | 3.08 |
| Tamaduitoare 1 | 13.5 | 2510 | 2.25 | 3.98 |
| Tamaduitoare 2 | 14 | 6080 | 1.89 | 1.64 |
| Tamaduitoare 3 | 14.9 | 11540 | 1.61 | 0.87 |
| Tamaduitoare 4 | 15.5 | 12600 | 1.6 | 0.79 |
| Ibolya | 9.7 | 318 | 5.36 | 31.45 |
| Bukki-basin | 12.6 | 1525 | 2.52 | 6.56 |
| Bukki-spring | 9.6 | 637 | 5.58 | 15.70 |
| Homos 1 | 15.2 | 398 | 4 | 25.13 |
| Homos 2 | 13.7 | 495 | 5.51 | 20.20 |
| Homos 4 | 11.9 | 604 | 3.76 | 16.56 |
| Homos 5 | 14.4 | 430 | 5.54 | 23.26 |
| Valato 1 | 15 | 1982 | 6.28 | 5.05 |
| Valato 2 | 14.8 | 1960 | 6.22 | 5.10 |
| Mikes | 15.5 | 1988 | 5.63 | 5.03 |
| Ileana | 22.8 | 6330 | 5.89 | 1.58 |
| Tisas | 22 | 6630 | 6.13 | 1.51 |
| Baile Reci C1 | 13.8 | 489 | 5.58 | 20.45 |
| C2a | 12.7 | 641 | 5.52 | 15.60 |
| C2b | 13.4 | 1183 | 3.09 | 8.45 |
| C3 | 14.6 | 1595 | 2.68 | 6.27 |
| C4 | 15.2 | 4330 | 6.14 | 2.31 |
| C5a | 13.9 | 2410 | 5.59 | 4.15 |
| C5b | 13.8 | 1463 | 3.67 | 6.84 |
| Baile Reci Sonda | 12.4 | 1352 | 5.9 | 7.40 |
| Iordan 1 | 12.4 | 590 | 5.56 | 16.95 |
| Iordan 2 | 12.4 | 1198 | 6.58 | 8.35 |
| Mofette Balvanyos | 13.1 | 41800 | 6.6 | 0.24 |
| Tinov-W | 10.9 | 94 | 7.02 | 106.38 |
| Tinov-Lake 1 | 14 | 56 | 3.93 | 178.57 |
| Tinov-Lake 2 | 15 | 53 | 3.93 | 188.68 |
| Lacul Sf.Ana | 18.8 | 14 | 6.74 | 714.29 |

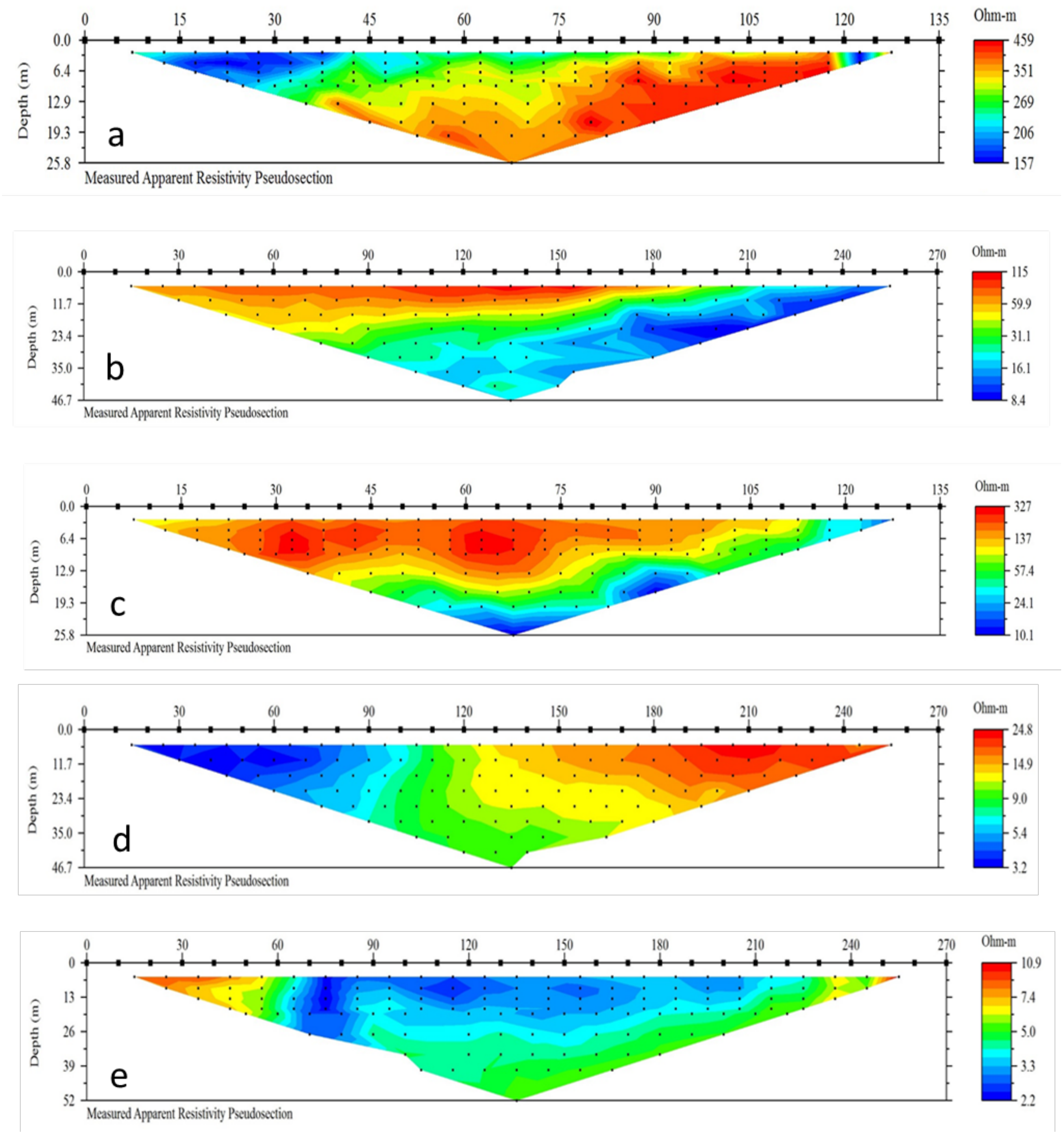


**Figure 3** – Measured apparent resistivity pseudosections resulted from ERT data (4 location):

a) Mohos Saddle (electrical resistivity domain: 157-**459** Ωm), b) Balvanyos –Transylvanya Basin (electrical resistivity domain : 8.4-115 Ωm), c) Balvanyos –Cold Baths (electrical resistivity domain : 10.1-327 Ωm), d) Mud Volcano area I (electrical resistivity domain : 3.2-24.8 Ωm), e) Mud Volcano area II (electrical resistivity domain : **2.2**-10.9 Ωm)

After the geophysical survey a group of students started a monitoring program of these water electrical properties and till now unexpected changes in water composition (which led to drop of the pH value of more than 0.7 units) were noticed.

Continuing to have guidance of the electrical signatures of groundwater resulted from samples, we next conducted geophysical measurements in locations which displayed distinctive hydrogeological settings. For comparison, in figure 3 there are given examples of Electrical Resistivity Tomography measurements resulted in 3 locations from the Balvanyos-Tusnad area as well from the Mud Volcano area (Homorod, Brasov County) (Figure 3).

Considering the electrical properties of geological features, the dramatic drop of the resistivity values (reaching even 2.2Ωm in active Mud Volcano area) were associated with groundwater presence and its chemical characteristics as well as with high permeability and porosity geological layers.

The extreme low resistivity values of observed in electrical sections characteristics for Mud Volcano area are given by the geo-extruded slurries which consist in fine solids (mostly clay) mixed with salty water of neutral pH and gases.

Mud and water samples from the active mud volcanoes were analyzed in laboratory and confirmed the results of the non-invasive geoelectrical measurements.

During the FIELD CAMP students were divided in working groups, leaving them the opportunity to make surveys in the same area with different geophysical methods. An example of such study is given in the next example, in an area with extremely conductive groundwater.

**Example from "Tamaduitoare" acid spring area**

(Part of cluster zone III –Figure 11)

The acid water basins from "Tamaduitoare" area have a total length of 8.80 m and hosts 4 springs with variable chemical composition. Despite the close position (1.3 - 2m space between the outflows) the water sources electrical conductivities are variable, ranging from 2510-12600 μS/cm and pH between 2.25 -1.6, at the time of geophysical survey

Geoelectrical measurements from Tamaduitoarelor- acid springs area, made using ERT acquisition technique (Wenner and Schlumberger arrays) were represented as apparent resistivity section in figure 4

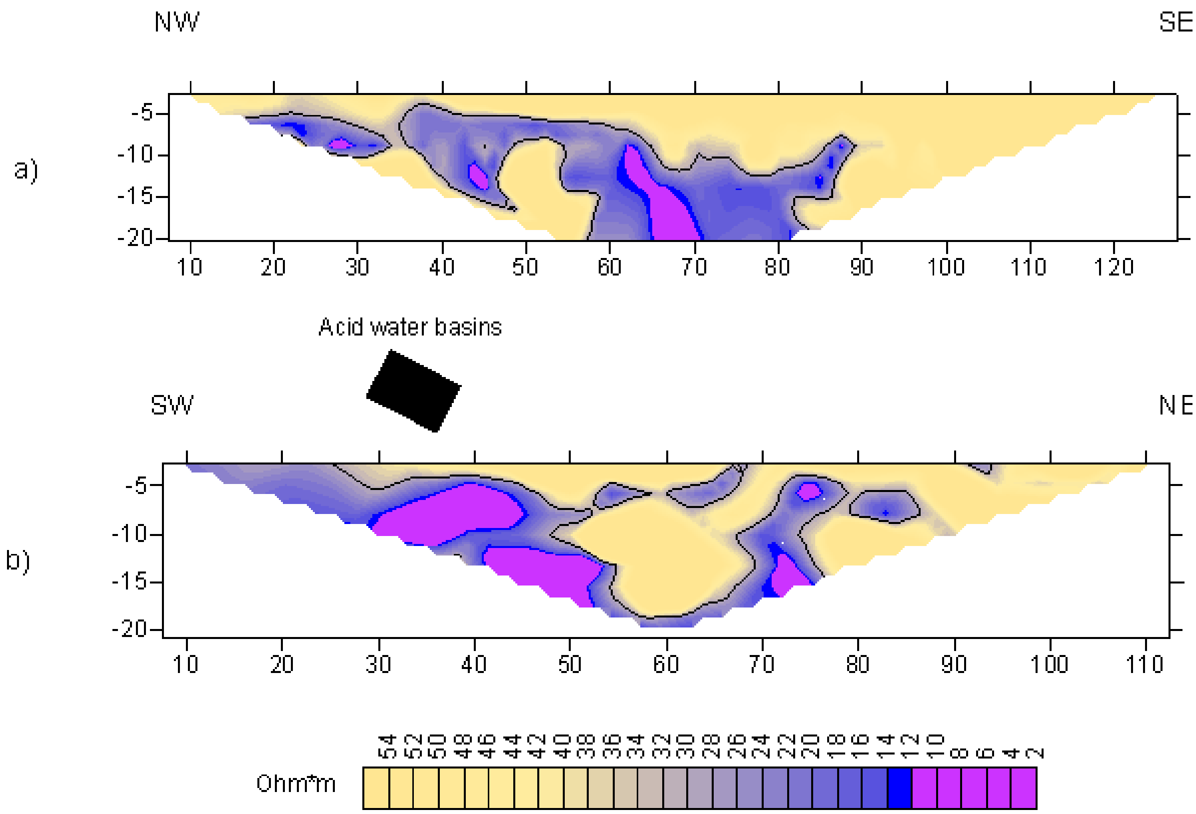


**Figure 4** - Apparent electrical resistivity sections from Tamaduitoarelor area: Profile I (a) and Profile II (b) ERT profile. Relative position of the 4 acid basins are marked

Extremely low resistivity values were observed on the two profiles executed in this area, along the acid baths location (Figure 5). Due to the terrain topography there were no possibilities of making measurements exactly in the location of the water outflows, the Profile I being located at 15m distance for the nr. 1 spring, while the other profile had 4.20 m distance between spring nr. 2 and electrode # 7 (30m on profile II). On Profile I, in the interval between 60-80m it can be noticed the low resistivity anomaly, suggesting that here it is a discharge area of a deeper groundwater source, located beneath 20m depth. On the second profile low resistivity anomalies can be noticed in the first half of the investigated alignment (SW direction). Such results are in good correspondence with the local situation, as can be observed in the nearby of the natural acid water accumulation in basins of ~1m depth.


**Figure 5** – "Tamaduitoare" area and the 4 acid water basins used by local and tourists to treat health problems. Despite the close location of this natural water accumulation basins (maximum 2m distance between them), the water color, pH, electrical properties and chemical parameters are variable. Depth of basin is of maximum 1.10 m

The Eda Omni IV field magnetometer used for area assessment was equipped with two sensors approximately 1m apart on the vertical (gradiometer system), which allowed also the calculation of a vertical gradient. This reduces the effect of deeply situated structures and allows the investigator to create maps with a better resolution of shallow magnetic bodies.

The detailed magnetic surveys carried out in the Ciomadul – St. Ana area produced new geophysical maps of total magnetic field and magnetic vertical gradient.

The Tamaduitoarea spring area is situated on steep forested slope, displaying reduced anthropogenic magnetic noise (signed posts, fences, spa treatment zone). In this area the grid consisted of 104 measurement points deployed in eight W-E oriented profiles reaching a maximum length of 65 meters. The distance between measurement points and the distance between the profiles was 5 meters (square grid).

**Table 2** - Magnetic susceptibility of magmatic and sedimentary rocks in surveyed areas

| Rock | Alteration | Mean magnetic susceptibility ($10^{-6}$SI) | Range of magnetic susceptibility values ($10^{-6}$ SI) |
|---|---|---|---|
| Dacite (Andesite?) | Medium feldspars kaolinization | 0.881 | 0.691 – 1.069 |
| Dacite | Low feldspar kaolinization | 0.425 | 0.202 – 0.590 |
| Dacite | Medium feldspars kaolinization | 0.362 | 0.271 – 0.537 |
| Dacite | High feldspars kaolinization | 0.128 | 0.092 – 0.177 |
| Dacite | High feldspars kaolinization | 0.047 | 0.018 – 0.089 |
| Sandstone | | -0.083 | -0.045 - -0.121 |

Magnetic susceptibility measurements have been carried out on rocks sampled from the surveyed areas (Tamaduitoarea spring and Apor) using a SM-20 instrument. The data presented in Table 2 illustrate as main magnetic susceptibility contrast that observed between the magmatic and the sedimentary rocks.

Contrasts of smaller amplitude are between the highly altered magmatic rocks with the less altered ones, and between the highly altered magmatic rocks and the sedimentary ones (diamagnetic micaceous sandstone).

The magnetic anomalies shown in Figure 6 are interpreted as magmatic (dacitic) bodies affected by hydrothermal alterations of high to medium intensity (high magnetic anomalies), and NW-SE and NE-SW fracture systems determining high hydrothermal alterations of the tectonized rocks (low magnetic elongated anomalies).

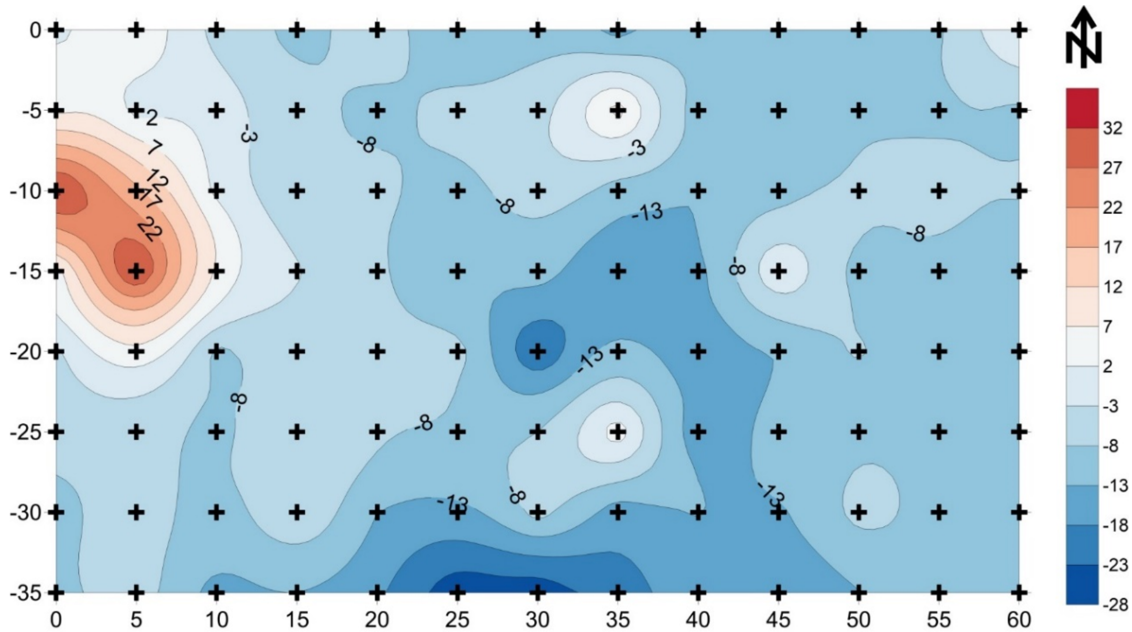

**Figure 6** - Total field magnetic map in the Tamaduitoarea spring area

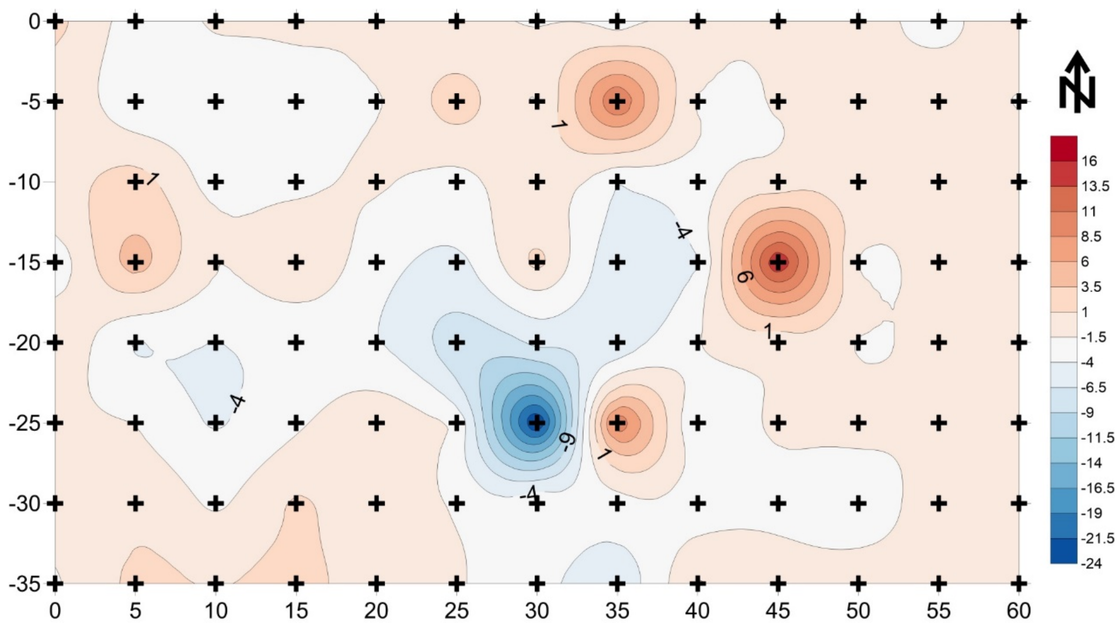

**Figure 7:** Vertical gradient magnetic map in the Tamaduitoarea spring area

The magnetic vertical gradient data in the Tamaduitoarea spring area (Figure 7), enhancing effects of shallow structures, suggests that the emergences of mineral groundwater and $CO_2$ are here mostly associated with a W-E trending low magnetic anomaly. This aspect, together with field observations carried out in the neighboring Apor area, lead to the interpretation of another fracture system (W-E) that controls the mineral groundwater upwelling as local emergences, as well as the high variability of their chemical characteristics on very small distances.

The geological and petrophysical observations determined the main lithological components, their degree of hydrothermal alteration and characteristic values of magnetic susceptibility.

The interpretation of magnetic, petromagnetic and geologic data in the Apor – Tamaduitoarea spring areas shown the location of the dacitic-andesitic structure, its contacts with the sedimentary formations and NW-SE and NE-SW trending fracture systems.

The magnetic vertical gradient data lead to the interpretation of a W-E fracture system that controls the upwelling in local emergences of mineral groundwater, explaining this way the high variability of the chemical characteristics on very small distances.

## Physico-chemical parameters of the water samples

- **Aim:** multiple application for local communities and scientific research like: classification of water types based on main ions (Figure 8), assessing water type usage, sustaining geophysical data interpretation.
- **Methods:** measured by using WTW Multi portable multiparameter systems for: pH, Temperature, electrical conductivity, salinity, total dissolved solids determination

  - portable turbidity meter WTW Turb 430IR

  - laboratory determination (spectrophotometry)

Water samples for the anions analysis ($F^-$, $Cl^-$, $Br^-$, $NO_2^-$, $NO_3^-$, $PO_4^3$, and $SO_4^{2-}$) have been collected in HDPE bottles. Each individual sample was filtered by using a 0.45 μm pore filter.

In the first stage, water chemical composition (main ions) was studied for **22 sources** using SEG Foundation funds. Results were shown to potential donors and helped us to gain support for more sources investigation (another 24 sources) and for more advanced chemical measurements (including microelements) for 35 sources. Results were represented using piper diagram (Figure 8)

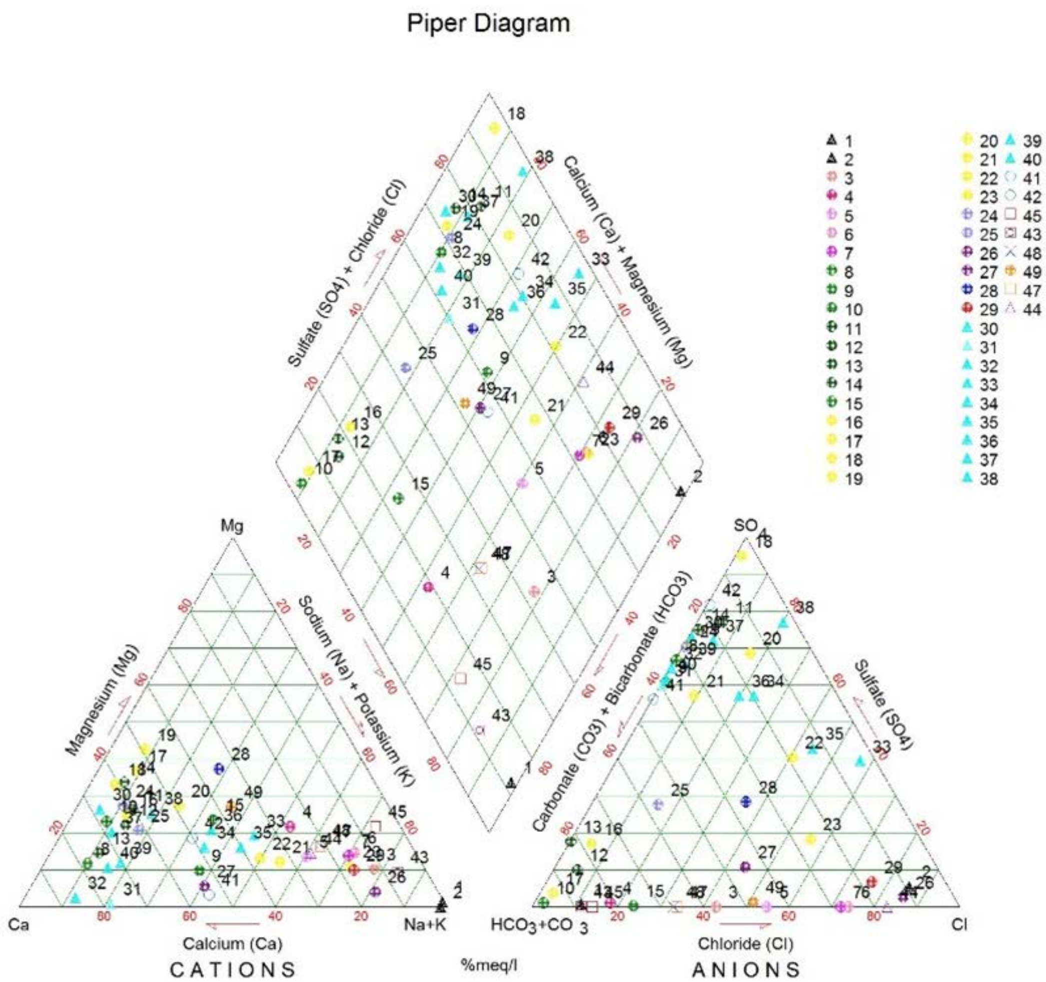


**Figure 8** – Summary of the main ion analysis (44 sources)

Cluster analysis was applied based on 11 physico-chemical parameters (pH, TDS, EC, turbidity, salinity, temperature, redox potential, dissolved oxygen, fluorine, chlorides, sulphates). In the obtained dendogram, 46 sources form the Balvanyos-Tusnad area were grouped into 14 statistically significant clusters. For cluster analysis Ward`s method (linkage calculation) with Euclidean distances was applied (Dlink/Dmax)×100<20; Figure 9).

The cluster analysis has revealed the sampling points depending on their origin, water type, geographical position between others sampling sites, and the presence of discontinuities, such as fractures or faults. The sampling sites which have the same characteristics were placed into the same cluster.

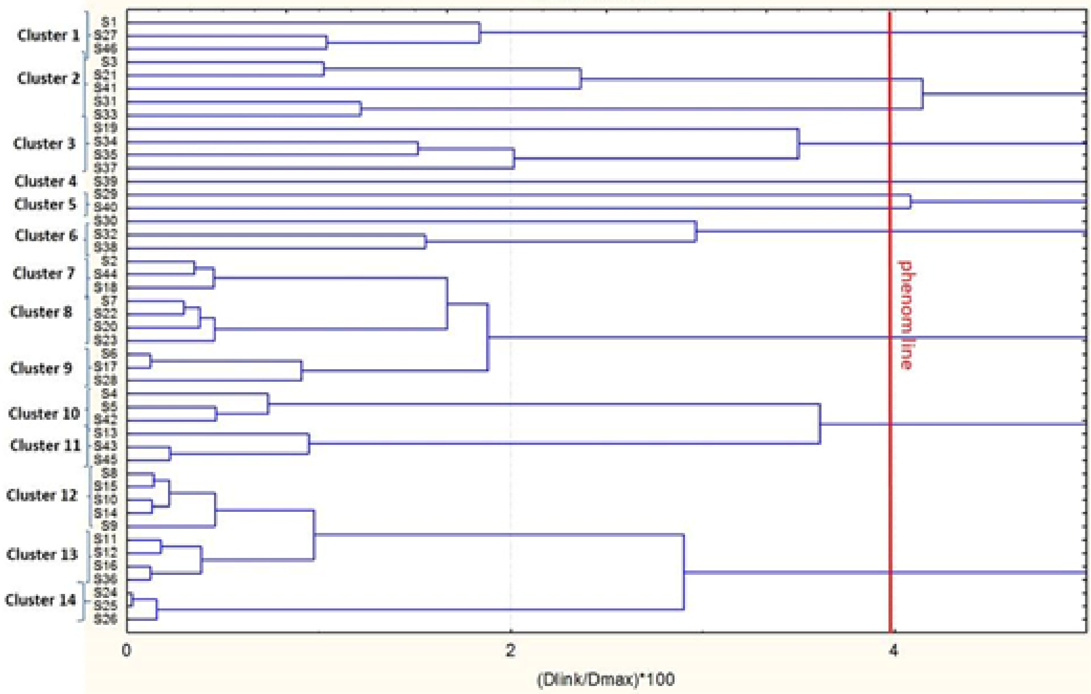


**Figure 9** - Dendogram showing clustering of the analyzed parameters in water samples (Ward's method, Euclidean distances)

From the multitude of groundwater discharges existing in the Tusnad-Balvanyos area, we selected a group of 20 outlets for which **it was devised a monthly monitoring program conducted by students** (starting from May 2015)**.** Time and space variations of the investigated outlets' properties allowed to outline lineaments of outflows with similar pH values, as well as clusters of outflows extremely diversified in terms of pH and electrical conductivity (Figure 10 & 11).

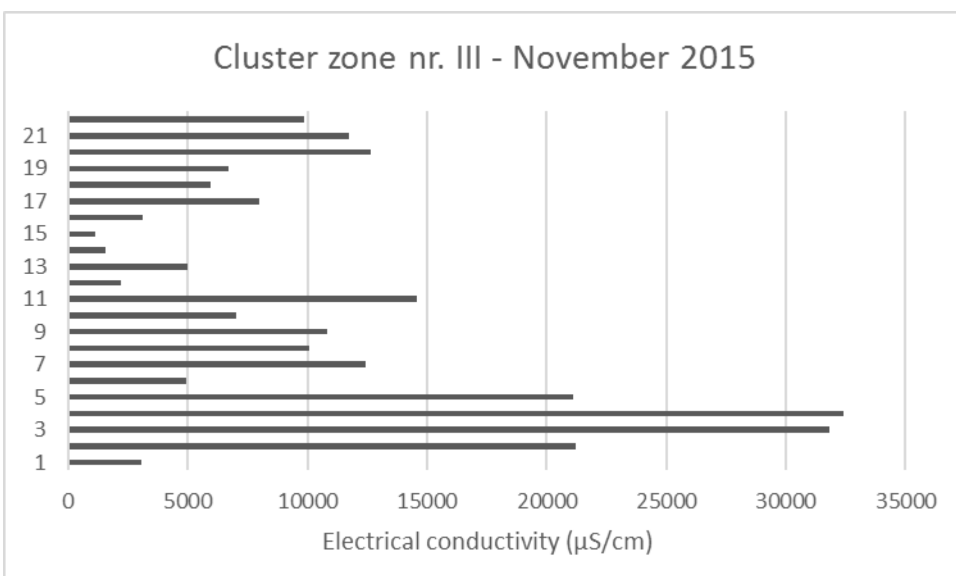


**Figure 10** – Variability of groundwater electrical properties of Cluster zone nr. III (22 sources)

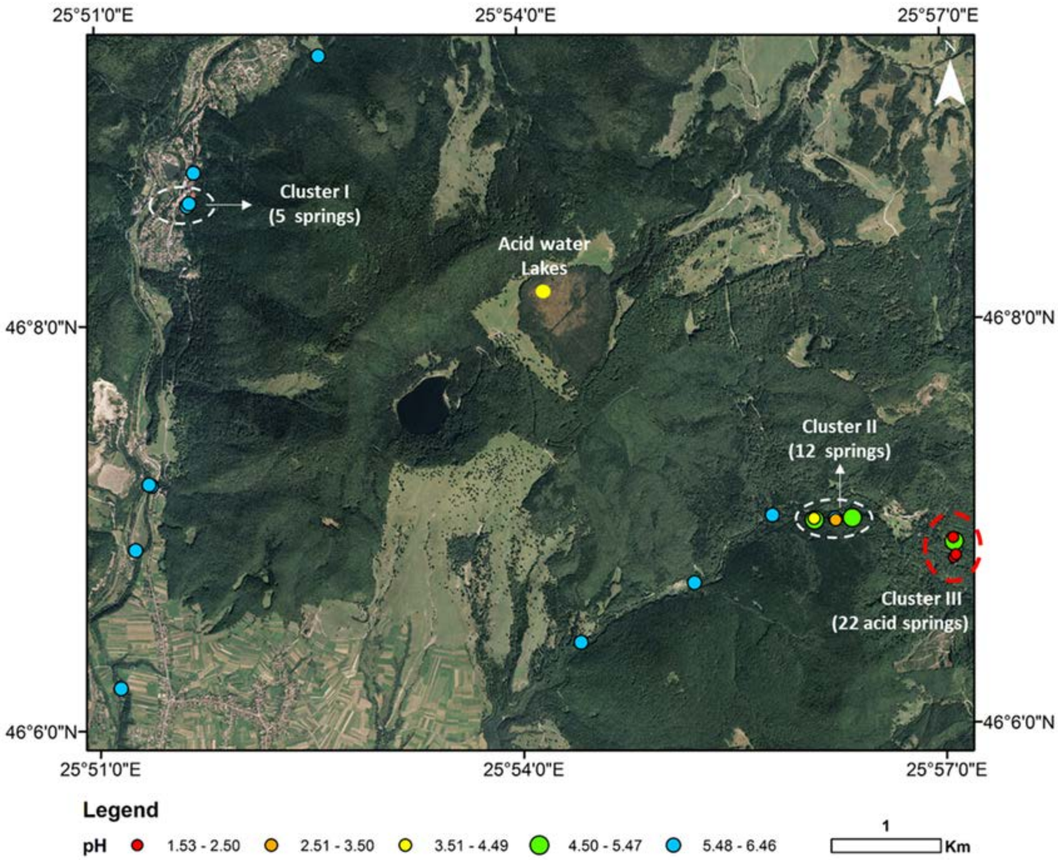


**Figure 11**-. Monitored springs from the Field Camp area – pH distribution

By considering the pH, we classified the springs as very acid (1.5-5pH) and moderately acid (>5pH). Slight higher pH values were noticed for the St. Ana Lake, hosted in the former volcanic crater. No alkaline water outflow was identified in this area.

A series of tepid (15-23°C) springs located at Tuşnad-Băi, on the Ciomadul volcano NW flank and an previously unreported (in the specific literature) gas pool ("mofette") Vallato (13.9$^0$C water temperature), which is situated on the SE slopes of the volcano were used for detailed analyses and to exemplify to students the type of information's "hidden" in water samples originating from deep sources.

It is customary to assume that sodium-chloride groundwater discharges derive either from fossil marine fluids (possibly associated also with hydrocarbon accumulations), or ensuing to the leaching of NaCl (halite) deposits. Waters complying with one of those two distinct situations can be identified, by plotting the corresponding Na concentration values versus the values of the Cl concentration. Using the results from the chemical analyses it was revealed that chloride water samples of the Ciomadul volcano do not match either the halite dissolution line, or the line corresponding to the modern-seawater dilution (Figure 10). In such a situation it was assumed that the saline parent water composition essentially resulted from water-rock interaction having occurred at depth. In this respect, one can invoke a magma-related process, like the one stipulated, for instance, by Giggenbach (1988): HCl released (together with other gases – CO2, SO2, H2S, HF, H2O vapors) by a cooling magma body, can react with the host rock, finally resulting a near-neutral pH, chloride groundwater, a type which is characteristic to high-temperature, magma-related geothermal systems worldwide.

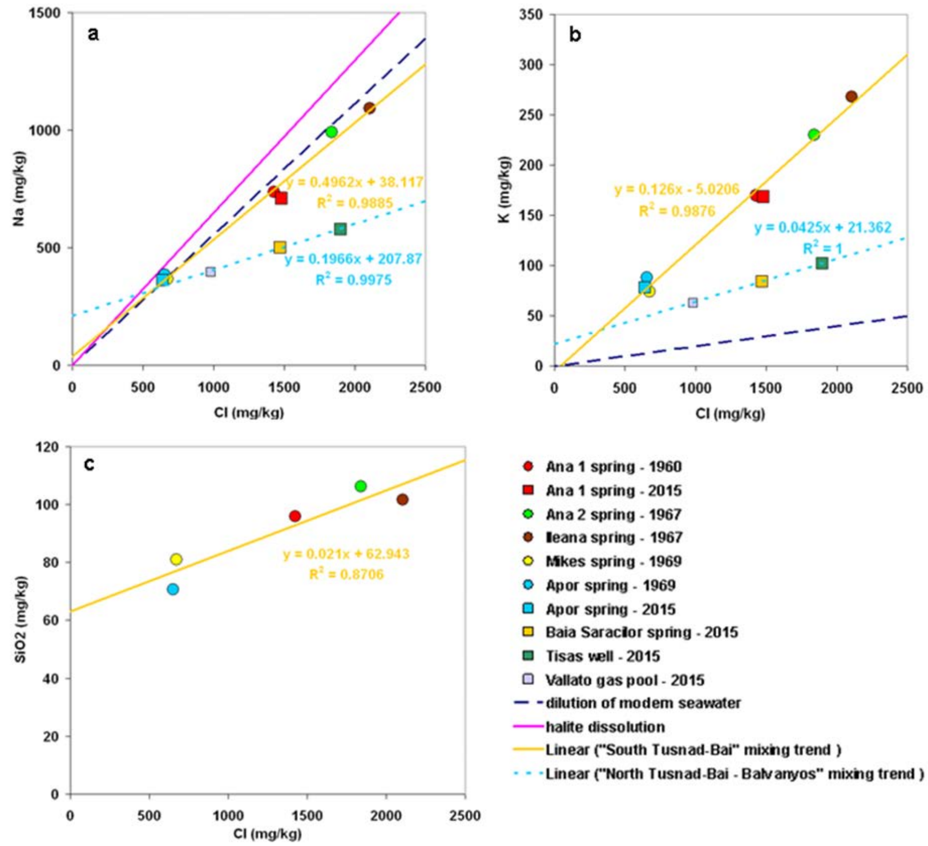


**Figure 12:** Plot of Na vs. Cl (a), K vs. Cl (b), and $SiO_2$ vs. Cl (c) concentrations for the considered groundwater discharges

The new data obtained during the Field Camp campaign were compared with old data (published in 1960) form this area. The good linear regressions obtained for certain samples collected over a large time-interval (spanning between the years 1960 and 2015) indicate that the contents of the involved chemical species (in this case Cl, Na, and K) remained fairly constant, both in the saline, and in the fresh end-members associated to the "South Tuşnad-Băi" group.

Chemical geothermometry is an interpretation method which takes advantage of the fact that an aqueous solution is expected to reach, at the temperature of a deep reservoir, chemical equilibrium with its host rock. The fluid will subsequently ascend toward ground surface outlets - becoming thus cooler; yet in spite of that, the concentration of certain dissolved species (or the ratio between the concentrations of two solutes), will undergo - during this upflow - virtually no changes (actually, only a slow chemical re-equilibration will occur).

Solute versus Cl mixing lines constructed for chloride groundwaters discharging from Ciomadul volcano (Romania) outlined the existence of two distinct, deep-origin saline parent-fluids. Chemical geothermometry additionally indicated that both saline end-members derived from hot, yet distinct reservoirs (Figure 12).

Groundwater reservoirs with temperatures in excess of 270$^0$C, and possibly reaching up to ~310$^0$C - as suggested by the chemical geothermometry assessments performed for chloride fluids discharged from Ciomadul volcano – require that a strong heat-source was located at depth. It hence appears that molten domains could still be present (as hypothesized, for instance, by Harangi et al., 2015) within the magma body existing beneath Ciomadul.

### $CH_4$ and $CO_2$ flux measurements

- **Aim:** assessing the geological emission to the atmosphere of $CH_4$ and $CO_2$ from the Ciomadu volcanic area
- **Methods:** closed chamber method, with accumulation chamber and funnel**,** using the WestSystem fluxmeter.

### $CH_4$ concentration in water

- **Aim:** assessing the concentration of $CH_4$ in the water, in order to verify if springs can be considered gas-bearing based on the amount of gas.

The studied area of Ciomadu Mt. is known to be characterized by high $CO_2$ emissions which appear as "dry" manifestations (mofettes) or wet mofettes (bubbling springs or pools). In order to bring new data about the gaseous emissions in this area, we performed the first assessment of the methane flux, dissolved methane content and stable carbon isotopic ratio of methane assessment.

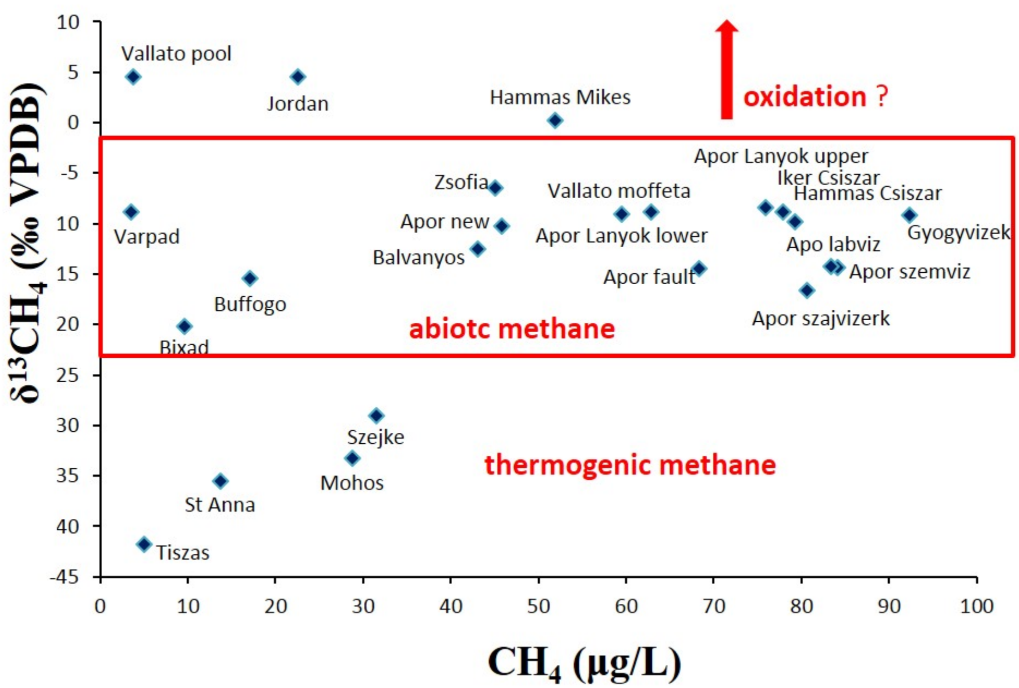


**Figure 13** - Stable carbon isotopic ratio of $CH_4$ vs. dissolved $CH_4$ content of the investigated springs

A total of **46 water sources** were investigated (including 29 mofettes, 3 drilled wells, 11 springs and 3 lakes). It resulted that total methane output of this area is in the order of $10^2$-$10^3$ kg/year, comparable to other volcanic systems in Europe.

The dissolved methane concentrations vary between 0.03 and 92.28 μg/L. The springs with the highest methane content have $\delta^{13}C$-$CH_4$ values between -15 and -5‰, which suggest a dominant abiotic origin (Figure 13). In geothermal systems abiotic $CH_4$ is generally attributable to Fischer-Tropsch Type reactions or high temperature water-rock interactions (e.g. Etiope and Sherwood Lollar, 2011; Tassi et al., 2012); pure magmatic $CH_4$ may be present but not quantifiable in the present data. Other springs seem to host dominantly thermogenic methane, likely from thermal cracking of organic matter in sediments involved in the volcanic plumbing system.

## Radon from spring water, soil and air

**Aim**: identifying sources of natural radiation in geological settings from different environmental samples

- $^{222}$Rn activity in the water is performed with the scintillation method, using the LUK-VR system with Lucas cell (Figure 14)
- $^{222}$Rn activity measurement is based on the sampling of soil gas and measuring the radon activity concentration of the samples, using a LUK3A radon detector
- $^{222}$Rn activity in the air was measured with the Radim 2P detector

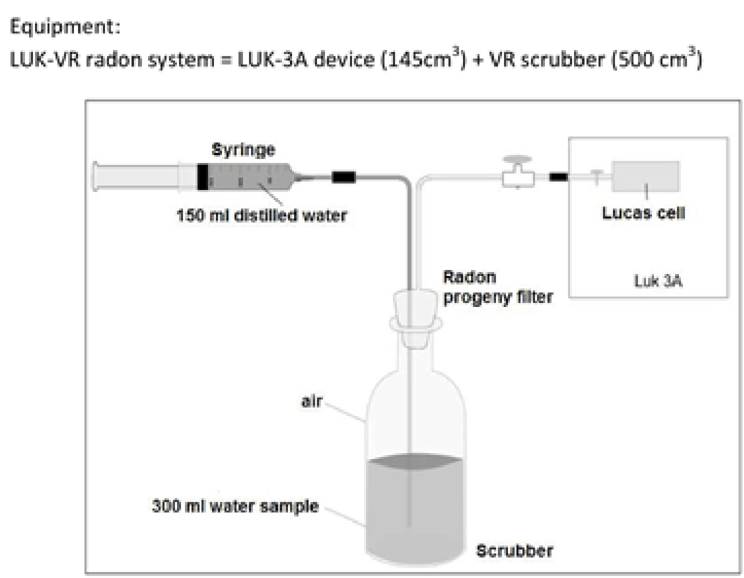


**Figure 14** - Sketch of the LUK-VR radon detector used for Rn assessment from water samples used for exercises during Field Camp

Radon ($^{222}Rn$) is a naturally occurring radioactive gas continuously generated by rocks and soils, with great mobility, formed from the decay of 226Ra (a member of the 238U decay chain). The radon gas in soil is used as indicator for different applications like uranium exploration and location of subsurface faults. This latter application was experienced for the first time by the students, participants of the SEG/TGS FIELD CAMP. The radon concentration in soil was also determined in 25 locations with LUK 3A device.

Near St. Ana Lake the maximum value of $^{222}Rn$ was found in soil (65.03 kBq/m$^3$), while the lowest value 9.8 kBq/m$^3$ was found near Bukos spring (Figure 15). The arithmetic mean of radon concentration in soil obtained in for the study area is of 32.63 kBq m$^3$.

The water outflows from the field camp location originate from different aquifers, situated at different depths below the surface. Thus, they represent a wide variety of mineral and radionuclide content, and sometimes extremely high values can also be observed. The daily consumption of mineral waters with high $^{226}Ra$ and $^{222}Rn$ content may have a significant contribution to the internal natural radiation exposure of the population. The radon concentrations in water varied between 1.8 kBq/m$^3$ and 27.2 kBq/m$^3$.

The maximum value was found in spring Vasas (27.2 kBq/m$^3$) and the minimum value was found in spring Vallato (1.8 kBq/m$^3$). The arithmetic mean of radon concentration in water obtained in this area is 13.59 kBq m$^3$, while the arithmetic mean of radon concentration in soil obtained in this area is 32,63 kBq m$^3$.

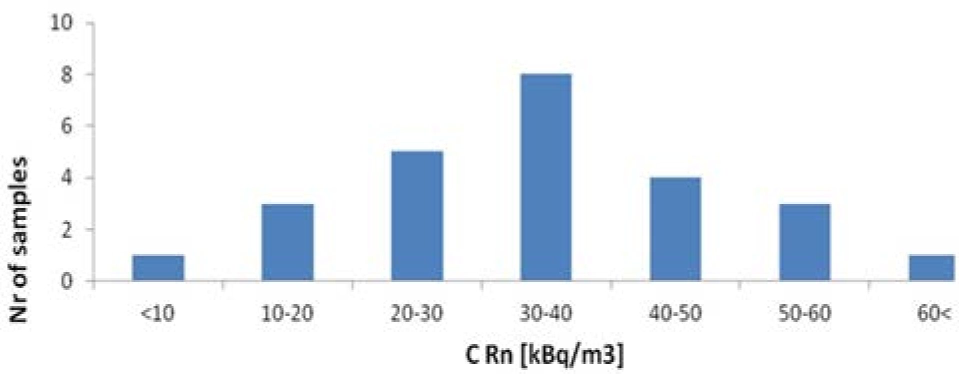


**Figure 15** - The distribution of radon concentration in soil in Ciomadu post-volcanic area

**This is just a glimpse of what we've done. More to come…….**

- New data to come: stable isotopic ratio of He (3He/4He), main ions and microelements from different mud volcanoes from Romania and their electrical parameters time variation, time-lapse variation of basic parameter of water outflows included in monitored program (conducted by awarded students).

- Create the motivation and involvement of students for field activities - The groundwater physical parameters monitoring program – conducted by students - it is scheduled to continue for at least one year.

- New data processing during classes: geophysical 2D models with topography data integration, geophysical 3D model for mud volcano area and results interpretation.

- Buildup of geochemical maps for general use (last one published using data from several sources of the Field Camp area is dating from 1960. We've extended the perimeter and types of parameters analyzed)

- Advanced training on chemical analyses of water samples for students who applied for thesis in the ESG project related subjects.

- Advanced training for on Electrical Resistivity Method for groundwater resources evaluation and testing the limits of the technology.

- Scientific papers with student's participation: 8 presented by students in 2015, 4 more are in working stages for 2016 student's conferences. List of presented papers will be upgraded continuous on the project website: www.geosol.ro/results

## References

Figures and text included in the present summary are part of ESG Project – SEG/FIELD CAMP 2015 results and partially can be found in papers presented in the ESG Session – GEO 2015 Symposium or SGEM Conference as follow:

**F. Chitea, A. Barla, A. Olariu – GIS DATABASE OF MINERAL SPRINGS FROM TUSNAD – BALVANYOS AREA, GEO 2015 Symposium – ESG Session, Bucharest**

**A. Olariu, F. C hitea – SHORT TIME MONITORING OF TUSNAD-BALVANYOS REPRESENTATIVE MINERAL SPRINGS, GEO 2015 Symposium – ESG Session, Bucharest**

**A. Ionescu, B.M. Kis, C. Baciu, A.I. Cozma, A. Sciarra, M. Moldovan, G. Etiope – FIRST ASSESSEMENT OF THE FLUX AND ORIGIN OF METHANE AT THE CIOMADU POST-VOLCANIC AREA (ROMANIA), GEO 2015 Symposium – ESG Session, Bucharest**

**A.I. Cozma, N.B. Brisan, A. Ionescu, C. Baciu, M. Moldovan – CONSIDERATIONS ON THE ORIGIN OF MINERAL WATERS IN CIOMADUL AREA (EASTERN CARPATHIANS) BASED ON CHEMICAL AND CHEMOMETRIC DATA, GEO 2015 Symposium – ESG Session, Bucharest**

**H. Mitrofan, M. Visan, F. Chitea - CHLORIDE GROUNDWATER DISCHARGES OUT OF CIOMADUL VOLCANO (ROMANIA): POSSIBLE EVIDENCE FOR SEVERAL DISTINCT DEEP-RESERVOIRS SATURATED WITH HIGH-TEMPERATURE FLUIDS, GEO 2015 Symposium – ESG Session, Bucharest**

**A. Enacheoaie, A. Olariu – GEOELECTRICAL STUDIES IN THE AREA OF BALVANYOS SPA, GEO 2015 Symposium – ESG Session, Bucharest**

**G.I. Ivan, I. Caragea, A. Gastescu, D. Ioane – DETAILED MAGNETIC SURVEYS FOR MINERAL GROUNDWATER IN AN ACTIVE POSTVOLCANIC ENVIRONMENT: ST. ANA – BALVANYOS AREA, ROMANIA, GEO 2015 Symposium – ESG Session, Bucharest**

**M. Moldovan, N.B. Brisan, A. Cozma, A. Ionescu, T. Sferle – RADON MEASUREMENTS IN SOIL AND MINERAL WATERS FROM BALVANYOS, TUSNAD AND HOMOROD AREAS, GEO 2015 Symposium – ESG Session, Bucharest**

**Chitea F., Ioane D., Serban A., 2015. ELECTRICAL PROPERTIES OF GROUNDWATER RESOURCES AND ITS IMPORTANCE FOR GEOPHYSICAL PROSPECTION, Proceedings of 15th International Multidisciplinary Scientific GeoConferences SGEM 2105, Vol 3, pp 823-830.**

Other references mentioned in text:

Etiope, G., Sherwood Lollar, B., 2013. Abiotic methane on Earth. Rev. Geoph., 51, 276-299.

Giggenbach W.F., (1988). Geothermal solute equilibria. Derivation of Na-K-Mg-Ca geoindicators. Geochim. Cosmochim. Acta, 52, 2749–2765.

Harangi S., Lukács R., Schmitt A.K., Dunkl I., Molnár K., Kiss B., Seghedi I., Novothny Á., Molnár M., (2015). Constraints on the timing of Quaternary volcanism and duration of magma residence at Ciomadul volcano, east–central Europe, from combined U–Th/He and U–Th zircon geochronology. J. Volcanol. Geotherm. Res., 301, 66–80.

Tassi, F., Fiebig, J., Vaselli, O., Nocentini, M., 2012. Origins of methane discharging from volcanic-hydrothermal, geothermal and cold emissions in Italy. Chem. Geol., 310–311, 36–48.

More on the results can be found here: www.geosol.ro/results


Thank you!