Diffuse Degassing Measurements as a Geochemical Exploration Tool: A Case Study From The Brady's Geothermal System (Nevada, USA)

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ABSTRACT

Due to subsurface degassing processes of volatiles in magma and/or groundwater, geothermal systems often emit great volumes of various gases (e.g. carbon dioxide, hydrogen sulfide and others) to the atmosphere through deep reaching fault zones. Some of the gas emissions can provide valuable insights into the reservoir characteristics of unexplored geothermal systems (exploration stage), but also into systems, which are under exploitation already (monitoring stage). Areas with high degassing rates can be used as indicator for permeable fault zones, which could act as potential target zones for geothermal production drillings. In this study we present a combination of three different techniques for the assessment of diffuse degassing processes.

Introduction

The method of diffuse degassing measurements has already been used for various purposes worldwide, such as volcanic hazard analysis or volcano monitoring (Hernandez et al., 2001; Fridriksson et al., 2006). Gas emissions can be determined by a number of geochemical exploration methods. Standard sampling techniques exist for gas emanations in hot springs or mud pools, but diffuse degassing measurements are not yet commonly used in geothermal exploration campaigns.

We have selected a study area within the Brady's geothermal system (Nevada, USA), which is already in use for electricity generation by a geothermal power plant and direct use by a vegetable dehydration plant. The Brady's geothermal field is located within the Basin-and-Range-province, an area characterized by E-W to WNW-ESE extensional motion of the lithospheric crust, which results in N to NNE striking fault zones. Amongst others the study area has already been assessed by detailed geological surface mapping (Faulds & Garside, 2003), geophysical surface exploration (e.g. 2D seismic reflection surveys) and 3D structural geological modeling (Jolie et al., unpublished data). In addition to that soil gas samples have been collected from the Brady's geothermal system by Lechler & Coolbaugh (2007). Analysis was carried out in the laboratory by gas chromatography (GC), inductively-coupled plasma-mass spectrometer (ICP-MS) and ion chromatography (IC). In our study we have used a set of three different geochemical in-situ exploration techniques – the accumulation chamber method, alpha spectroscopy and gamma spectroscopy. The results of the diffuse degassing survey will be compared with the pattern of fault zones shown in the 3D structural

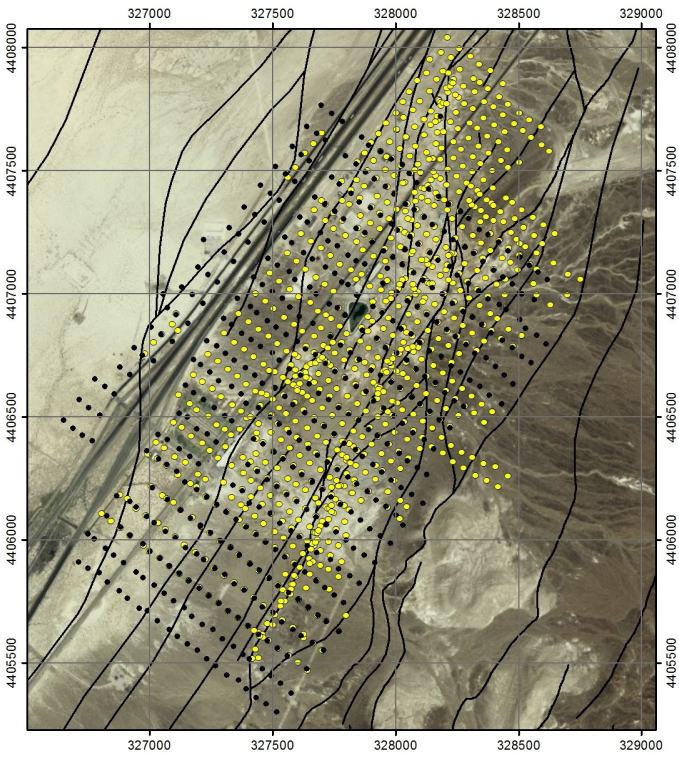

Figure 1. Detail of study area with fault traces (black lines), Rn measurement sites (black points), CO_2 and H_2S measurement sites (yellow points).

geological model. Gas measurements could provide a tool for the identification of highly permeable zones in the reservoir. In combination with 3D structural geological models those information could be used for the planning of drilling operations.

Field Mapping

The study area has a size of approximately 5.4x3.4 km and is located within the area of the 3D structural geological model (Jolie et al., 2012). Gas measurements have been carried out along NW-SE profiles (Fig. 1), perpendicular to the major strike direction of the main fault zones at Brady's geothermal field.

Spacing between cross sections varies from 50-100 m and along cross sections from 40-50 m. Gamma radiation has been measured at ~14,000 sites, alpha radiation at ~500 sites and CO_2 and H_2S flux at ~930 sites. The three week survey was carried out in March and April 2012.

Methods

Carbon Dioxide and Hydrogen Sulfide Flux

Various techniques can be applied for the determination of ground CO_2 fluxes. Most common is the accumulation chamber method and the dynamic concentration method. All measurements of diffuse CO_2 and H_2S emission rates in the study area were performed according to the accumulation chamber method (Parkinson, 1981).

The used instrument is a portable diffuse flux meter from West Systems (Fig. 2). The device is equipped with a LI-COR LI-820 single path, dual wavelength, non-dispersive IR (NDIR) carbon dioxide analyzer (West Systems, 2002). Hydrogen sulfide flux was determined with a Draeger Polytron II electrochemical detector, based on the chemical cell reaction $H_2S + 2\ O_2 \rightarrow H_2SO_4$.

The apparatus is composed of a gas accumulation chamber connected with the IR gas analyzer. The LI-820 analyzer again is connected via a bipolar analog-to-digital converter (ADC) to the controlling unit (PDA). For the measurement the accumulation chamber type A has been chosen, since it is more sensitive in comparison to the accumulation chamber type B. It covers an area of 0.0314 m^2 and has an internal volume of $3.01x10^{-3}$ m^3 (West Systems, 2002).

Figure 2. A) The accumulation chamber is connected via two flexible tubes (inlet/outlet) with the gas analyzer. The measurements are controlled by a wireless PDA. B) If required soil temperatures can be determined with a thermocouple.

Determination of Alpha and Gamma Radiation

The activity concentration of the noble gas radon is determined with a radiometric measurement. The resulting short-lived daughter products of the radon decay (alpha radiation) are counted. Directly after the decay of radon, the remaining Po-218 residual is present as positively charged ion, since the emitted He core tears electrons from the atomic shell. Due to the application of an electrostatic field the ions precipitate on the surface of a semiconductor detector. The number of the detected Po-218 ions is equivalent to the radon concentration in the measurement chamber.

Measurements of Rn activity in soil gases was performed with two SARAD RTM 2200 monitors (Fig. 3). Gas from the soil atmosphere at 100 cm depth was pumped up to the sensor in the RTM 2200 monitor.

The RTM 2200 is a universal radon/thoron monitor for portable and stationary applications with a high sensitivity. The alpha spectroscopic analysis has a short response time even at low Rn concentrations. The thoron concentration will be determined simultaneously. The instrument has additional temperature, humidity, barometric pressure, and flow rate sensors. The RTM 2200 consists of a high voltage gauge with an electrostatic collection of ionized Rn daughter nuclides (generated inside the gauge) on the

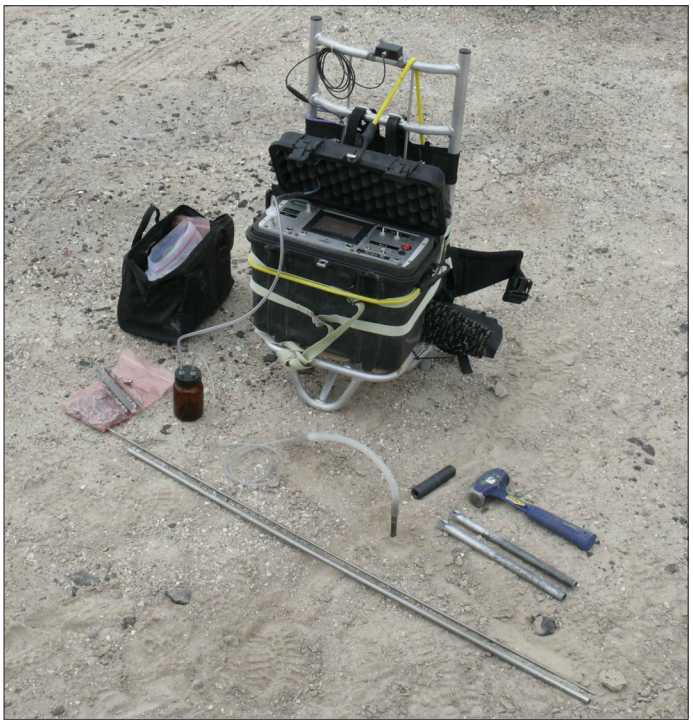

Figure 3. Equipment for determination of Rn concentration consists of the RTM 2200 monitor, a 105 cm long metal probe, tubes and tools for the installation and removal at the sampling site. A glass flask has been interconnected between the metal probe and the RTM 2200 with flexible tubes to avoid entering fluids.

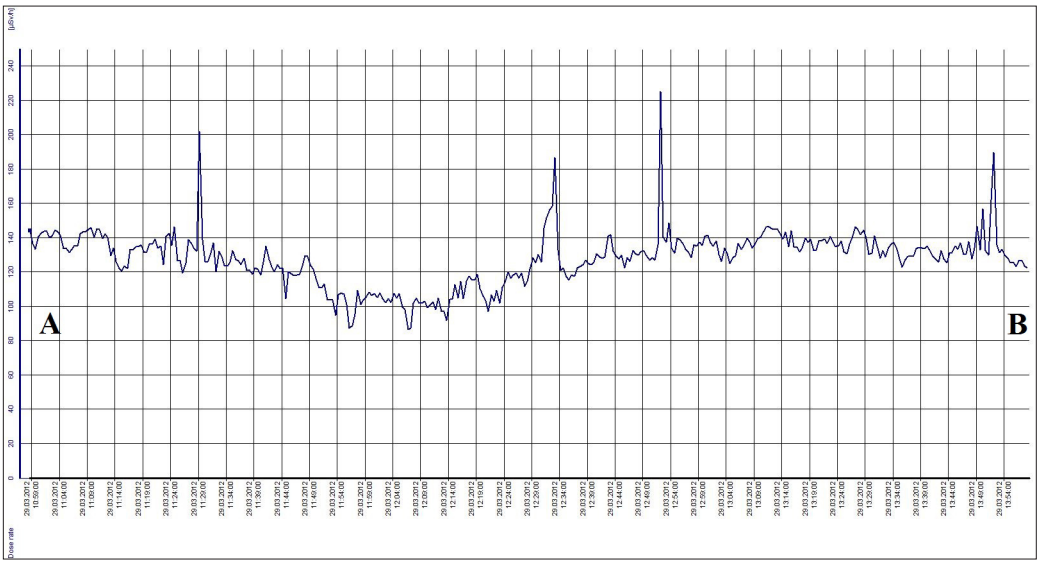

Figure 4. Local dose rate variation along profile A-B (see Fig. 5).

Figure 5. Profile of measured local dose rate from A-B of Fig. 4. At sampling site ID1033 H_2S and CO_2 measurements have been carried out.

surface of a silicon detector. The internal volume is approximately 90 cm^3 and the sensitivity is 1.5/3.2 cpm/(kBq/m) for radon and 1.5 cpm/(kBq/m) for thoron. The range is 0-10 MBq/m.

Gamma radiation was determined with the RTM 2200 by measuring the local dose rate (ODL) along defined profiles perpendicular to the major strike direction. The complete gamma spectrum from 0-2,850 keV has been recorded at each sampling site. We identified and evaluated three characteristic nuclides (Bi-214, Tl-208, K-40) to deduce the local dose rates.

A sodium iodide scintillator (NaJ(TI)) with a coupled photomultiplier (PMT) was used. The entering gamma radiation results in particle-hole stimulations in the NaJ monocrystal. During electron-hole recombination photons are emitted, which induce an electron avalanche in the PMT. The electron avalanche can be detected as voltage signal. Dependent on the wavelength of the gamma quantum different voltage signals can be observed. Each voltage signal is assigned to a defined energy (keV) during the calibration.

The apparatus was mounted on a stable backpack frame. An integrated GPS sensor recorded the track to allocate the spectra to its corresponding coordinate. We applied 30 sec recording cycles, which resulted in a sampling site spacing of 40-50 m along the cross sections.

Results

Preliminary results show a broad distribution of signals from background values up to increased values for CO_2 flux, H_2S flux, alpha radiation and gamma radiation. Strong variations in gas fluxes have been determined in particular along fault zones that are connected to the geothermal reservoir, but also in areas without obvious geothermal surface manifestations (Fig. 4 & 5). Especially in the vicinity of geothermal surface manifestation increased carbon dioxide and hydrogen sulfide fluxes have been measured (Fig. 6 & 7). Further data processing and analysis is intended for a comprehensive understanding of the gas emission at the Brady's geothermal field. We expect to be able to trace fault lineaments at the surface due to variable gas emanations. Results will be compared with the mapped fault pattern in the 3D structural geological model in order to explain the anomalous gas fluxes.

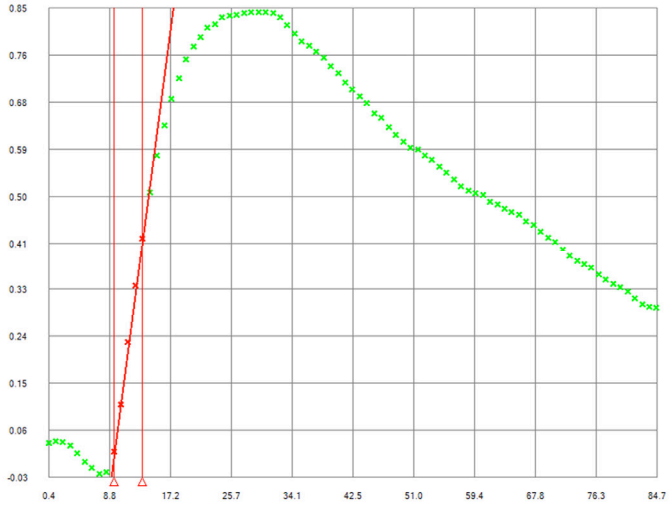

Figure 6. H_2S emission in ppm (y-axis) versus time (x-axis) at sampling site ID1033 (Fig. 5). H_2S flux: 0.102 ppm/sec; ErrQ. 0.998.

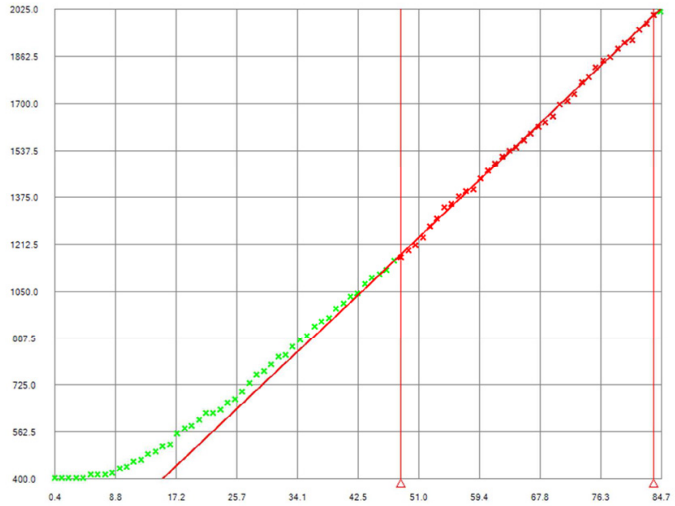

Figure 7. CO_2 emission in ppm (y-axis) versus time (x-axis) at sampling site ID1033 (Fig. 5). CO_2 flux: 23.552 ppm/sec; ErrQ. 0.999. Both CO_2 flux and H_2S flux (Fig. 6) at sampling site ID1033 show increased emission rates.

Outlook

Dependent on the results of the conducted survey it is foreseen to densify the measurement grid in areas with anomalous gas emissions. This will help to better delineate zones of high fluxes. In addition, further gas measurements could be used as another tool for the detection of permeable fault zones.

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