GFZ Helmholtz Centre Potsdam — GEMex

Novelties from fluid geochemistry of the Acoculco Enhanced Geothermal System

Jacopo Cabassi[1*], Barbara Nisi[1], Orlando Vaselli[1,2], Matteo Lelli[3], Francesco Norelli[3], Franco Tassi[1,2], Juan Sánchez-Avila[4], Belinda Sandoval Rangel[4], Eduardo Gonzalez Manzano[4], Thomas Kretzschmar[4], Romel González Hernández[5], Carlos Ramirez Gaytán[5], Ruth Alfaro Cuevas Villanueva[5], Yan Rene Ramos[6], Roberts Gamez Bocanegra[6]

1 CNR-IGG Institute of Geosciences and Earth Resources, Florence, Italy; 2 Department of Earth Sciences, University of Florence, Florence, Italy; 3 CNR-IGG Institute of Geosciences and Earth Resources, Pisa, Italy; 4 Center for Scientific Research and Higher Education, Ensenada, Mexico; 5 University of Michoacán, Morelia, Mexico; 6 University of Guanajuato, Guanajuato, Mexico

1 Introduction

For the task 4.3 – Geochemical characterization and origin of cold and thermal fluids, a field campaign was carried out from the 25th of January to the 5th of February at the Acoculco Enhanced Geothermal System (AEGS), to measure diffuse soil CO_2 fluxes (Fig. 1a) and perform water and gas sampling (Fig. 1b) .

The main purposes were to: 1) identify the spatial distribution of the CO_2 soil fluxes and their correlation with the main fault/fracture systems; 2) geochemically and isotopically characterize the cold and thermal springs and gas emissions (Los Azufres and Alcaparrosa).

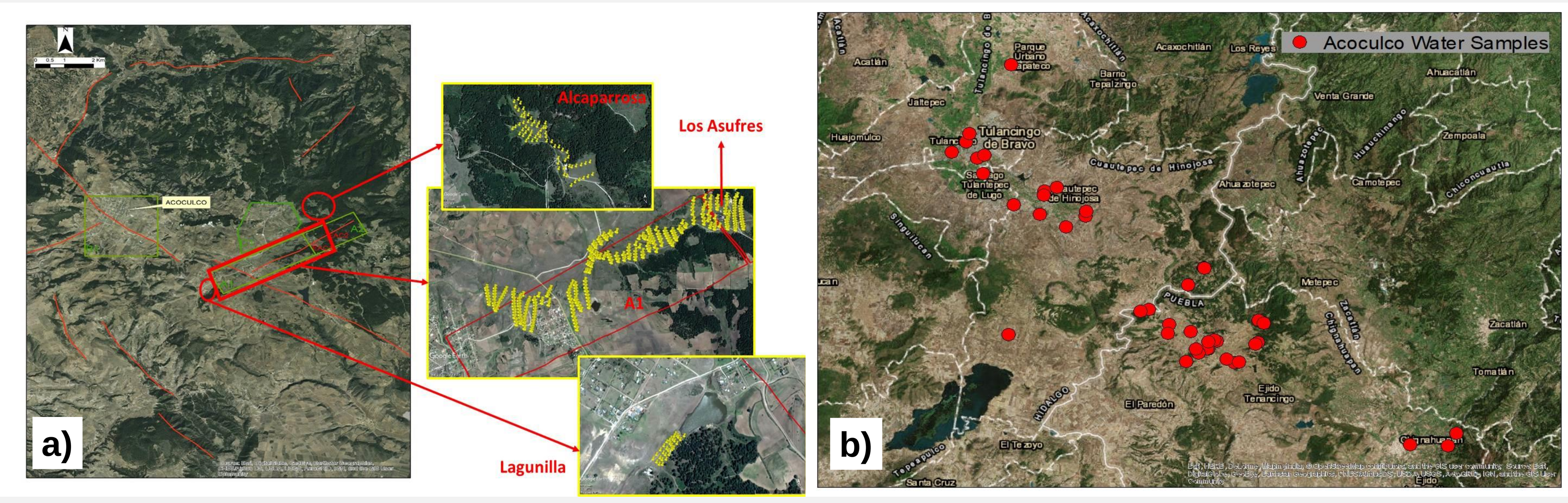

Fig. 1 - Location of the CO_2 soil fluxes measurements (a) and water samples (b)

2 Methods

The ϕCO_2 values were measured at 418 sites within the Acoculco Caldera using the Accumulation Chamber (AC) method (e.g. Chiodini et al., 1996, 1998; Gerlach et al., 2001; Cardellini et al., 2003) using a metal cylindrical vase (the chamber) and an Infra-Red (IR) spectrophotometer (Licor® Li-820) in a closed circuit. Among all the areas affected by tectonic features, that one corresponding to the red polygon A1 (Fig. 1a) was targeted for soil diffuse CO_2 measurements (ϕCO_2) based on a previous geological campaign. In addition, further three areas (Los Azufres, Alcaparrosa and "Lagunilla"), characterized by gas emission and/or evident argillic alteration, were also investigated (Fig. 1a).

Water samples from 45 thermal and cold discharges, located inside and outside the Acoculco Caldera (Fig. 1b), and free gas samples from three bubbling pools (one at Los Azufres and two at Alcaparrosa) were collected inside the study area. In-situ measurements (temperature, electrical conductivity, pH, total alkalinity) of cold and thermal waters from springs and wells were performed by a portable multi-meter probe. The water samples were analysed at the IGG laboratories of Pisa and Florence (Italy) for anions, cations, trace species and water isotopes (δD-H_2O and $\delta^{18}O$-H_2O). Gas samples were analysed in Florence to quantify the gas fraction (CO_2, H_2S, N_2, Ar, O_2 and CH_4) and the carbon isotopes of CO_2 and CH_4.

3 Results and Discussion

The ϕCO_2 resulted to be characterized by low values (between 0.12 and 48.9 g m^{-2} day^{-1}; Fig. 2), implying that most CO_2 flux data were associated with soil respiration, reflecting a low permeability of the geothermal system. Relatively higher values were only recorded close to the CO_2(H_2S)-rich gas emissions of Los Azufres and Alcaparrosa (Fig. 2 a,c). No univocal correlations between CO_2 flux anomalies and fault systems were observed. The low CO_2 flux values were likely due to the presence of: 1) very thick grass cover associated with large swamping areas; 2) water-saturated soils related to the climatic conditions. However, flux measurements performed in dry conditions (Peiffer et al., 2014) showed no significant variations with respect to those of this study.

CO_2 output for the 3 zones:

1. A1 (area 2000*10³ m²): ~27 tons/day
2. Lagunilla (area 11.5*10³ m²): ~0.1 tons/day
3. Alcaparrosa (area 215*10³ m²): ~2.3 tons/day

The 45 studied waters, located inside and outside AEGS, are fed by meteoric waters according to the δD-$\delta^{18}O$ values (similar to those of Los Humeros, suggesting the pivotal role played by the meteoric component at regional scale; Fig. 3), although for a few samples evaporation and slightly positive $\delta^{18}O$-shift (water-rock interaction or isotopic exchanges with CO_2) cannot be excluded. A hydrothermal input within the Acoculco Caldera is testified by: 1) acidic-SO_4-rich waters located at Los Azufres and Alcaparrosa, also characterized by the highest contents of B and NH_4 (Figs. 4,5,6) and 2) $\delta^{13}C$-CO_2 values (from -4.5 to -4.1 ‰ vs. V-PDB) of the free gas samples. The $\delta^{13}C$-CH_4 values (from -40.5 to -33.8 ‰ vs. V-PDB) at Los Azufres and Alcaparrosa seem to be consistent with thermogenic processes. Distal waters (e.g. those from Tulancingo and Chighahuapan) are nearly neutral and Ca(Na)-HCO_3 in composition (Figs. 4,5). Nevertheless, the Ca-HCO_3 thermal waters from Chignahuapan showed some chemical features that may imply a contribution by hydrothermal fluids, as follows: 1) relatively high TDS; 2) relatively high temperature; 3) high NH_4, B and Li (Figs. 4,5,6). The origin of the Na(Ca)-HCO_3 and Ca(Na)-HCO_3 waters (Fig. 5) is likely due to water-rock interaction processes involving Na(Ca)-silicates from the volcanic rocks. Some samples (e.g. from Tulancingo) had Ca and HCO_3 derived by congruent dissolution of limestones, which extensively outcrop around the AEGS. Deep contribution for these waters is regarded as negligible.

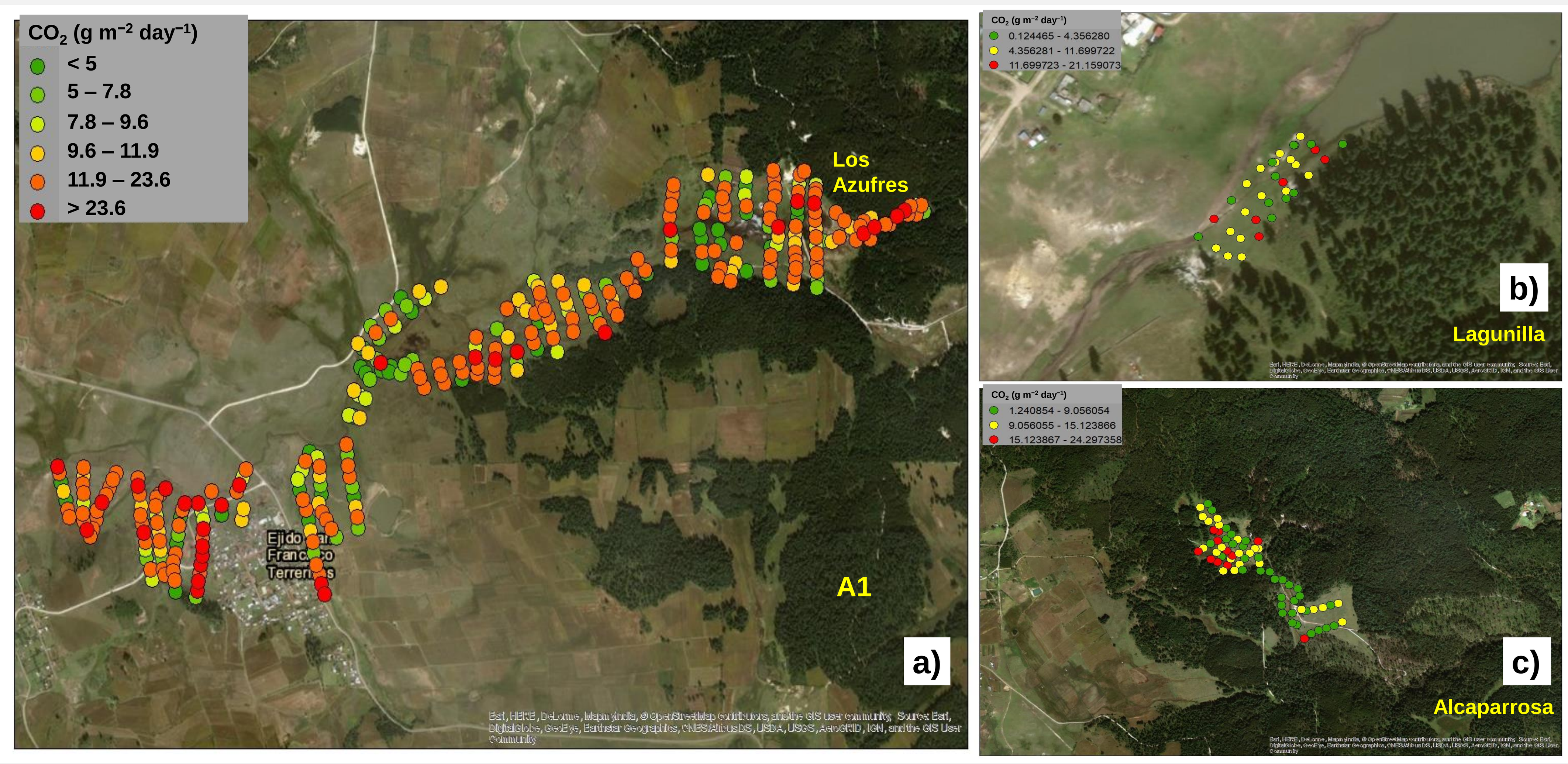

Fig. 2 - Dot-map of the CO_2 flux values for: a) polygon A1 and Los Azufres; b) "Lagunilla" and c) Alcaparrosa

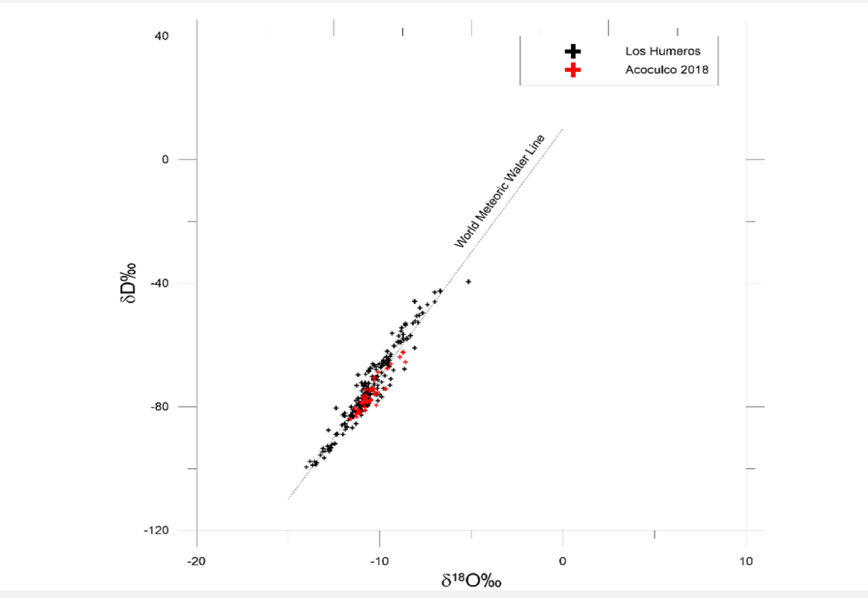

Fig. 3 - Classical correlation diagram $\delta^{18}O$‰ vs. δD‰

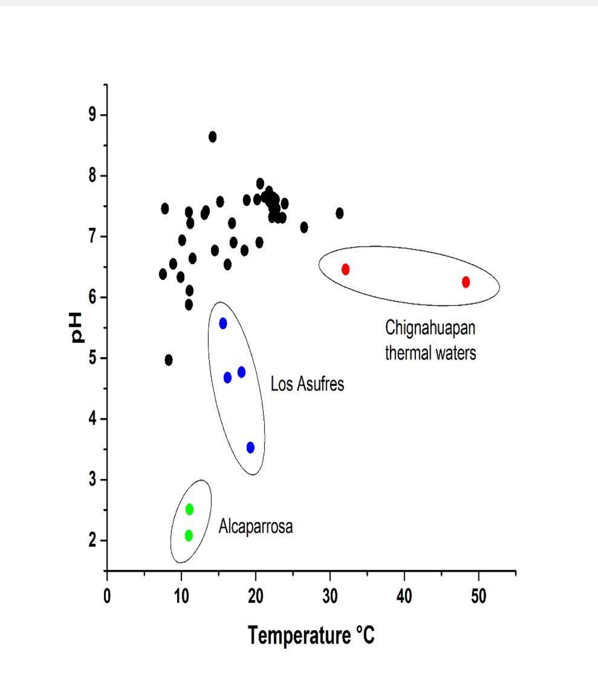

Fig. 4 - Binary plot T vs. pH

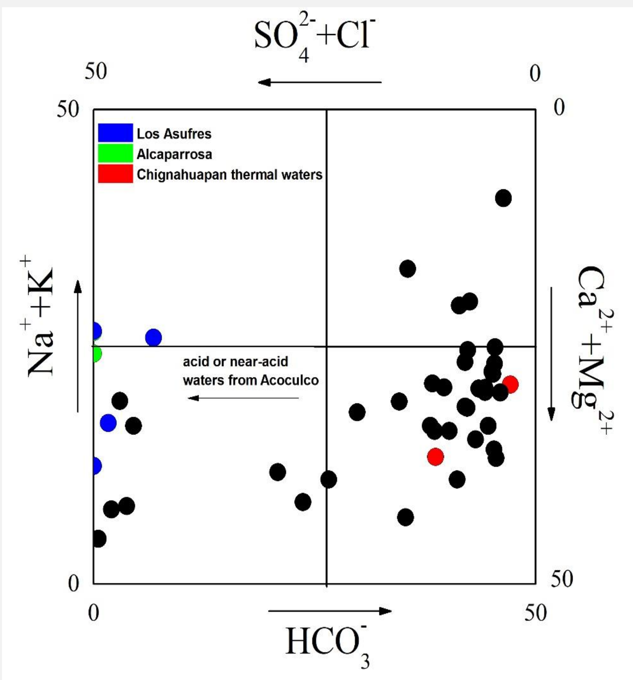

Fig. 5 - Waters square diagram

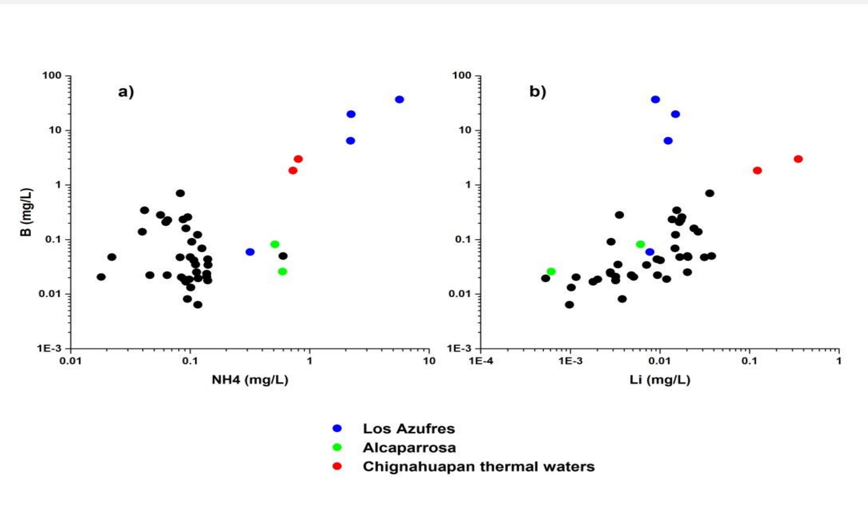

Fig. 6 - NH_4^+–B (a) and Li^+–B (b) diagrams

4 References

- Cardellini, C., Chiodini, G., Frondini, G.: Application of stochastic simulation to CO_2 flux from soil: mapping and quantification of gas release. J. Geophys. Res. 108, 2425, doi:10.1029/2002JB002165, 2003.
- Chiodini, G., Frondini, F., Raco, B.: Diffuse emission of CO_2 from the Fossa crater, Vulcano Island. Bull. Volcanol. 58, 41–50, 1996.
- Chiodini, G., Cioni, R., Guidi, M., Raco, B., Marini, L.: Soil CO_2 flux measurements in volcanic and geothermal areas. Appl. Geochem. 13, 543–552, 1998.
- Gerlach, T.M., Doukas, M.P., McGee, K.A., Klesser, R.: Soil efflux and total emission rates of magmatic CO_2 at the Horseshoe Lake tree kill, Mammoth Mountain California, 1995–1999. Chem. Geol. 177, 85–99, 2001.
- Peiffer, L., Bernard-Romero, R., Mazot, A., Taran, Y.A., Guevara, M., and Santoyo, E.: Fluid geochemistry and soil gas fluxes (CO_2–CH_4–H_2S) at a promissory Hot Dry Rock Geothermal System: The Acoculco caldera, Mexico. J. Volcanol. Geoth. Res., 284, 122–137, 2014.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 727550 and the Mexican Energy Sustainability Fund CONACYT-SENER, project 2015-04-68074

Partners

We acknowledge the Comision Federal de Electricidad (CFE) for kindly providing support and advice and for granting access to their geothermal fields. Data has been kindly provided by CFE.We also acknowledge our Mexican colleagues for their help an collaboration.

Contact us

jacopo.cabassi@igg.cnr.it
CNR-IGG, Via G. La Pira 4, 50121 Florence (Italy)

m.lelli@igg.cnr.it
CNR-IGG, Via G. Moruzzi 1, 56124 Pisa (Italy)

Visit us
www.gemex-h2020.eu