

GEO-NETWORK OF LATINAMERICAN-GERMAN ALUMNI (GOAL)

CONTENT

1. Editorial note
2. Jörg Matschullat's note
3. Causas y efectos de los agrietamientos y hundimientos en la zona urbana de San Luis Potosí, México
4. Devastating wildfires across Sierra Madre Oriental, northeastern México
5. An overview on the geochemistry of arsenic originating from geothermal systems in Latin America
6. Geochemical monitoring of volcanic systems in the Lesser Antilles
7. About (the need of) a Smart Data Management System
8. Una nueva estructura computacional en Geografía que no es tan nueva
9. Encuentro GOAL Brasil y I Encuentro GOAL Virtual 2020
10. GOAL's new members
11. Obituario
12. International Scientific Events

1. Editorial Note

Christina Ifrim, Martin Meschede

christina.Ifrim@jura-museum.de, meschede@uni-greifswald.de

The GOAL network has recently agreed on two new coordinators for the German side, Prof. Dr. Martin Meschede (Universität Greifswald) and PD Dr Christina Ifrim (SNSB Jura-Museum Eichstätt). We both gladly accepted this request. We started this new mission with a challenge: How do you network in pandemic restrictions? We solved it by establishing a series of regular online meetings of the GOAL members and are happy to have met so many colleagues online! After trying different online platforms, there was one found to which even members from countries with restrictions have access and can join us. However, instable network connections sometimes interrupt the discussion by a missing sound transfer. We are thus sure: Online meetings cannot replace personal meetings, and the next round of presentations and workshops is planned actively by Reinaldo from the Latin American side and us. The next physical meeting of GOAL members is scheduled for April 2022 in Greifswald and 2023 in Cuba. In case of ongoing pandemic restrictions, alternative data are already agreed upon.

GEO-NETWORK OF LATINAMERICAN-GERMAN ALUMNI (GOAL)



Christina: I am the Science Director of the Jura-Museum in Eichstätt and like that a scientist of the State Natural Collections of Bavaria SNSB. The most prominent fossil in the collection I curate is the Eichstätt specimen of Archaeopteryx. My main field of research are Cretaceous marine ecosystems and their response to environmental changes, particularly cephalopods and from various platy limestones. I mostly worked in Mexico but my studies cover all of Latin America and many other parts of the world. I am habilitated at the Ludwig-Maximilian-Universität München LMU. In addition, I have a teaching assignment at the Katholische Universität Eichstätt-Ingolstadt.

GEO-NETWORK OF LATINAMERICAN-GERMAN ALUMNI (GOAL)



Martin: I have been working in Latin America mainly during the 90s and 00 years. My last activities with respect to Latin America have been on research vessels in the Caribbean and the Scotia Sea/Southern Atlantic (e.g., expedition PS119 with RV Polarstern in 2019) dealing with the plate tectonic evolution of the two smaller plates located in the North and South of South America. I am currently head of the department of regional and structural geology, Institute of Geography and Geology, University of Greifswald, Germany.

Together we will continue to “knit” the network in order to strengthen transfer of knowledge and technology in geosciences particularly in quickly developing fields like digitalization, strategic metals, environmental sustainability and other 21st century topics. We are very much looking forward to meet you in person and therefore currently put in great efforts to get the funding for it!

GEO-NETWORK OF LATINAMERICAN-GERMAN ALUMNI (GOAL)

2. Prof. Jörg Matschullat's note

Jörg Matschullat, matschul@tu-freiberg.de

Queridas y (e) queridos amigas y (e) amigos da nuestra (nossa) red (rede) GOAL,

Before I continue in a bi-lingual gibberish, let me send you warm greetings from Freiberg. As you all know, the German GOAL bridgehead has two magnificent new heads, Christina Ifrim (paleontologist) and Martin Meschede (structural geologist), who continue and develop our (Klaus and I) engagement with full force. Their choice has been an excellent one and I feel truly relieved for having been able to hand over the running sticks to these great colleagues.

Why do I say so? Well, I do see the GOAL Network – also independent of any DAAD support to be of utter value and relevance to the development of both a) inner Latin American development of the geosciences and b) ongoing and developing expert development between German and Latin American geoscientists at large. To me, it did not need the recent pandemic to understand that we all share this one planet and thus, we share the common fate and opportunity of humankind. We geoscientists often shy away from taking responsibility on the big scale – and leave this ever to often to other fields of expertise that are less inhibited and more daring.

Yet, it is the geosciences in their bandwidth that already have a toolbox, and will definitely further develop that toolbox which helps us coping with the plethora of global challenges. This goes beyond the seventeen Sustainability Developments Goals (SDG's) and encompasses key issues such as biodiversity (yes, you paleontologists, you can truly contribute), climate change in all its aspects, and natural disasters, from inundations, droughts and water availability, via soil losses and landscape instability to earthquake and volcanism. And we will not neglect natural resources in all its bandwidth, the geoscientific base for any attempt to enter into what we call circular economy.

Many if not most of you in our network already have experience and expertise, which is most valuable and yet – often overheard. And some of us have their grip on methods which could help many others to face those challenges. Let us tighten our grip, holding hands and progressing together in order to entice young people to help us with their creativity and impatience, and to jointly contribute to finding better solutions than the ones, we have in stock so far. There is a lot to be done – let us do it!

Abrazos y (e) abraços – vamos para frente

3. Causas y efectos de los agrietamientos y hundimientos en la zona urbana de San Luis Potosí, México.

Rubén Alfonso López Doncel, Instituto de Geología, Universidad Autónoma de San Luis Potosí, México
rlopez@uaslp.mx

Introducción

Un problema actual que está afectando de manera importante la infraestructura de muchas ciudades tanto en México como en otras partes del mundo y que parece tomar cada vez mas importancia, es la presencia de importantes fallas, agrietamientos y hundimientos en las áreas urbanas de las ciudades.

La ciudad de San Luis Potosí, en el centro de México es un ejemplo donde esta ocurriendo este fenómeno. Aquí las fallas, los agrietamientos y hundimientos afectan seriamente tanto a la infraestructura civil, como al patrimonio particular de los habitantes (Fig. 1 y 4), llegando incluso en algunos casos a provocar el desalojo y demolición de algunas viviendas

El origen de este fenómeno ha sido siempre asociado a procesos de subsidencia (Pacheco et al., 2010, Julio-Miranda, 2012), sin embargo, estudios recientes parecen sugerir que hay otros factores adicionales que aceleran y agravan este fenómeno.

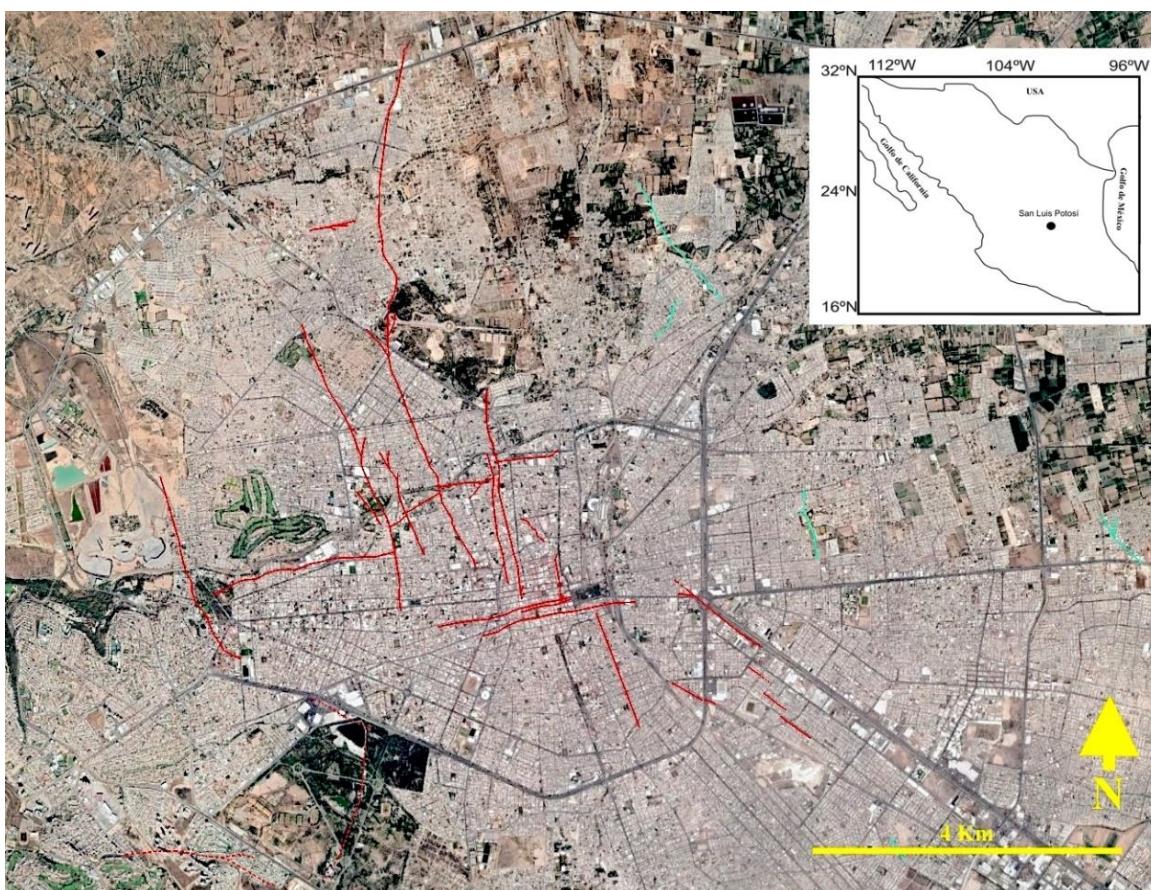


Figura 1. Localización de los agrietamientos en la zona urbana de San Luis Potosí (líneas rojas).

Origen y efectos de la subsidencia

El origen de la subsidencia asociada a estos agrietamientos se ha atribuido normalmente a la sobreexplotación de los mantos acuíferos. Cuando se extrae un cuerpo de agua de un relleno sedimentario granular, los poros antes llenos de agua y por lo tanto incompresibles, quedan vacíos. Debido a la carga litoestática, estos poros empiezan a comprimirse causando con esto dos efectos notables, 1) la pérdida de porosidad en el sedimento y 2) un adelgazamiento de la cubierta sedimentaria granular (Fig. 2B y 2D). Suponiendo que el relleno sea homogéneo en sus 3 dimensiones, sucederá un adelgazamiento o compactación de la cubierta granular igual en todas partes, sin embargo, cuando la base, o piso rocoso donde descansa la cubierta granular no es homogénea (Fig. 2D), la compactación o adelgazamiento será distinto, causando una compactación diferencial entre una zona gruesa y una delgada. La compactación diferencial y la configuración del piso rocoso controlan entonces la formación de fallas y de agrietamientos (Fig. 2). El fenómeno de los hundimientos se ha explicado por medio de la “reactivación” de paleocausas y paleodrenajes, los cuales se encuentran sepultados y colmatados por el relleno granular (Fig. 3), sin embargo, durante épocas de precipitaciones extremas el agua en el subsuelo utiliza los antiguos causas y drenajes, lo cuál causa remoción y retrabajo de las partículas, dejando finalmente un hueco o una estructura tubular vacía (tubing en inglés, Fig. 3B,), los cuales colapsan debido al peso litoestático (Fig. 3C). La Figura 4 muestra algunos de los efectos que producen estos fenómenos sobre la infraestructura y los edificios.

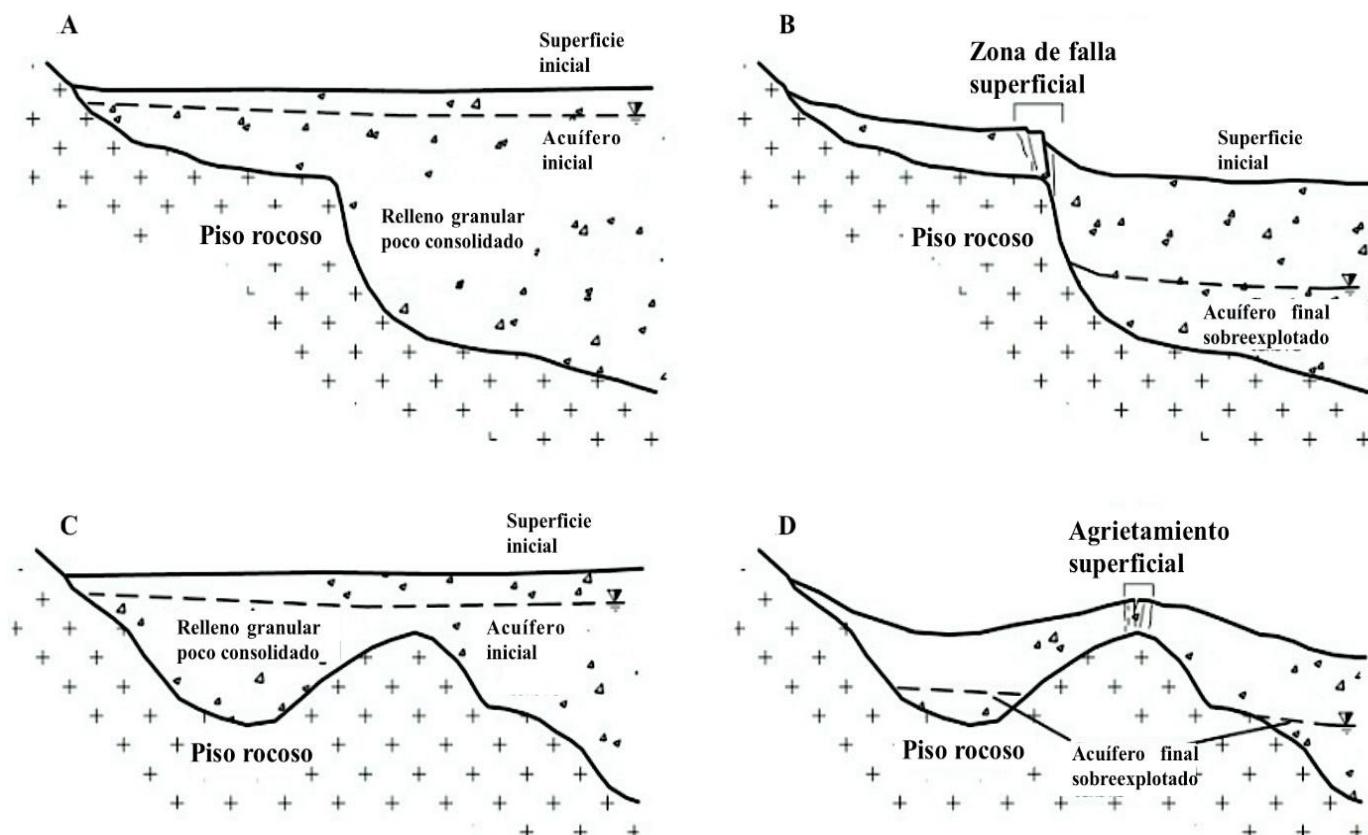


Figura 2. Formación de fallas y fracturas superficiales asociadas a una compactación diferencial del relleno granular, que forma el acuífero del valle de SLP (según Carpenter, 1999).

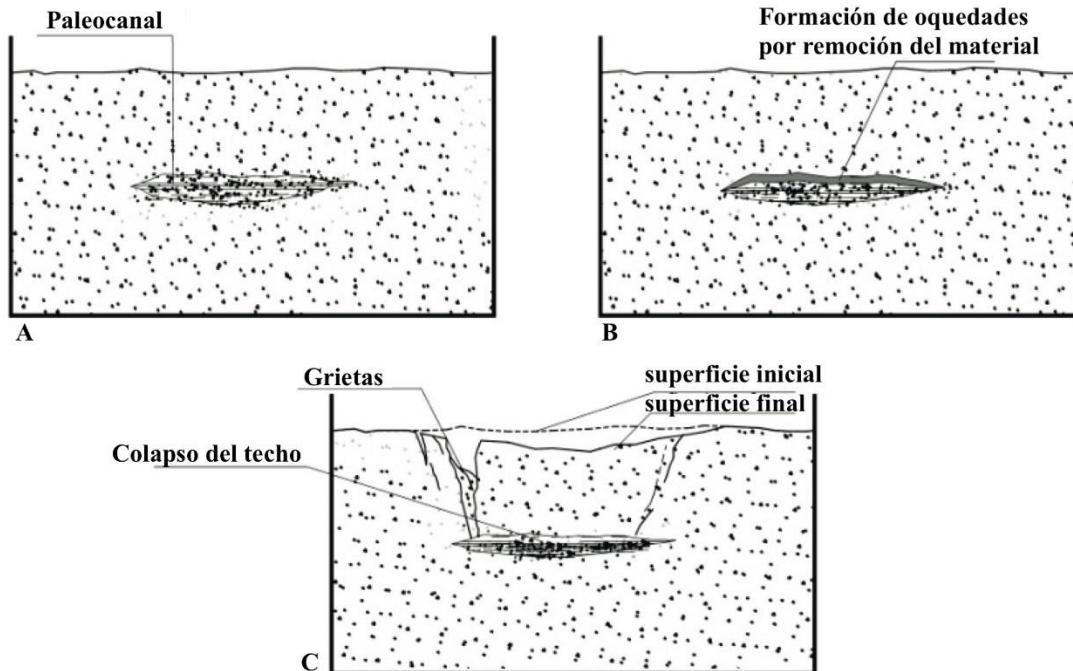


Figura 3. Formación de fracturas y hundimientos asociadas a paleocanales (Pacheco-Martínez et al., 2010).



Figura 4. Ejemplos de daños a la infraestructura causados por agrietamientos y hundimientos en San Luis Potosí.

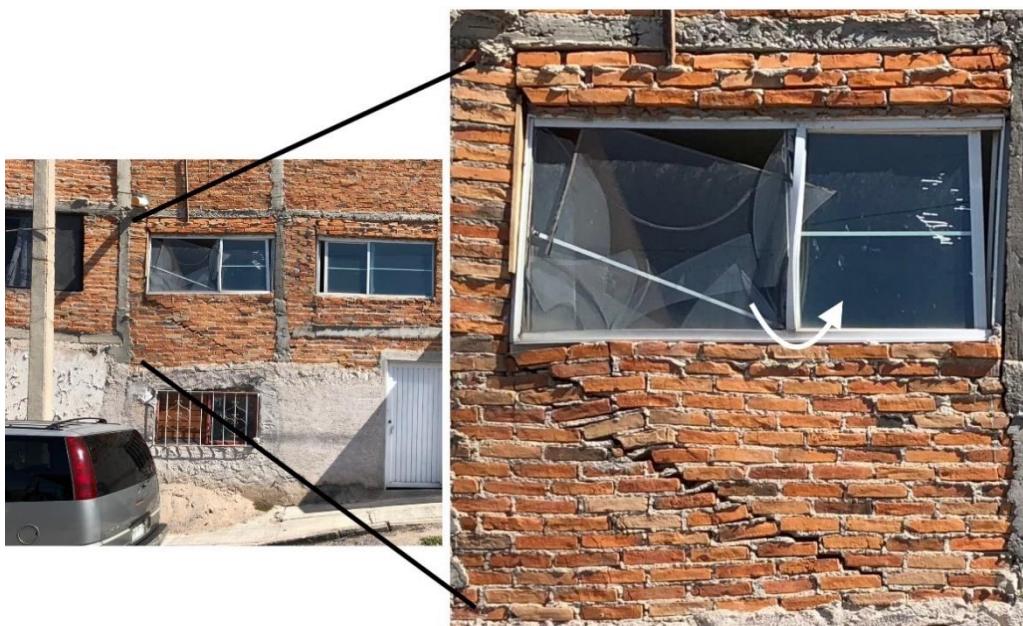
Caso San Luis Potosí

Aunque este fenómeno ha sido explicado por las causas arriba descritas, existen ciertas características en los agrietamientos y hundimientos de San Luis Potosí que sugieren que hay otros factores, además de los ya descritos y que ciertamente ocurren, que contribuyen y aceleran la formación de estas estructuras.

En la Figura 5 se reconoce que además del agrietamiento en pisos y paredes de las construcciones hay una torsión en los marcos de las ventanas y puertas, indicando esto que no solo hay movimiento vertical, asociado a extensión, sino que hay indicios de un movimiento lateral. Hasta la fecha se han reconocido varios edificios que muestran además de rompimiento en paredes por extensión, torsión marcada de sus estructuras (Fig. 5). Otro de los fenómenos asociados es la formación de grandes oquedades que ocurren siempre en la traza de agrietamientos y fallas. Cuando estas oquedades suceden en la zona urbana construida suceden hundimientos que provocan colapso de calles, banquetas y causan grandes daños a redes de agua y drenaje y cuando ocurren en zonas rurales se convierten en zonas peligrosas para la fauna local y el ganado, modifica enormemente el drenaje de la zona y muy comúnmente se han utilizado como basureros naturales provocando contaminación (Fig. 4). El que estas oquedades se encuentren siempre asociadas a agrietamientos y fallamientos ha sido siempre explicado por "lavado" causado por el agua meteórica que claramente utiliza estas zonas como drenajes naturales. Sin embargo, se ha detectado que estos hundimientos muestran una geometría muy peculiar que comúnmente ocurre en forma de escalones (echelones, Fig. 6). A pesar de que estas fallas afectan suelo y relleno granular semiconsolidado fue posible identificar estrías, que, como indicadores cinemáticos, permitieron establecer que adicional al movimiento vertical existe una ligera componente horizontal (Fig. 6). Analizando la geometría de las fallas y los hundimientos y sabiendo que existe una componente de desplazamiento lateral es posible asumir que los hundimientos representan zonas de transtensión formando locales depresiones tipo "pull apart" (Fig. 6 y 7).

Otro aspecto que sugiere la presencia de un movimiento lateral es que existen importantes agrietamientos con hundimientos escalonados y que no tienen un movimiento vertical, es decir, no hay evidencia de que se comporten como fallas normales (Fig. 6 y 7).

Actualmente se está trabajando en el análisis mas detallado de los indicadores cinemáticos, de la geometría de las fallas, así como el empleo de técnicas modernas en el manejo de imágenes satelitales y otras nuevas técnicas de análisis remoto con las cuales se podrá aportar mas información que nos permitan establecer la existencia del movimiento lateral en los agrietamientos y hundimientos en la zona conurbada de San Luis Potosí.



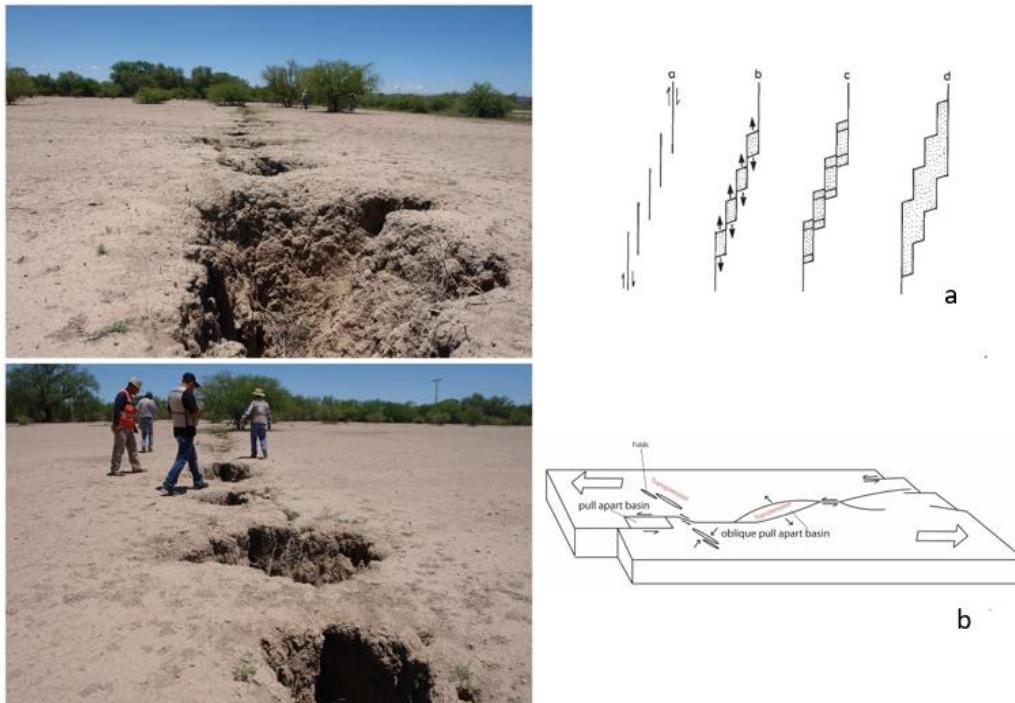


Figura 6. Modelo representativo de subsidencia. Modificado de https://ca.water.usgs.gov/land_subsidence (2020).

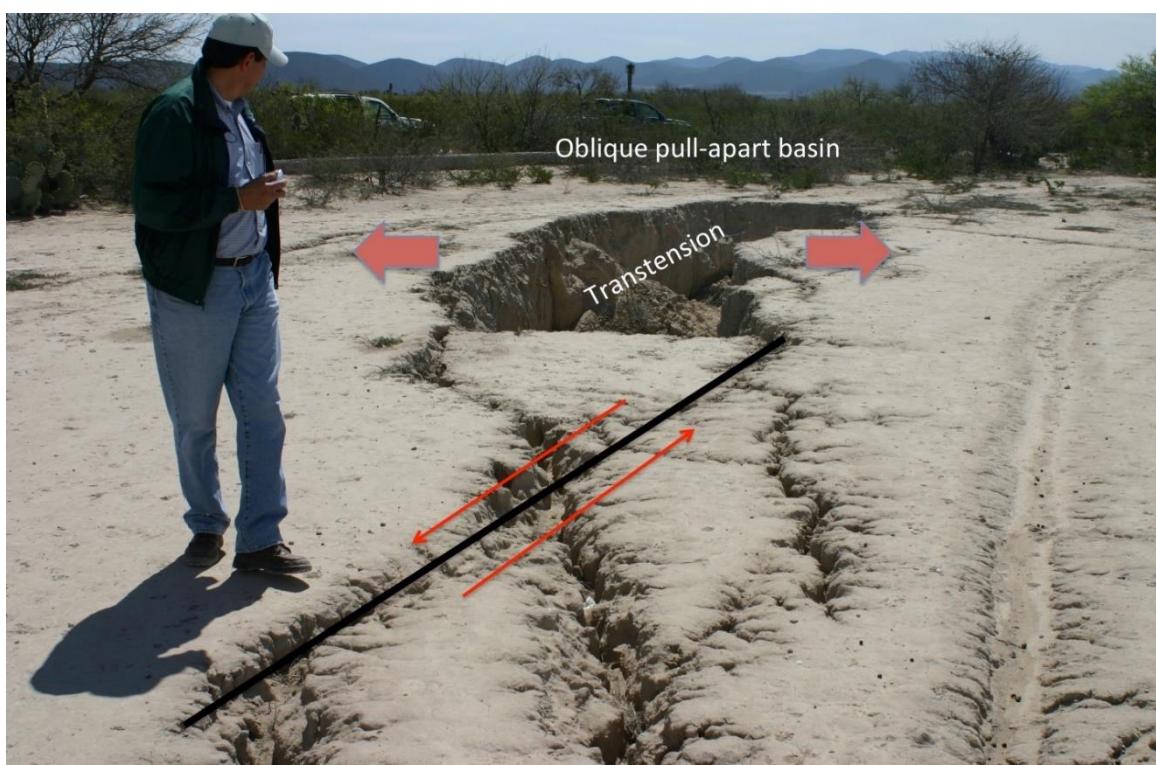


Figura 7. Detalle de las cuencas transtensionales en San Luis Potosí.

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4. Devastating wildfires across Sierra Madre Oriental, northeastern México

Igor Ishi Rubio Cisneros, Senior-Expert Geology Interpreter,
Grupo de Geología Exógeno y del Sedimentario
igor_rubio@yahoo.com

The Sierra Madre Oriental in northeastern Mexico shares its history with the Cordilleran orogenic belt of western North America and holds the natural protected area of National Park Cumbres de Monterrey, including some world-class outcrops (Goldhammer, 1999; Cantú-Ayala et al., 2013; Fitz et al., 2017). The physiographic province is a transboundary ecoregion with endemic species ([NOAA](#)– National Oceanic and Atmospheric Administration; Salinas-Rodríguez et al., 2017). Recent wildfires threatened the Sierra after a year of climate breakdown. Experts' relate the source of ignition near to tourist cabins.

Historically, the Sierra has recovered from comparable infernos (1998), but fear overwhelms settlers remembering burnings in California (2020) and Australia (2019). Winter burn in 2021 advanced from an unprecedented north polar vortex (e.g., NOAA, 2019). In March, this province became an unfortunate region where converging dry winds pushed by the Niña from the west collided with a pervasive cold and dry weather from the north and lack of a consistent Atlantic Meridional Overturning Circulation, which is now a weak Gulf Stream System (NOAA, 2020; Caesar et al., 2021). All regional natural phenomena converged over the stressed Rio Grande watershed basin near the northern Gulf of Mexico ([NOAA](#)). In mid-March, these wildfires made an aerosol factory for the nearby city of Monterrey, dispersing burned material to the atmosphere and Texas. However, no contingency declared any preparation for health impacts. In February, state authorities published a preliminary document for managing the National Park. The campaign heated the situation since a limited assessment remarked the importance of dealing with wildfires during an environmental crisis, limiting a declaration of emergency response for regenerating the ecosystem. The region faces political decisions masking forensic science with affairs to deliberate fires for land clearance or geoengineering practices.



Figure 1. Maps for locations of wildfires March 24-25, 2021, retrieved from NASA-FIRMS– Fire Information for Resource Management System, and Comisión Nacional Forestal. Fires are in red over a green layer representing the natural protected area. A ruler indicates the extent of the disaster. Earth data is from weather satellites using VIIRS– Visible Infrared Imaging Radiometer Suite, and MODIS– Moderate Resolution Imaging Spectroradiometer.

https://firms2.modaps.eosdis.nasa.gov/map/#:adv;d:2021-03-24..2021-03-25;l:noaa20-viirs,viirs,modis_a,modis_t,3,graticule,firms_static_modis,countries,protected_areas;@-100.0,25.3,10z
<https://www.facebook.com/CONAFOR.Central/photos/a.503551089767127/3733388840116653/>

In April, sudden showers refreshed the woodlands allowing firefighters and volunteers to control the hazard before rising again. Nonetheless, a series of sites scattered reclaimed fire from ash, which remained until the end of the month. In May, the state government declared water stress and drought in the main water reservoirs, mainly at the Cerro Prieto dam filling with less than 17%. The state warned of water shortages and intermittent supply of the service in the metropolitan area.

Albeit the tension, a sudden tropical storm called Andres formed on Mexico's Pacific coast, commencing the hurricane season. The violent disturbance of a low-pressure channel in the west brought humidity and precipitation to the east while moving accordingly with cold front #49 from the north to meet in northeastern Mexico. Rainstorms and hail covered the northern states of Coahuila, Nuevo León, and Tamaulipas. On April 11, an unexpected cloud formation overlaid the sites with scars and burns produced from wildfires and land-use changed. Also, clouds covered other areas reported with hydrologic stress, or where the heated ground and solar radiation prevailed as in the dry dam of Cerro Prieto (Figure 2).

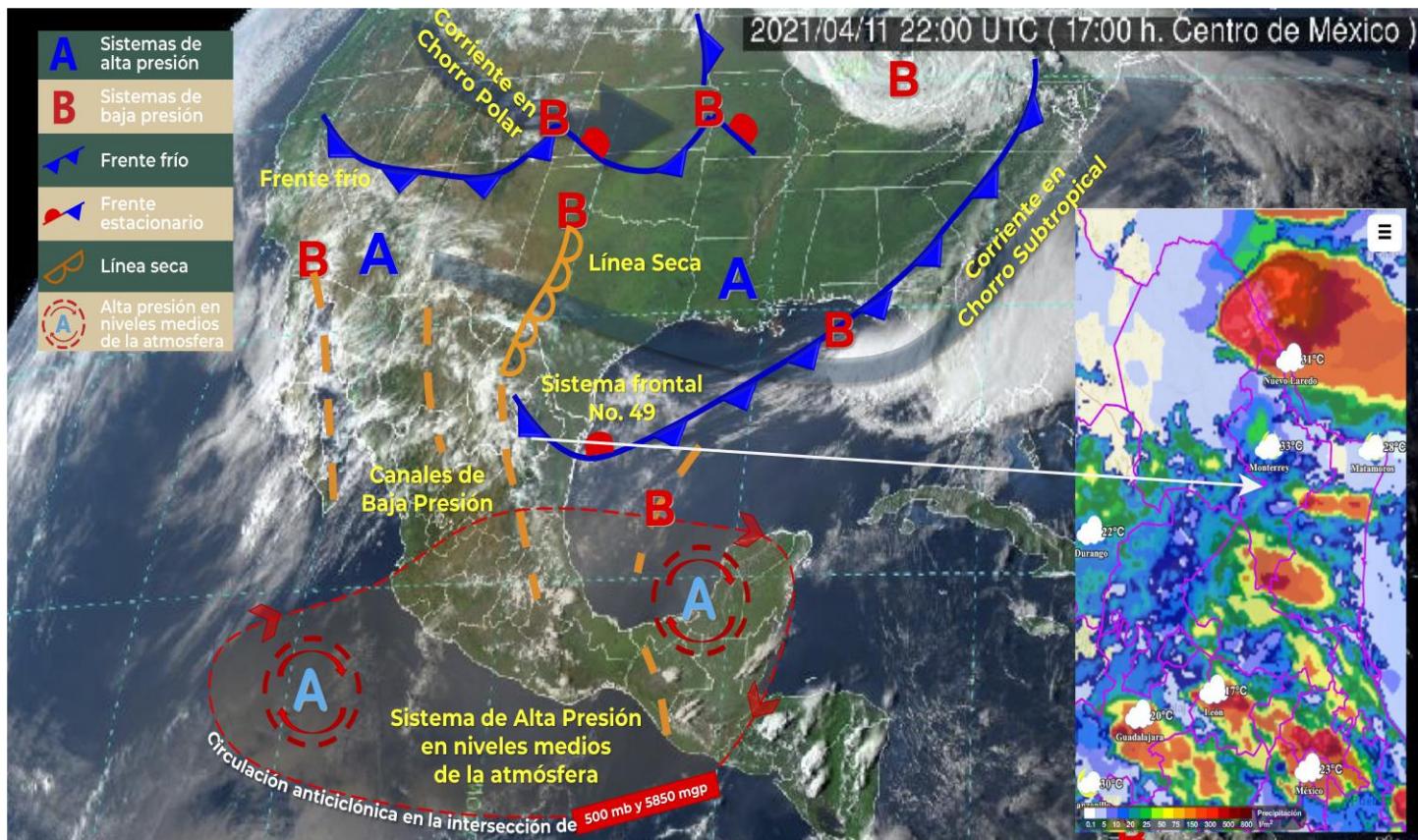


Figure 2. Interpreted map showing the distribution of the weather system on April 11, moving rainfall eastwards over locations where wildfires and stressed land exist. Data retrieved from Secretaría de Medio ambiente y Recursos Naturales (SEMARNAT) and Comisión Nacional del Agua (CONAGUA).

Similar paradigms showing the cooling function of rain demonstrated how the hydrological cycle plays a vital role in regulating the Earth's energy balance regarding solar radiation and land exploitation (Huryna & Pokorný, 2016). From these facts, we have to protect our heritage, trees, forests, and water for keeping natural resources availability, while mitigating regional alterations to nourish healthier citizens.

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5. An overview on the geochemistry of arsenic originating from geothermal systems in Latin America

Nury Morales-Simfors^{1,2,3} and Jochen Bundschuh^{2,3}

¹Rise Research Institutes of Sweden, Linköping SE-581.83, Sweden

²School of Civil Engineering and Surveying, University of Southern Queensland, Australia

³UNESCO Chair on Groundwater Arsenic within the 2030 Agenda for Sustainable Development, University of Southern Queensland, Australia

nury.simfors@usq.edu.au, jochen.Bundschuh@usq.edu.au

ABSTRACT

Geothermal fluids and volcanic emissions are important sources of arsenic (As), resulting in elevated concentrations of As in ground-, surface-water and soil, which may negatively affect the environment and human health. Arsenic originating from geothermal features and volcanic activities are common in Latin America forming a serious risk on the livelihoods of millions of people. This summary attempts to provide an overview of geochemistry of As originating from geothermal sources in 15 countries of Latin America, mostly related to present volcanic activity ($0.001 < \text{As} < 73 \text{ mg/L}$) and the transboundary Guarani Aquifer System ($0.001 < \text{As} < 0.114 \text{ mg/L}$). The data and information compiled in this summary is part of two studies published by Morales-Simfors et al. (2020) and Bundschuh et al. (2020). Most of the geothermal systems and volcanoes mentioned in this study are near to densely populated cities, where total As concentrations in natural ground- and surface- water exceeded the safe drinking water guideline of 0.01 mg/L , recommended by the World Health Organization (WHO). The holistic assessment of As originating from geothermal features and volcanic emissions along with its geochemistry, mobility and distribution would be an important driving force to formulate a plan for establishing a sustainable As mitigation in vulnerable areas of Latin America in the near future.

1. Background

The compiled data in this summary is part of the work of Morales-Simfors et al. (2020) and Bundschuch et al. (2020), related to geochemical aspects of As in geothermal fluids and volcanic emissions from Latin America (Fig.1). Most of the studied sites (~93%) are from active (e.g. Sabancaya (Peru), Villarrica (Chile), Copahue (Argentina), Colima (Mexico)) and past (Platanares and Azcualpa (Honduras), Los Humeros (Mexico)) volcanic areas. These volcanic areas correspond to the sites of geothermal springs, geothermal wells, crater lakes, surface waters (lakes, rivers) and fumaroles. Geothermal waters related to plutonic intrusions have been reported only from Cerro Prieto (As: 0.32–5.18 mg/L) in northern Mexico and geothermal waters not related to volcanism or plutonism are reported from Guarani Aquifer System. The collected data sets are used to delimit and characterize the different geoenvironments from which As is mobilized in Latin America through geothermal and volcanic processes. However, further studies of the mobility and distribution of As would be necessary in order to formulate a plan for establishing a sustainable As mitigation in vulnerable areas of Latin America.

1.1. Geoenvironmental and geothermal settings containing arsenic

Different types of geological settings have been identified releasing As to different surface-near environments through geothermal fluids and volcanic emissions. Arsenic emissions due to active volcanism (As: 0.001-73 mg/L) is the best studied group. However, other geoenvironments, such as the low-enthalpy geothermal sites (As: 0.35-0.45 mg/L, Platanares hot springs in Honduras) in areas of past volcanism (which covers a large area since it follows as a belt behind the active volcanic zone), plutonic intrusions (As: 0.32-5.18 mg/L, Cerro Prieto in Mexico), and non-volcanic hydrothermal systems which-with very few exceptions-have not even been considered for geothermal exploitation and much less for studying As. The same applies for fossil hydrothermal systems, which are former hydrothermal/volcanic systems commonly found in the past volcanic areas. They are of interest for metal-mining and are well-known source of As.

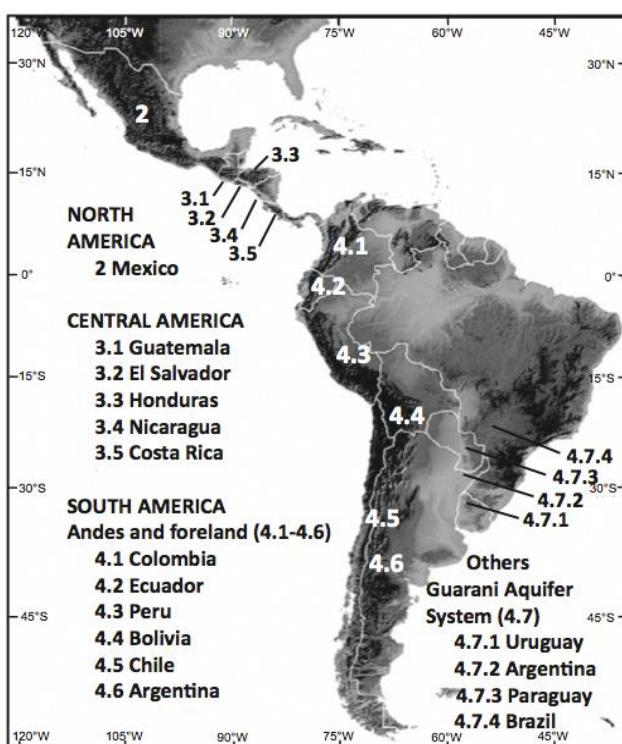


Fig. 1. Simplified location map showing the countries included in the study of As in Latin America (See Morales-Simfors et al., 2020).

1.1.1. Arsenic in geothermal reservoirs related to active volcanism

In Fig. 1 is shown 12 countries (out of 20) counting on areas of active volcanism. From this area, about 170 active volcanoes are known where corresponding geothermal reservoirs can be formed at depths of a few kilometers under favorable conditions. These show respective variable chemical compositions due to variable host rock materials, however, all can be considered as mature systems with chemical equilibrium between the host rock and the geothermal fluids of the reservoir. These areas are related to subduction zones along the Pacific coast where oceanic plates are subducted below continental plates. These processes are the origin of active volcanism generating numerous high- and low-enthalpy geothermal systems. These are characterized by high temperature and pressure which favors rock-water interactions resulting in high As concentrations in geothermal fluids (several to some tens of mg/L – 0.10-73.6 mg/L; Table 1). These geothermal fluids, and the volcanic emissions, which release gases or solid particles, can form important sources of As and cause serious impact to different close-surface environments. Surface manifestations of these geothermal systems include geothermal springs, fumaroles and steam fields.

1.1.2. Arsenic in areas of past volcanism: present and fossil geothermal reservoirs

Geothermal reservoirs are also found in formerly active volcanic systems where magma bodies still contain residual heat able to warm up water. These geothermal reservoirs are of low-enthalpy and due to lower temperature and pressure result in reduced rock-water interactions when compared to those in active volcanic zones. Geothermal systems of this type are generally found in the areas behind those of active volcanism, i.e., in the east of the present active volcanic zones of Latin America's active volcanic front. Geothermal manifestations, in particular thermal springs where deep circulating meteoric water emerges are frequent. Examples from Honduras are Platanares (boiling hot springs and exploration wells, As: 0.45 and 0.35 mg/L), Azacualpa springs (As: 0.08 mg/L) and from Chile is the Tatio geyser field (As: 0.59–20 mg/L).

In addition, in these areas of former volcanism, there is another important potential As source related to this past volcanic activity. This source is the fossil geothermal/volcanic systems which include precipitated As-rich minerals. These can locally form important mineral deposits such as gold ore deposits. Here rocks have been altered by fossil geothermal systems, thermal spring deposits and stockworks, volcanic sulfide deposits, and epithermal veins or vein-breccias where geothermal fluids have formerly entered faults and shear structures carrying As, Hg, and Sb (Nelson, 1990). High As concentrations in veins and stockworks have for example been reported from Nicaraguan deposits: Matagalpa (As: 39-91 mg/kg), La Libertad (As: <20-41 mg/kg), Bonanza (As: 20-380 mg/kg), and Siuna-Rosita (As: <20-120 mg/kg) (Sundblad and Swedish Geological Company, 1985; Delgado Quezada et al., 2020). Through natural dissolution or accelerated by mining activities they can impact ground- and surface water, leading to important enrichment of As in groundwater and other environments.

Country	Location	Water Source	Water type	Temp C	pH	Eh (mV)	EC (mS/cm)	TDS (Mean)	As (mg/L)
Mexico	Cerro Prieto GF (3)	well	Na-Cl	300.0	6.2		16.2		5.18
	Los Humeros, Puebla (17)	well	Na-Cl to Na-HCO ₃ -SO ₄ -Cl	304.0	7.9				73.60
Guatemala	Zunil GF (5)	well	Na-Cl	239.3	7.7	-72	3.0		4.80
	Tecumburro GF (4)	spring	Na-Cl to Na-HCO ₃ -Cl	63.6	5.5				0.63
Honduras	Azacualpa GF (4)	spring		99.0	8.4		3.3		0.080
	Platanares GF (6)	spring	Na-HCO ₃ -SO ₄	98.0	8.8				0.45
	Pavana GF	spring							0.11
El Salvador	Ahuachapan	well		31.7	6.9				0.080
	Berlin GF (5)	well	Na-Cl		6.4				11.700
	Berlin GF (7)	spring	Cl	64.5	6.9				0.080
Nicaragua	Momotombo GF (3)	well	Na-Cl	80.0	8.3	62		4932	2.090
	Monte Galan (3)	spring	Na-HCO ₃ -SO ₄ to Na-Mg-Ca-HCO ₃ -SO ₄ -Cl	44.0					0.11
Costa Rica	Miravalles GF (13)	well	Na-Cl	215.5	7.0	291	12.7		25.40
	Rincon de la Vieja (4)	well	Na-Cl	247.3	6.5	281	10.2		10.00
Colombia	Capur	spring		22.8	7.6		11.3	6675	38.0
Ecuador	Papallacta Lake Basin (7)	spring		41.0					
	Imbadura (4)	spring	Cl-HCO ₃	41.0					
Bolivia	Poopo's Lake Basin (16)	spring	Na-Cl to Na-HCO ₃ -Cl	17.0					
Chile	Puchuldiza	spring		80.7	7.7		6.8	4526	12.09
	El Tatio (2)	spring	Na-Cl	71.2	6.5		14.6	8705	26.40
Peru	Ulucan	spring		74.0	6.6		13.8		28.10
	Yacamane 6	spring		83.2	6.6	13	5.4		11.10
Argentina	Copehue	spring			0.4				4.52

Table 1. Total arsenic concentrations, water source, temperature, pH and TDS for selected geothermal waters in Latin America. Arsenic concentrations and TDS in mg/L (For more information of major, minor and trace elements for geothermal waters see Table SM1 in Morales-Simfors et al. 2020).

1.1.3 Arsenic in geothermal reservoirs of plutonic intrusions

In addition to geothermal reservoirs related to volcanic magmatic intrusions, plutonic intrusions can also lead to the formation of geothermal reservoirs. Heat is generated by minerals of the intrusions of granites or other acidic rocks, which possess high contents of radioactive elements such as uranium (U), thorium (Th), and potassium (K). These intrusions can form important geothermal reservoirs if a sealing cover such as sedimentary rock. Further, water in fractured sedimentary rocks overlying the intrusive body can itself be heated by conduction from below and form a geothermal reservoir. The last is the case at Cerro Prieto (Mexico) which is the largest of the geothermal plants globally (by installed capacity), located in an extensional sedimentary basin with subsequent pluton intrusions ("pull-apart" basin). This sedimentary reservoir has high temperatures (280-350°C) similar to those in active volcanic zones but lower As contents ranging from 0.32-5.18 mg/L. This is mainly due to the occurrence of different host rocks in both types of geothermal systems. The geothermal reservoirs in active volcanic zones have volcanic rocks as host, containing As-rich minerals such as arsenopyrite. In contrast to the sedimentary host rocks, geothermal fluid generally contains less As and the dissolution by water-rock interaction even at similar temperature results in lower As concentrations. This kind of geothermal system can result in geothermal springs as well. However, in most cases, such geothermal systems are of low-enthalpy.

1.1.4. Arsenic in hydrothermal basins which are not related to volcanism and plutonism

There are some other geothermal systems which are not related to volcanic or plutonic magmatism. These are low-enthalpy hydrothermal systems heated through conductive heat flux from the earth's interior. They are typically found in areas where the earth's crust is thin and the heat flow and geothermal gradient significantly exceed those of the respective average continental crust. High temperatures of generated geothermal reservoir and favorable mineralogical and (hydro)geochemical conditions can increase rock-water interactions leading to increasing dissolution of mineral/rocks and As mobilization. This for example is the case of (normally on regional scale) deep circulating groundwater being heated, together with the long residence time, which facilitates water-rock interactions mobilizing As as found in the Guarani aquifer. This transboundary aquifer system is shared between Argentina, Brazil, Paraguay and Uruguay (covering 1,200,000 km²). Recharge area and discharge area are thousands of kilometers apart from each other and groundwater reaches depths of over 1000 m below the earth's surface (Foster et al., 2009). In some areas As concentrations exceed the World Health Organization (WHO) guideline value of 0.01 mg/L for As in drinking water. In the discharge area along the Argentinian-Uruguayan border, the low-temperature thermal springs are especially used for therapeutic and recreational resorts.

2. Impacts of arsenic on environmental and human health

There are different pathways through which these As sources, i.e. geothermal water and volcanic emissions can contaminate near-surface environments and freshwater resources vital for drinking and irrigation. The most important geothermal fluids contaminating freshwater sources in Latin America are:

2.1. Surface water: Geothermal fluids of As-rich water into surface water bodies have been reported in several places across Latin America. Most easily, they can be detected where water emerging from geothermal springs discharges into creeks, rivers and lakes. There are several examples, in particular in the volcanic areas of Latin America including Papallacta Lake (Ecuador) where As from geothermal springs (As: 0.7–3.2 mg/L) discharges first into the Tambo river (As: 2.7–5.7 mg/L) which then flows into Papallacta Lake (As: 0.22-0.37 mg/L). This water is an important drinking water resource for the region with an As concentration level above the WHO guideline limit of 0.01 mg/L and required mitigation methods. Sediments of river lake are further adversely impacted by the As from the geothermal springs Loa river (northern Chile) and its sediments is impacted by geothermal waters discharging from the Tatio-Geyser Field, with As concentrations exceeding 20 mg/L in thermal discharges being the principal As source which severely increases – together with other natural As sources in the river's recharge area - the As concentration of river water and sediments. Loa river is the main surface water resource of the region and, also supplies the regional capital of Antofagasta at the Pacific coast (Alsina et al., 2014; López et al, 2012; Muñoz-Sáez et al., 2015) and had required installation of drinking water treatment plants. The environmental impact of As-rich sediments through Loa river into the Pacific Ocean is a further environmental concern. When the geothermal water is discharged directly in the underground into the surface water body, the process often remains unrecognized and only few examples have been described.

2.2. Groundwater: In several regions of Latin America, geothermal water with high As concentrations discharges into freshwater aquifers used for drinking water supply and/or irrigation, so it has been found that this is the reason for elevated As concentrations observed in the respective groundwater bodies. Since there are no surface manifestations, this process is difficult to recognize and in most cases it is overseen or misinterpreted. Some examples where the process has been recognized are: Los Altos de Jalisco area (As: 0.015-0.102 mg/L, western Mexico), where groundwater containing a geothermal component (as indicated by elevated temperatures) is predominantly used for irrigation (Hurtado-Jiménez and Gardea-Torresdey, 2006). In this case, 34% of the samples exceed the national drinking water limit for As (0.025 mg/L) and 92% exceeded the WHO guideline value (0.010 mg/L). Estimated As exposure doses from drinking indicated potential health effects (Bundschuh et al., 2017). Another example is the vicinity of the San Salvador and San Miguel volcanoes (El Salvador), where wells used for drinking water supply including those of large cities as the capital San Salvador and San Miguel, partly contain As in concentrations exceeding the 0.010 mg/L limit, which can be explained by As inputs from the magmatic system of these volcanoes. In the area of Telica (northwestern Nicaragua), where geothermal impacted groundwater (As: 0.01-0.3 mg/L) is used for drinking purposes (Delgado Quezada et al., 2020) is another example. However, only from the Telica site, studies on human health and biomarkers have been performed so far.

2.3. Volcanic ash emissions contaminating freshwater sources

Volcanic ash due to past and present volcanic activity can have significant impacts not only close to the eruption site but also hundreds or thousands of kilometers far away. It can adversely impact drinking water sources and respective water supplies (predominantly groundwater sources), agricultural soils and crops. A well-known example is the Chaco-Pampean plain (Argentina), ash resulting from the Andean volcanism has been deposited over millions of years and distributed within aquifer sediments in an area covering over 1 million km². By dissolution of the volcanic glass under respective favorable geochemical conditions, mobilization of As from volcanic glass and/or secondary formed As oxyhydroxides of Fe and Mn into groundwater exposes millions of people to As (Nicolli et al., 2012, Bundschuh et al., 2017).

In the northern parts of the Chaco-Pampean plain, As concentrations range from 0.47 to 0.8 mg/L in groundwaters and from 0.05 to 9.9 mg/L in geothermal sources (Nicolli et al., 2012). Another example of freshwater contaminated by As (and other trace elements) was reported during the eruptive period of the Copahue volcano (Argentina) in 2002. High As concentrations (0.18 to 113 mg/kg) in volcanic ash, accumulated along the Río Agrio watershed, contaminated the Caviahue Lake, which was used for drinking water supply. The impact of this single event showcases the magnitude of impact considering thousands or tens of thousands or more of such events taking place during millions of years impacting the Chaco-Pampean plain and potential (unknown) As inputs in groundwater system in other Latin American regions and countries.

4. Conclusion

This summary shows the geochemical aspects of As in different geological settings in Latin America in order to provide a rational assessment of what is existing and what needs to be done in future research. A large-scale As contamination of ground- and surface-water in these regions has placed this metalloid into the focus of public and scientific attention during the present decade. Geothermal waters with the highest As levels were found to be of Na-Cl type. In Fig. 2 the Cl-Na diagram depicts a strong positive correlation between Cl⁻ and Na⁺, at Na⁺ concentrations (>10 meq/L). The Cl⁻ enrichment in geothermal reservoir fluids may come from host rock-interactions and/or dissolution of magmatic HCl gas. Although the presence of As in geothermal fluids and volcanic emissions is a well-known fact, its wide geographical appearance and potential environmental impacts are often neglected or underestimated. Environmental impacts of the contamination of freshwater sources by As-rich geothermal fluids and their mixing e.g., with shallow groundwater have only been investigated in a few areas, including Jalisco in Mexico and the Managua area in Nicaragua. However, this process exists possibly in many other sites. In addition, potential risks for human health are associated with natural bathing or man-made pools used for recreation and tourism exposing people to high levels of As which are derived from geothermal features as observed in Argentina, Chile, Mexico and Nicaragua. In overall conclusion, holistic assessments of As derived from geothermal fluids and volcanic emissions are crucial in order to define and execute As mitigation strategies which will lead to the supply of As-safe drinking and irrigating water for the population of Latin America.

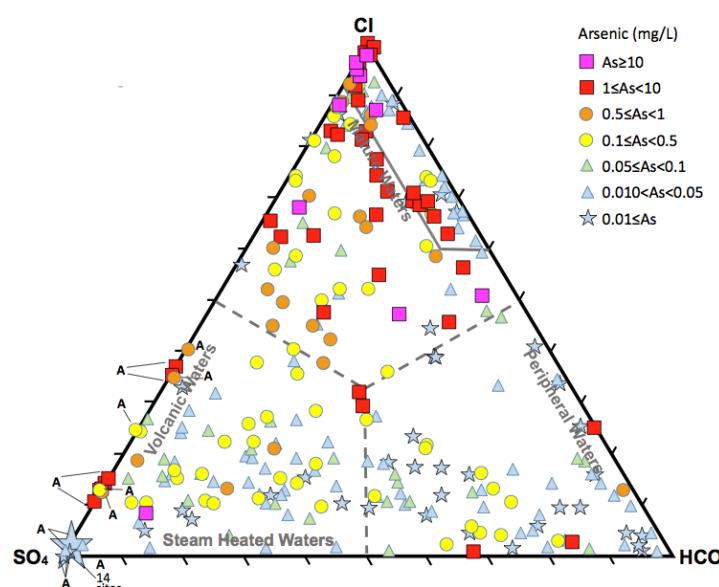


Fig. 2. Chemical characterization of geothermal waters and related fluids of Latin America. Data have been plotted according to Table SM1 in Morales-Simfors et al. (2020).

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6. Geochemical monitoring of volcanic systems in the Lesser Antilles

Erouscilla Joseph¹ and Nury Morales-Simfors^{1,2,3}

¹Seismic Research Centre, The University of the West Indies

²RISE Research Institutes of Sweden, Linköping SE-581.83, Sweden

³School of Civil Engineering and Surveying, University of Southern Queensland, Australia

pjoseph@uwiseismic.com, nury.simfors@usq.edu.au

Systematic geochemical monitoring of volcanic systems in the English-speaking islands of the Lesser Antilles was initiated by The University of the West Indies (UWI) Seismic Research Centre (SRC) in 2000, as part of its volcanic surveillance programme for the English-speaking islands of the Lesser Antilles (Fig. 1a). This programme established baseline studies for understanding of the hydrothermal systems in Dominica and Saint Lucia during periods of quiescence and permitted the characterization of the geothermal fluids associated with them (Joseph et al., 2011; Joseph et al., 2013). Unfortunately, information on the composition of trace elements in the thermal waters are still very limited.

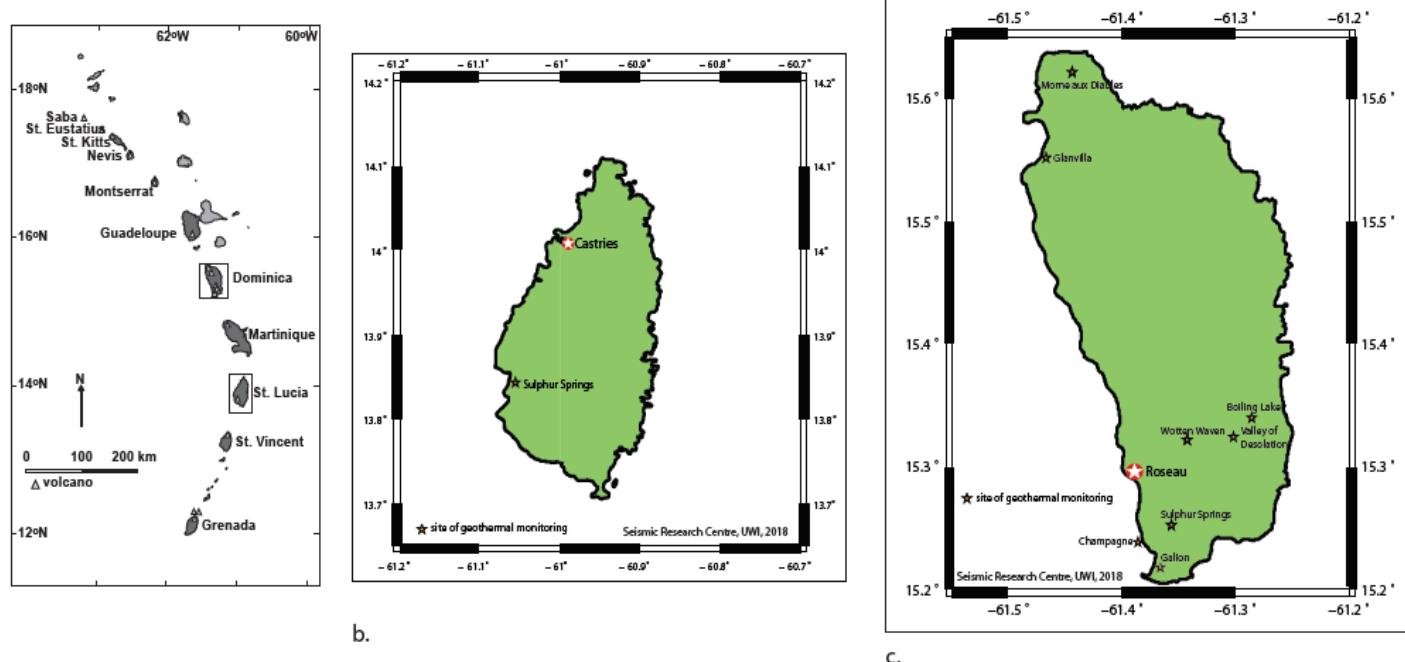


Fig. 1. a. Map of the Lesser Antilles (modified from Lindsay et al., 2015), b. Map of St. Lucia showing sites of geothermal activity and monitoring, and c. Map of Dominica showing sites of geothermal activity and monitoring.

Saint Lucia

The Sulphur Springs geothermal field is an energetic geothermal field associated with the Soufrière Volcanic Centre in southern Saint Lucia (Fig. 1b). The main area of the geothermal field is comprised of numerous hot springs, bubbling mud pools, boiling springs, and fumaroles in an area of strongly argillic altered volcanic rock approximately 200m x 400m in size. The hydrothermal waters have a sodium/calcium acid-sulphate type compositions (pH = 3 – 7, SO₄ = 78 – 4008 mg/L; Na (14 – 333 mg/L), and Ca (4 – 1313 mg/L)), and are of primarily meteoric origin (Joseph et al., 2013, Table 1). These waters are steam-heated water typically formed by the absorption of H₂S-rich gases in the near surface oxygenated groundwater.

Dominica

The island of Dominica is located in the Lesser Antilles, with nine (9) potentially andesitic-dacitic volcanic centres, many of which have highly active volcanic-hydrothermal systems. This study evaluates data obtained of the geochemistry of thermal waters from (4) geothermal areas across the island (Valley of Desolation, Sulphur Spring, Watten Waven, and Morne aux Diables) (Fig. 1c). Detailed geological information of these volcanic centres and their historic geothermal activity can be found in Lindsay et al., (2005). The Valley of Desolation (VoD) is situated within the Morne Trois Pitons National Park in the south-central part of Dominica and represents a phreatic or phreatomagmatic eruption crater within massive lavas associated with the Peléan dome of Morne Watt (Mayer et al., 2017). The hydrothermal activity associated with the Watten Waven is concentrated in and adjacent to the River Blanc, a tributary of the Roseau River, near the Watten Waven caldera margin. The area is characterised by the presence of numerous bubbling pools and fumaroles with temperatures of up to 99°C (Joseph et al., 2011). Sulphur Springs is located on the margin of the Soufrière depression in the Sulphur Springs National Park region at an altitude of 275 m above sea level. Measurements taken in the last 100 years indicate that fumarole temperatures are between 90°C – 100°C. This geothermal area in Morne aux Diables is referred to as a ‘Cold Soufrière. It occupies an area of ~ 25 m² and is situated to the north of the main summit area. The activity manifests as milky-to-clear vigorously bubbling pools and cold “frying pan” features with temperatures of 23°C – 28°C and a strongly acidic pH (1-2) (Lindsay et al., 2005). There is also strong smell of H₂S at the site.

The thermal waters of Dominica are predominantly acid-sulphate in character (SO₄= 32– 5200 mg/L, pH= 1 - 7), and likely formed because of dilution of acidic gases in near surface oxygenated groundwater (Joseph et al., 2011). The waters are of primarily meteoric origin with δ¹⁸O ranging from -1.75 to 10.67‰, and δD from -6.1 to 14.5‰, however are affected by evaporation effects at/near the surface.

Sample Name	Date	pH	Temp. (°C)	Na	Ca	SO ₄	Chemical composition type
				mg/L	mg/L	mg/L	
Sulphur Springs, Saint Lucia	2014	6 - 7	27 - 85	100 - 240	42 - 174	22 - 1020	Na/Ca-SO ₄
Sulphur Springs, Saint Lucia	2017	6 - 7	32 - 87	29 - 210	33 - 268	83 - 1313	Na/Ca-SO ₄
Morne aux Diables, Dominica	2014 - 2017	1 - 5	23 - 27	16 - 71	8 - 44	25 - 4288	Na-SO ₄
Sulphur Springs, Dominica	2014 - 2017	1 - 7	29 - 95	26 - 207	38 - 271	163 - 2629	Na-SO ₄
Valley of Desolation, Dominica	2014 - 2017	2 - 7	20 - 99	20 - 2127	9 - 647	10 - 6600	Na-SO ₄
Watten Waven, Dominica	2014 - 2017	2 - 7	25 - 96	8 - 938	12 - 116	10 - 858	Na-SO ₄

Chemical composition of volcanic waters from the Lesser Antilles.

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7. About (the need of) a smart Data Management System

Sergio Espinosa, compañía SEG Geoscience and Exploration en la ciudad de Vancouver, Canadá
sergio.espinosa.geophysics@gmail.com

In oil/gas and mineral exploration as well as in other applications of geological sciences, such as in engineering and shallow subsurface investigations, decisions are always made based on objective measured data and on sometimes subjective interpretations. Such decisions could be for example choosing the right place to drill (e.g. with the expectation of a 50% rate of success in oil exploration, or of a 5% rate of success in the mineral industry) or when calling the red alarm when hydro-technical parameters tell us that a heavy rain might trigger a slope- or tailings dam failure.

Those decisions are based on managing and assessing probabilities in space and time.

An example from daily life could be given as follows: Let's imagine we enter an elevator lobby with four different non-intelligent elevators: two on the left side and two on the right side. When optimizing waiting time, where are we going to wait for the next elevator to leave? We will wait somewhere in the middle of all four, since we do not know what elevator will leave first. But if we have information (sufficient and good data) that the two elevators on the right side have just left, we will locate ourselves somewhere closer to the two elevators on the left side, since they have a higher probability of leaving earlier. This would be just an analogy to e.g. ore transport processes in mining operations.

Another example could be given from the hurricane season. We all have seen on TV the prediction of a hurricane path. The line extending from the actual hurricane eye is the most probable predicted path in space (e.g. hitting Alabama) and time (e.g. in 3 days). The fan opening along this most probable path represents the uncertainty associated with the prediction. So, the longer the prediction, the larger the uncertainty and the wider the fan. However, the more and better meteorological observation data we have, the more certain the predicted path and the narrower will be the path fan. This means that we deal not only with probabilities, but also with associated uncertainties. Also, we will never be certain at 100% where exactly the hurricane will move next. But, as said, something seems to be clear, the more and the better the quality of the empirical data, the more certain the prediction.

So, deciding about where to drill in order to discover economic mineralization, about when to give evacuation alarm because of a slope failure, or about planning those sites where future human settlements and infrastructure will be developed, is always about managing and assessing probabilities and uncertainties in space and time. Those probabilities and uncertainties are always based on acquired historic and on actual data. We want to reduce the risk of failure and increase the probability of success by having the right data and by assuring a high data quality.

So, it is all about probabilities, uncertainties, and risks.

We might calculate deterministic scenarios of flooding based on hard spatial data, such as topography, and on real time monitoring such as precipitation time series, but predicting a catastrophic scenario in the next 100 years needs definitely a probabilistic approach. This means that the eternal discussion about Determinism and Probabilism, two terminologies borrowed from Philosophy, goes on and will probably never end.

When huge amounts of data are available, we definitely need to apply Statistics and Data Mining (the Big Data approach: Machine Learning, in popular and modern vocabulary). For better results, these data need to be managed wisely. So, we need a smart database and GIS system in order to manage our historical and our steadily incoming data. We need a smart Data and Information Management system (DIM) in order to dim the risk and probability of failure.

So, again, it is all about probabilities, uncertainties and risks, and it is about managing data and information.

In our exploration projects, we might not always need a geophysicist, we might not always need a geochemist, we might not always need a specialized geologist, such as a structural geologist. But we will always need a GIS expert and a database manager. In our engineering projects, we might not always need a geophysicist, we might not always need a geological or geotechnical engineer, we might not always need a specialized geologist, such as a hydrogeologist. But we will always need a GIS expert and a database manager. In fact, the GIS and database manager, the data management specialist, should be there even before any single project starts.

The database manager should design the general data architecture, including policies and standards, and should design specific data architectures including the use of abundant metadata for all special disciplines, e.g. for exploration Geophysics, for geochemical certificates used in resource estimation calculations, for time series used in any micro-seismic, InSAR, climatological or hydro-geological monitoring, etc.

Long-term archives and server repositories for day-to-day use should be implemented. Loose data should be brought into structured data, so that they can be used in relational databases and can be visualized and interpreted with industry-standard software.

The human component is also needed. Multi-disciplinary communication among all team members is needed: IT personnel, data management specialists, professionals from special technical disciplines should communicate steadily and smoothly with each other.

Projects have failed, where millions of dollars have been wasted and only little and poor results have been achieved, because of the lack of data QAQC, because of poor data management, and because of lack of communication among team members.

Members of all different technical disciplines should strictly apply QAQC procedures and, together with the Data and Information Management team (DIM), should contribute to design the corresponding data architecture in order to appropriate, to own, as well as to implement the data management standards on a routine basis.

Do we need to add more condiments to this recipe for success? Probably yes.

8. Una nueva estructura computacional en Geografía que no es tan nueva

Katty Fernanda López Escobar, Facultad de Ciencias Naturales de la Universidad de Guayaquil, Ecuador
kathylopez@ug.edu.ec

Wolfram es un nuevo lenguaje que no es tan nuevo. Desde 1980 Stephen Wolfram da a conocer esta herramienta que se va dando paso en varias disciplinas, inicialmente fue elaborado como una herramienta para los matemáticos. En todo este tiempo la han ido adaptando a otras disciplinas, la geografía es una de ellas. A quienes conocemos y usamos los Sistemas de Información Geográfica nos cuesta creer que haya algo que supere lo amigable de un SIG. Pero Wolfram nos permite ir un poco más allá de metadatos y de excelentes presentaciones. Este lenguaje es como tener un SIG y un software matemático, ya que permite presentar resultados estadísticos espacialmente, lo que hace que el análisis y la presentación mejore grandemente. Otra ventaja es que tienes a tu alcance imágenes de satélite de alta resolución, ósea es un Google Earth potenciado. No todo es tan color de rosa y también tiene sus desventajas. Una de ellas es que el manejo y uso ha sido desarrollado en forma de programación e implica aprender comandos y algo de programación, finalmente vale la pena con todo lo que te ofrece. Actualmente Wolfram está ofreciendo capacitaciones y busca investigadores que quieran usarlo, en una próxima publicación podremos compartirles accesos a estas capacitaciones desde sus países.

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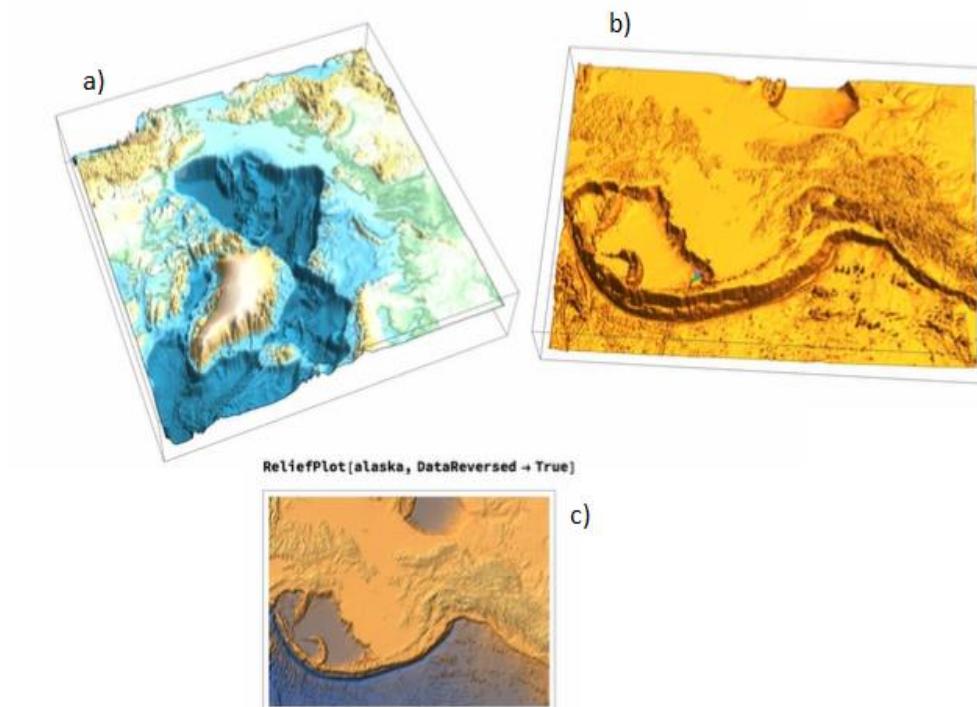


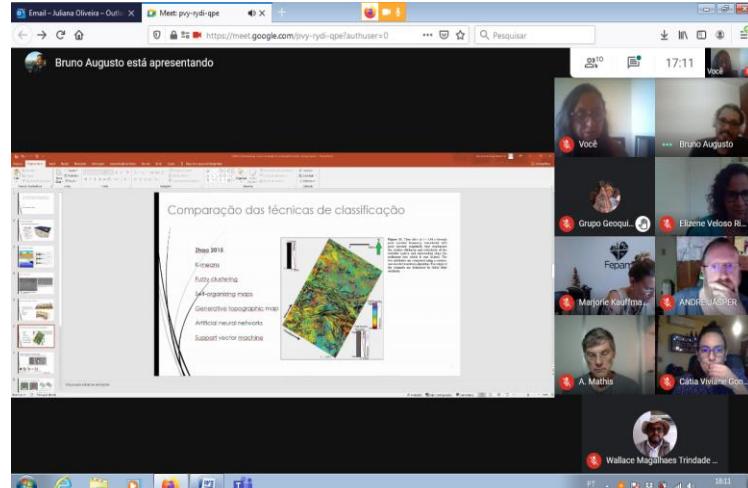
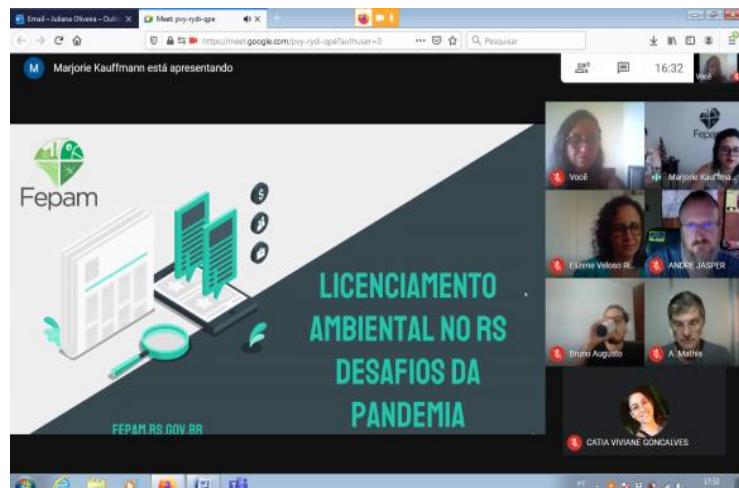
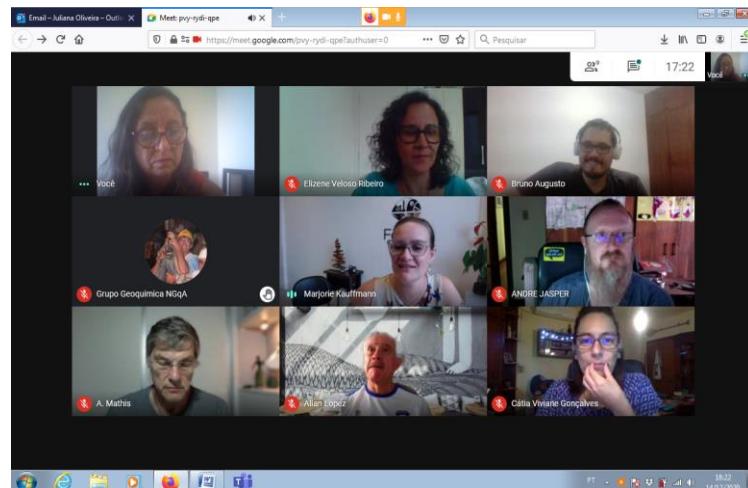
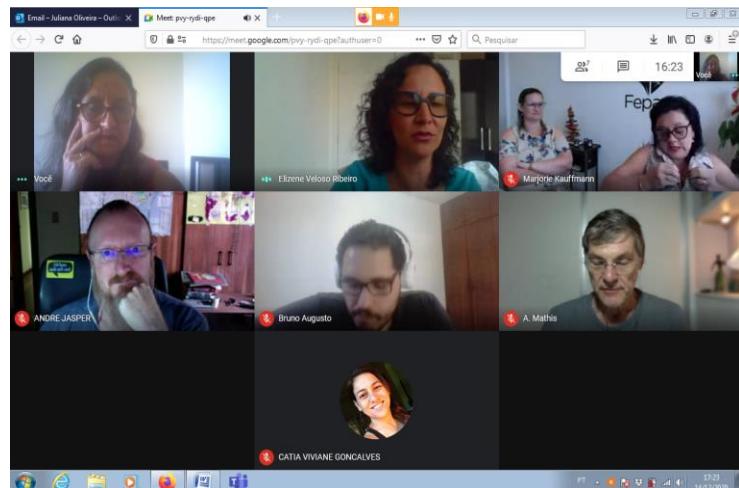
Imagen de un modelado de cotas en Alaska, Wolfram puede seguir editando para profundizar la fosa de la figura o la elevación de sus alrededores. a) Cotas editadas mediante el comando Reverse. b) Variación en color. d) Vista de planta de la zona de interés (Alaska).

9. II Encuentro GOAL Brasil y I Encuentro GOAL Virtual 2020

Juliana Oliveira, Coordinadora Nacional de GOAL-Brasil, jaso_rx@hotmail.com

Un grupo de geocientíficos de la red GOAL Brasil llevo a cabo el II Encuentro Nacional, el 14 de diciembre del 2020, de forma virtual en la plataforma Meet. De esta manera se realizó lo propuesto durante el I Encuentro presencial en Belo Horizonte, en el año 2018, como parte de los Encuentros bianuales.

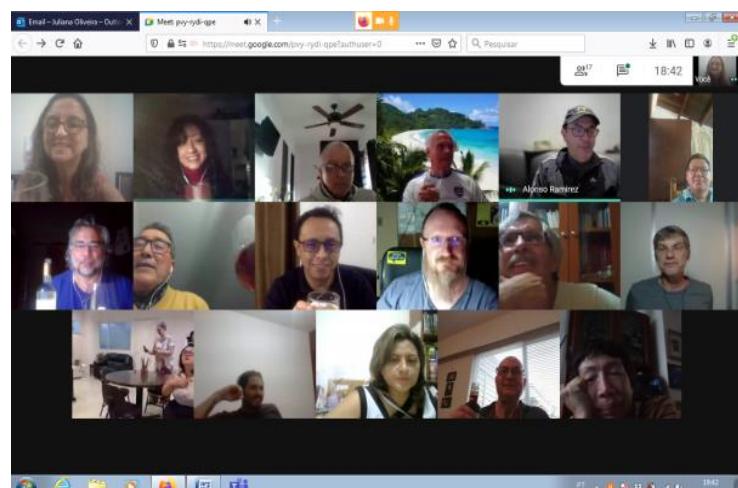
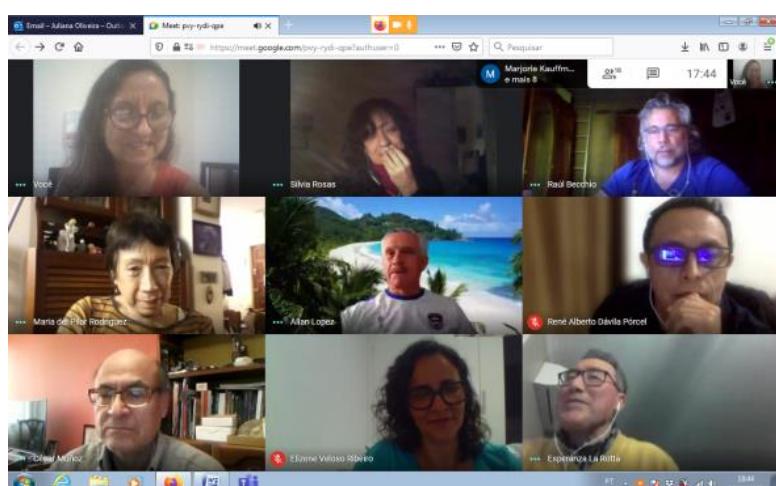
El Encuentro Goal Brasil 2020 consistió de dos partes: En la primera parte se reunieron los participantes brasileños con el objetivo de consolidar la red y discutir diferentes temas generales. En este encuentro se presentaron dos charlas científicas, la primera sobre "La Gestión Ambiental en el Río Grande del Sur y los Desafíos durante la Pandemia" por Marjorie Kauffmann y la segunda sobre "El uso de redes neurales convolucionales para la interpretación de datos sísmicos", presentada por Bruno Augusto Alemão. Estas dos charlas fueron seguidas por una discusión para tratar varios temas de interés general y para terminar se propuso continuar con un encuentro presencial o virtual cada dos años. Durante este encuentro se votó y se aprobó el seguimiento de la coordinadora nacional de Brasil, Juliana Oliveira, hasta el 2022, la cual propuso que se escogiera un nuevo coordinador durante el próximo encuentro.



Newsletter No. 1

June 2021

Durante el “Encuentro a nivel Nacional”, se invitó a nuestros colegas internacionales de la red GOAL, para que ingresaran y participaran durante la segunda parte de la reunión. De esta manera se pudo ampliar la discusión sobre el futuro de la red frente al inminente cambio de los coordinadores alemanes. El resultado del encuentro fue bastante productivo, porque conseguimos concretar y reforzar nuevas áreas de colaboración, como encuentros nacionales e internacionales, y escoger los nombres para los nuevos coordinadores de Alemania. Además terminamos nuestro encuentro con un brindis, despidiéndonos y deseándonos un Feliz Año Nuevo 2021.



10. GOAL's new members



Sergio Espinosa (sergio.espinosa.geophysics@gmail.com), nacido en Nicaragua. Sus estudios universitarios fueron realizados en los campos de Geofísica Aplicada a la Exploración (Diplomado), Geotermia (Maestria) y Sismología (Doctorado) en la Universidad de Freiberg, Alemania. Luego hizo un post doctorado en Sismología en la Universidad Libre de Berlin (Freie Universität Berlin) y fue investigador invitado en el campo de Amenaza Sísmica en GFZ Potsdam. Desde el 2019 trabaja como consultor en el área de geofísica con la compañía SEG Geoscience and Exploration en la ciudad de Vancouver, Canadá. Sergio tiene mas de 20 años de experiencia en minería y exploración de minerales (cobre, oro, zinc, hierro, potasio etc) en diferentes ambientes geológicos, especialmente con énfasis en Latinoamérica. Además tiene experiencia en geofísica aplicada a ingeniería, amenazas naturales y riesgo sísmico.

11. OBITUARIO

Registramos con profundo pesar el fallecimiento de nuestro colega **Néstor Gerardo Molinas Villalba** de GOAL-Paraguay, ocurrido el 11 de abril.

Néstor se desempeñaba como docente y Director de Extensión Universitaria de la Facultad de Ciencias Agrarias de la Universidad Nacional de Asunción-UNA, donde su esposa, la Prof. Dra. Zully Concepción Vera de Molinas, es actualmente la rectora. Realizó estudios de posgrado en la Universidad de Göttingen, y se vinculó a GOAL hace ocho años. Se destacó por su espíritu académico, investigativo y administrativo, a la vez que fue muy dinámico en nuestra red. Para su familia y sus colegas de GOAL-Paraguay van nuestras sentidas condolencias.

De la misma manera, lamentamos el deceso de la geóloga **Rafaela Portilla**, acaecido el 25 de mayo, esposa de nuestro colega paraguayo y Presidente de la Asociación de Geólogos de su país, Juan Carlos Benítez. Hacemos llegar a Juan Carlos nuestro sentido pésame.

12. International Scientific Events

ICGES 2021: 2nd International Conference on Geology and Earth Sciences, July 15-17, 2021 in Singapore. More information: www.icges.org

Geoanalysis 2021: 11th International Conference on the Analysis of Geological and Environmental Materials, 01-06 August, 2021 in Freiberg, Germany. More information: <https://geoanalysis2021.de/en/>

ICGEPP 2021: 15. International Conference on Geothermal Energy and Power Production, August 16-17, 2021 in Istanbul, Turkey. More information: <https://waset.org/geothermal-energy-and-power-production-conference-in-august-2021-in-istanbul>

ICGHVET 2021: 15. International Conference on Geologic Hazards: Volcanoes, Earthquakes and Tsunamis, November 15-16, 2021 in Jeddah, Saudi Arabia. More information: <https://waset.org/geologic-hazards-volcanoes-earthquakes-and-tsunamis-conference-in-november-2021-in-jeddah>

EAGE Conference on Near Surface in Latin America & Online Mineral Exploration Workshop, 3-5 November, 2021. More information: <https://eage.eventsair.com/first-eage-conf-on-near-surface-in-latin-america/abstract-submission-and-instructions>

GOAL Homepage: <https://geonetwork-goal.org>

If you have any question or comments, please contact:
Nury Morales-Simfors, GOAL Newsletter Editor, simforsmoralesnury@outlook.com

Design: Maria Elena Vargas, maelvama@gmail.com

Reviewed by: Reinaldo García, GOAL Regional Coordinator, rgarcia9@gmail.com