Article **Journal of Research and Development**
December 2022, Vol.8 No.22 6-13

Monitoring of cities with tectonic and volcanic activity, Jocotepec and Ciudad Guzmán, Jalisco: Case studies

Vigilancia de zonas tectónica y volcánica activas con población. Estudios de caso, Jocotepec y Ciudad Guzmán Jalisco

PEÑA-GARCÍA, Laura Elizabeth†*, GARAVITO-ESPINOZA, Daniel Alejandro, MACIEL-FLORES, Roberto and ROSAS-ELGUERA, José

Universidad de Guadalajara. Centro Universitario de Ciencias Biológicas y Agropecuarias. Camino Ramón Padilla Sánchez 2100, Nextipac, 44600 Zapopan, Jal.

ID 1er Author: *Laura Elizabeth, Peña-García* / **ORC ID:** 0000-0002-9008-133, **Researcher ID Thomson:** U-4752-2018, **CVU CONACYT ID:** 311129

ID 1er Co-author: *Daniel Alejandro, Garavito-Espinoza*

ID 2do Co-author: *Roberto, Maciel-Flores* / **ORC ID:** 0000-0002-1908-7738, **CVU CONACYT ID:** 206469

ID 3er Co-author: *José, Rosas-Elguera* / **SNI CONACYT ID:** 10786

DOI: 10.35429/JRD.2022.22.8.6.13 Received: July 20, 2022; Accepted: December 30, 2022

Abstract

Jalisco is located in the contact of tectonic plates that have generated earthquakes along the coast and within the continent, its limits include several geological provinces: Central Table, Jalisco Block, Sierra Madre del Sur, Sierra Madre Occidental and Mexican Volcanic Belt, the latter, characterized by its recent volcanic and tectonic activity, within it there are various towns such as Jocotepec and Ciudad Guzmán that, recently, have been affected in their infrastructure by landslides and differential settlements of the land, of which it is unknown for sure. its origin and even when the movement has been reported, it has not been measured as a whole to define if it is a sunken block (which can be associated with tectonism) or it is only a subsidence (extraction of water or decomposition of organic matter). Due to the deformation of the soil in several towns in Jalisco, as is the case of Jocotepec and Cd. Guzmán, it is proposed to implement a methodology that includes the measurement of the deformations that have occurred considering milestones outside the graben, monitoring possible gas emissions (methane and radon) in the cracks, install geophysical equipment to determine if the Curie point is affected and detect punctual seismicity. Keywords; Tectonic trenches, gases, active volcanism, ground deformation.

Tectonic trenches, Active volcanism, Ground deformation

Resumen

Jalisco se ubica en el contacto de placas tectónicas que han generado sismos a lo largo de la costa y dentro del continente, sus límites incluyen varias provincias geológicas: Mesa Central, Bloque Jalisco, Sierra Madre del Sur, Sierra Madre Occidental y Faja Volcánica Mexicana, esta última, caracterizada por su actividad volcánica y tectónica reciente, dentro de ella existen diversas poblaciones como Jocotepec y Ciudad Guzmán que, en fechas recientes, han sido afectadas en su infraestructura por deslizamientos y asentamientos diferenciales del terreno, de los cuales se desconoce con seguridad su origen y aun cuando se ha reportado el movimiento, no se ha medido en su conjunto para definir si es un bloque hundido (que pueda asociarse a tectonismo) o solo es un hundimiento (extracción del agua o descomposición de materia orgánica). Por la deformación del suelo en varias poblaciones de Jalisco, como es el caso de Jocotepec y Cd. Guzmán, se propone implementar una metodología que incluye la medición de las deformaciones ocurridas considerando mojoneras fuera del graben, vigilar las posibles emanaciones de gases (metano y radón) en las grietas, instalar equipo de geofísica para detectar sismicidad puntual.

Fosas tectónicas, Dolcanismo activo, deformación del terreno

Citation: PEÑA-GARCÍA, Laura Elizabeth, GARAVITO-ESPINOZA, Daniel Alejandro, MACIEL-FLORES, Roberto and ROSAS-ELGUERA, José. Monitoring of cities with tectonic and volcanic activity, Jocotepec and Ciudad Guzmán, Jalisco: Case studies. Journal of Research and Development. 2022. 8-22:6-13.

† Researcher contributing as first author.

Article **Journal of Research and Development**
December 2022, Vol.8 No.21 6-13

Introduction

The decade of the nineties was decreed by the United Nations (UN) as the decade for disaster prevention. During this decade, the University of Guadalajara (UdG) carried out the first Risk Atlas for the Guadalajara Metropolitan Area (UdG, 1994). The UN made an account of the disasters that have occurred worldwide and stated that.

The objectives set to prevent disasters were not achieved, so they propose to continue with the necessary actions for an indefinite period of time to achieve the reduction of disasters worldwide. Among these actions were courses (now taught at the undergraduate and graduate levels), dissemination of information resulting from research on hazards and risks, through various publications and through web pages.

The General Law of Ecological Balance and Environmental Protection was created, State Law on Ecological Balance and Environmental Protection and the Law on Civil Protection were created. In addition, the definitions of Risks, Threats and Vulnerability were introduced.

In addition, institutions such as the National Center for Disaster Prevention (CENAPRED) and, at the state and municipal level, Civil Protection Units were created and strengthened.

Five geological provinces converge in Jalisco; Sierra Madre del Sur, Jalisco Block, Sierra Madre Occidental, Mesa Central and Mexican Volcanic Belt, whose ages are 200 million years old to date, besides having a patrimonial sea (where the greatest number of epicenters are registered), islands and marine platform of interest, but little studied, geologically speaking.

Jalisco according to the General Secretariat of the Government of the State of Jalisco - Directorate of Municipal Studies (2022) is located in the central western part of the Mexican Republic (approximate coordinates 20º 34'00" N and 103º40¨35" W), bordered to the west by the Pacific Ocean, to the north by Nayarit, Zacatecas and Aguascalientes, to the northeast by San Luis Potosí, to the east by Guanajuato, to the south by Michoacán and Colima. Jalisco is divided into 125 municipalities, nine of which form the Guadalajara Metropolitan Area, and twelve administrative regions.

Its morphology is varied, starting with the coast of the Pacific Ocean and highlighting some elevations such as; El Nevado de Colima (4,260 meters above sea level), Colima Volcano (3,820 meters above sea level), Sierra de Tapalpa (2,940 meters above sea level), Tequila Volcano (2,940 meters above sea level), Cerro Viejo (2,880 meters above sea level), Sierra el Tigre (2,840 masl), Sierra de Manantlán (2,840 masl), Sierra Alta (2,850 masl), Sierra Huichola (2,860 masl) and Cerro Gordo (2,670 masl).

The main urban and industrial settlements compete for space and water resources in the valleys of La Barca, Ocotlán, Ameca and Guadalajara, which are located within the Chapala, Colima and Tepic-Chapala tectonic basins.

Among the main active tectonic zones are the Chapala graben (including the Cítala graben), Tepic-Chapala and Colima grabens, which converge in the Triple Union located in the Zacoalco de Torres - San Marcos region. Within the Chapala graben there are volcanoes dissected by faults or associated to regional faults of E-W direction.

The aforementioned grabens have been filled by sediments throughout their history. Geothermal wells drilled in San Marcos report 750 m thick sediments, which have intercalations of organic matter and sediments. In the south of Lake Chapala, organic matter has generated chapopotera and methane gas emanation.

ISSN-On line: 2444-4987

The region is tectonically active as evidenced by historical and current seismicity in different parts of Jalisco. On March 25, 1806, a strong earthquake collapsed the vaults of the main temple, burying approximately 2,000 people, Government of Jalisco (2022). In 1568, there was an earthquake with an estimated magnitude of 7.6 that affected the communities of Ameca to Sayula (Suter, 2015). In Cd. Guzmán, on March 25, 1806, a strong earthquake collapsed the vaults of the main temple, burying approximately 2,000 people where there have been strong earthquakes, which have caused the death of thousands of inhabitants (Gobierno de Jalisco (2022)).

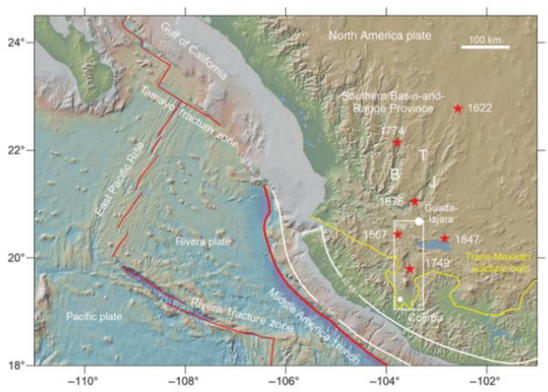

Figure 1 In 1847, in Ocotlán, east of Jocotepec, a 5.7 magnitude earthquake occurred where at least 58 people died
Source: (Suter, 2018)

We present a detailed review in two localities that evidence ground subsidence: Jocotepec and Ciudad Guzmán. The available information is found in scientific journals, popularization, congress abstracts, laws.

Our purpose is to present a proposal to monitor ground subsidence in populations or localities vulnerable to aquifer overexploitation and/or seismic activity.

The identified sites of interest were located using the Google Earth program and periodic feedback was obtained through the Mendeley program, Dianet fins, ScienceDirect Messa, Academia.edu and ResearchGate. From the above, papers associated with the topic and the area of study were selected and are cited as references. The literature review shows that Jocotepec and Ciudad Guzman are located near regional faults such as graben or semi-graben, but also where recent volcanic activity has developed, as in Ciudad Guzman.

Ciudad Guzmán and Jocotepec: Geologic Locations

The western part of the Transmexican Volcanic Belt is characterized by the presence of three tectonic trenches (Figure 1). Jocotepec is located at the western end of the Chapala graben, which had been considered a seismically inactive tectonic depression. However, 1847 a 5.7 earthquake was recorded that caused heavy damage in Ocotlán due to ground motion (Suter, 2018).

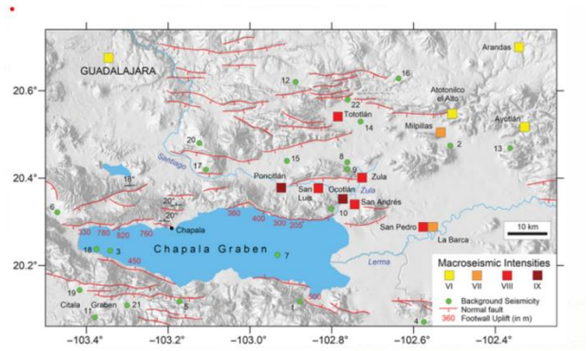

Figure 2 Seismotectonic map of the Chapala graben region showing the macroseismic intensity distribution for the Chapala graben earthquake of October 2, 1847
Source: (Suter, 2018)

The position of the light on this shaded relief map is in the west (Figure 2). Fault traces and the amount of uplift of the footwall are based on interpretation of the topographic relief. Floor wall dips are from Garduño-Monroy et al. (1993) Taken from Suter 2018.

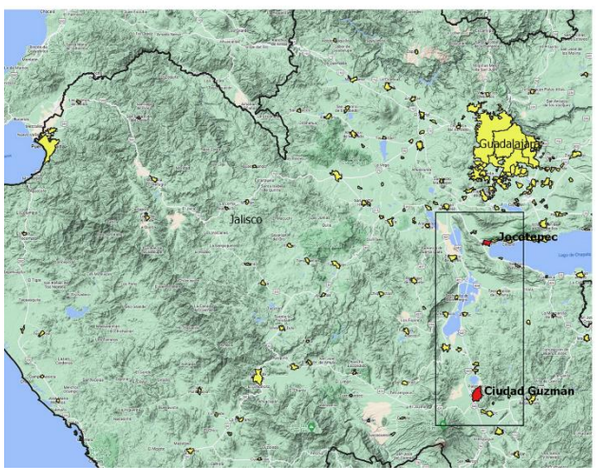

Figure 3 Ciudad Guzmán, located in the Colima graben. On October 22, 1749, there was an earthquake with a magnitude of 5.8 that caused severe damage to the communities of Amacueca, Sayula and Ciudad Guzmán
Source: (Suter, 2019)

ISSN-On line: 2444-4987

Both Ciudad Guzmán and Jocotepec are located in the Transmexican Volcanic Belt whose characteristic is the recentness of its volcanism and seismic activity. This last province, the FVM, in its western section near the Guadalajara Metropolitan area, stops having an E-W orientation and splits to partially have a NW-SE orientation (from Tepic to Guadalajara) associated with the Tepic Chapala graben and another has an almost N-S direction (from Colima to San Marcos), forming part of the Colima graben.

Figure 4 On March 25, 1806, a strong earthquake collapsed the towers and vaults of the main temple, burying approximately 2,000 people (Government of Jalisco (2022)

During the field work carried out, it was observed that the localities identified with recent and continuous affectations are the following: Guadalajara Jocotepec Highway (Mex. 15), between the beltway and the intersection with the junction to Jocotepec, the constant settling of the road causes continuous maintenance. Figure 5 shows the locations with damage).

Current damage

The damage in Ciudad Guzmán today is evident, Figures 5 and 6 is a dramatic example of this. To the south of Ciudad Guzmán there are "abras" (Figure 6), a term coined in the locality to define cracks or deformations of the soil that occur in different parts of the city, following a preferential direction of N45E.

Figure 5 Damaged houses in Cd. Guzmán
Source: (Photo from Maciel-Flores archive)

Figure 6 Abrasions formed in Cd. Guzmán
Source: (Photograph from the Maciel-Flores archive).

As in Ciudad Guzmán, in Jocotepec there are damaged houses that make them uninhabitable, as well as roads with drops close to one meter, such as those illustrated in Figure 7.

Figure 7 Road and houses damaged by a settlement in Jocotepec (Photograph from the Maciel-Flores archive).
Guadalajara - Colima Highway (Mex. 54), kilometer 6 approximately, there is a constant settlement near the intersection with the railroad

ISSN-On line: 2444-4987

Discussion

Aquifer Monitoring

Basically, land subsidence can be related to massive groundwater extraction or tectonic activity. In recent years, in Jalisco, there has been an increase in the cultivation of berries in large greenhouses, as is the case in Jocotepec and Ciudad Guzmán, which is predominantly used in highly developed greenhouses in the municipalities of Jocotepec, Sayula, Ciudad Guzmán, and Tapalpa.

Some researchers, especially in this southern region of Jalisco, have worked to identify the environmental costs that have been generated by the agricultural sector, in the Sayula region for example, the agricultural sector has generated some impacting actions such as the increase in the depth of the water table (Macias-Macias, 2008). The abundance of water in the valley caused a change in land cover and land use between 2000 and 2015 which represents an increase in the extension of protected agriculture or greenhouses in Sayula (Ezzahra et al., 2015). In the regions of Cd. Guzmán, Sayula and Jocotepec, the production of grains and other commodities has been shifted away from the production of grains and other commodities to promote the export of berries.

Macias-Macias and Sevilla (2020) cite that berries "Consume a large amount of water, the scarcest natural resource in our country. Almost 70% of the available fresh water is used in the agricultural sector, although this varies from region to region.

If we analyze Tables 1 and 2, we can see that water use in Jalisco is mainly in the agricultural sector. Table 1, elaborated with data from 2016, and Table 2, elaborated with data from 2019, show the increase of groundwater use in general in the state of Jalisco. This is the reason why several countries have opted to grow their products abroad, in order to conserve the water resource and also in soil, declaring this resource as strategic".

Use of water in Jalisco			
By type of use and source (Hm^3/year), 2016			
Use	Underground	Superficial	Total
Agricultural	1,990	1,729	3,719
Public supply	365	699	1,064
Self-sufficient industry	203	8	211
Total	2,558	2,436	4,994
Source, National Water Information System (SINA-CONAGUA, 2016)			

Table 1 Water use in Jalisco in 2016
Source: (SINA-CONAGUA, 2016)

Use of water in Jalisco			
By type of use and source (Hm^3/year), 2019			
Use	Underground	Superficial	Total
Agricultural	2,007	1,726	3,733
Public supply	371	699	1,070
Self-sufficient industry	211	9	221
Total	2,590	2,435	5,024

Table 2 Water use in Jalisco in 2019
Source: (CONAGUA. 2019. Subdirección General de Administración del Agua)

Table 3 shows the pressure exerted on the water resource in the municipality of Ciudad Guzmán.

Millions of cubic meters per year				
Year	Average annual recharge	Extraction	Average annual availability	Deficit
2007	266	130.92	135.08	0
2009	266.1	163.26	102.84	0
2015	266.1	287.05	0	-20.95
2018	266.1	293.02	0	-26.92

Table 3 Water statistics in the Ciudad Guzmán Aquifer
Source: (Prepared based on data from Diario Oficial de la Federación, August 13, 2007; August 28, 2009; April 20, 2015; January 4, 2018. Macias- Macias and Sevilla (2020)

In a first approximation we underline that the increase in water demand associated with berry crops and population increase requires a higher water extraction that may cause soil settlement.

In a preliminary study, the water table depths of existing wells and wells in the Zapotlán basin were taken. This information was modeled in 3D, the result of which is shown in Figure 4. The geometry of the water table is apparently associated with geological structures oriented N45E and which cause slopes in the aquifer.

ISSN-On line: 2444-4987

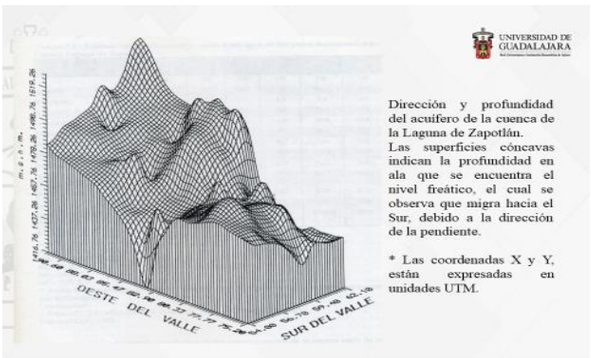

Figure 8 Modeling of the Zapotlán Lagoon aquifer

Seismic Monitoring

Jocotepec and Ciudad Guzmán are localities whose geological history is associated with extensional stresses (Rosas-Elguera, 1996) that formed the Chapala and Colima gabbens. Recent seismic activity has been documented in both cases (Suter, 2018 and 2019).

Figure 9 Proposed location of seismic equipment and accelerographs for Ciudad Guzmán Jal.

Figure 10. Proposed location of seismic equipment and accelerographs for Jocotepec Jal.

In Figures 9 and 10 we present a first approximation of two local seismic/accelerographic networks, one in Jocotepec and the other in Ciudad Guzmán. The purpose in both cases is to determine the ground accelerations, this information can be used to regulate the construction criteria and avoid severe damages that can be translated into human lives.

Acknowledgments

The work was carried out with the support of the Geosciences Academic Corps (CA-974, CUCBA and CUVALLES) and with PRODEP funding for the acquisition of field equipment.

References

Alatorre Zamora, Miguel Ángel, et al. (2015). Chapala half-graben structure inferred. A magnetometric study. Geofísica Internacional; Vol. 54 No. 4, 2015. Recuperado de https://repositorio.unam.mx/contenidos/4102127

CONAGUA. 2019. Subdirección General de Administración del Agua. http://sina.conagua.gob.mx/sina/anexos.html .

de La Fuente-G., J., & Verma, S. P. (1993). Catalogo de aparatos volcánicos de la parte centro-occidental del Cinturón Volcánico Mexicano. *Geofísica Internacional*, *32*(2), 351–386. https://doi.org/10.22201/IGEOF.00167169P.1993.32.2.568

Ezzahra Housni Fátima, Macías Macías Alejandro, Magaña González, Claudia Rocío; Bracamontes Del Toro Humberto; Najine Abdessamad, 2015. *Cambio de uso de suelo por Invernaderos en el Municipio de Zapotlán el Grande, Jalisco: Un análisis Multitemporal*. Revista Ingeniantes Año 2 No. 1 Vol. 1. Available from: https://www.researchgate.net/publication/303897570_Cambio_de_uso_de_suelo_por_Invernaderos_en_el_Municipio_de_Zapotlan_el_Grande_Jalisco_Un_analisis_Multitemporal

Ferrari, L., & Rosas-Elguera, J. (2000). Late Miocene to Quaternary extension at the northern boundary of the Jalisco Block, western Mexico: The Tepic-Zacoalco Rift revised. *Undefined*, *334*, 41–63. https://doi.org/10.1130/0-8137-2334-5.41

Ferriz, H., et al. (1986). Volcanismo riolitico en el eje neo volcánico mexicano. Geofísica Internacional; Vol. 25 No. 1, 1986. Recuperado de https://repositorio.unam.mx/contenidos/42066

ISSN-On line: 2444-4987

Ficha Técnica del Sistema Nacional de Información del Agua. Publicado por la Comisión Nacional del Agua, 2016. Recuperado de http://sina.conagua.gob.mx/sina/anexos.html Tenenbaum, B. A. (1997). Los Sismos en la Historia de México. Tomo 1. By Virginia García Acosta and Gerardo Suárez Reynoso. (Mexico City: UNAM; Centro de Investigaciones y Estudios Superiores en Antropología Social; Fondo de Cultura Económica, 1996. Pp. 718. Illustrations. Bibliography. No Price.). *The Americas*, *54*(2), 295–296. https://doi.org/10.2307/1007753

Zapotlán el Grande | Gobierno del Estado de Jalisco. (n.d.). Retrieved November 20, 2022, from https://www.jalisco.gob.mx/es/jalisco/municipios/zapotlan-el-grande

INEGI. (n.d.). *México en cifras*. Retrieved November 20, 2022, from https://www.inegi.org.mx/app/areasgeograficas/?ag=14#collapse-Resumen

Medina Orozco, L. E., Alí, S., Nava, V., Alexander, ;, Duque, S., González Villegas, R., Barrales Martínez, A., Medina Orozco, I. N., & Rivas, M. A. P. (n.d.). *Estimación de la Huella hídrica, calidad de agua y alternativas para la producción de arándano en el centro de México*. Retrieved November 20, 2022, from https://www.convibra.org/congresso/res/uploads/pdf/artigo_pdf4KTlrM16.04.2021_20.40.45.pdf

Instituto de Geología - UNAM. (n.d.). *Carta Geológica Mexicana*. Retrieved November 20, 2022, from https://www.geologia.unam.mx/contenido/carta-geologica-mexicana

Lugo-Hubp, J. (n.d.). *El relieve de la República Mexicana | Revista Mexicana de Ciencias Geológicas*. Retrieved November 20, 2022, from http://satori.geociencias.unam.mx/index.php/rmcg/article/view/1255

Macías Macías, A., & Sevilla García, Y. L. (2021). Naturaleza vulnerada. Cuatro décadas de agricultura industrializada de frutas y hortalizas en el sur de Jalisco, México (1980–2020). *Entre Diversidades. Revista de Ciencias Sociales y Humanidades*, *8*(1), 64–91. https://doi.org/10.31644/ED.V8.N1.2021.A03

Macías Macías, A. (2008). Costos ambientales en zonas de coyuntura agrícola: La horticultura en Sayula (México). *Agroalimentaria*, *13*(26), 103–118. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1316-03542008000100008&lng=es&nrm=iso&tlng=es

Maciel F. R. y Rosas Elguera J. G. 2006a, An extensión between the Sierra Madre Occidental volcanic arc and Trans-Mexican Volcanic Belt volcanic arc: a volcano sedimentary evidence. International Conference on Continental Volcanism—IAVCEI 2006. *Undefined*.

Maciel Flores Roberto 1981. Geological Mapping in Geothermal Exploration with Special References to Tephochronology and Paleomagnetic Techniques. UNU-GTP

Maciel Flores Roberto, & Universidad de Guadalajara. (2006). *Evolución bio-geológica, durante el Pleistoceno, en la Sierra de la Primavera, Jalisco, México*. http://repositorio.cucba.udg.mx:8080/xmlui/bitstream/handle/123456789/4714/Maciel_Flores_Roberto.pdf?sequence=1&isAllowed=y

Maciel-Flores, M.-T. y R.-E. (2015). *La biodiversidad en Jalisco: Estudio de Estado*. https://www.biodiversidad.gob.mx/region/EEB/estudios/ee_jalisco

Maciel Flores Roberto, Maciel Tejeda Christian Alexander, Rosas Elguera José Guadalupe, Peña García Laura Elizabeth, García García Edith Xiomara, González Rendón Ruth Leticia, Gómez Rizo Rodrigo. 2021. Prometeo ediciones.

Maciel-Flores Roberto, Rosas-Elguera José, Peña García Laura Elizabeth, Robles Munguía Celia, García García Edith Xiomara, Zamudio Ángeles David, Palacio Prieto José Luis, Maciel Tejeda Christian Alexander. 2020. Geositios de interés como geopatrimonio en Jalisco, México. Avances. Universidades, cultura y desarrollo sostenible. Universidad Autónoma de Zacatecas «Francisco García Salinas» © Instituto Regional del Patrimonio Mundial en Zacatecas.

ISSN-On line: 2444-4987

Mahood, G. A. (1980). Geological evolution of a pleistocene rhyolitic center — Sierra La Primavera, Jalisco, México. *Journal of Volcanology and Geothermal Research*, *8*(2–4), 199–230. https://doi.org/10.1016/0377-0273(80)90105-5

Michaud François, Bourgois Jacques, & Parrot Jean-François. (n.d.). *Tectonic development of the Jalisco triple junction (Western Mexixo)*. Retrieved November 20, 2022, from https://www.researchgate.net/publication/262142534_Tectonic_development_of_the_Jalisco_triple_junction_Western_Mexixo

Rosana, I., Arturo SANDOVAL José Alfredo Cih, M. I., & Moreno Sandoval, A. J. (n.d.). *La agricultura por contrato: Berries en Jalisco*. Retrieved November 20, 2022, from https://www.ecorfan.org/handbooks/Handbook_Produccion_Comercializacion_y_Medio_Ambiente_T1V1/Particiones/1.pdf

Nieto Samaniego, A. F. (2000). Avances de la Geología Mexicana en la última década. *Boletín de La Sociedad Geológica Mexicana*, *53*(1), i–iv. https://doi.org/10.18268/BSGM2000V53N1X1

Peña García Laura Elizabeth 2009. Contaminación por nitratos y nitritos en los acuíferos de la comunidad de río Blanco Jalisco; y evaluación de sintomatología asociada a metahemoglobinemia en niños menores de cuatro años de edad. Tesis de Maestría en Salud Ambiental. CUCBA. http://repositorio.cucba.udg.mx:8080/xmlui/handle/123456789/4839

Rosas-Elguera, J., Urrutia Fucugauchi, J., & Maciel Flores, R. (n.d.). *Geología del extremo oriental del Graben de Chapala, breve discusion sobre su edad: Zonas geotermicas Ixtlán de Los Hervores-Los Negritos, Mexico*. Retrieved November 20, 2022, from https://www.researchgate.net/publication/290826996_Geologia_del_extremo_oriental_del_Graben_de_Chapala_breve_discusion_sobre_su_edad_Zonas_geotermicas_Ixtlan_de_Los_Hervores-Los_Negritos_Mexico

Rosas-Elguera, J., Nieto O. J., and Urrutia-Fucugauchi, J., 1993, Ambiente estructural en la frontera norte del bloque Jalisco, in Delgado-Argote, L., and Martín-Barajas A., Contribuciones a la tectónica del Occidente de México: Unión Geofísica Mexicana. Monográfica. Secretaría de Medio Ambiente y Recursos Naturales/ Comisión Nacional de Áreas Naturales Protegidas/ Logros 2019 (1ra Ed.) México Hecho en México / Made in México.

Gobierno del Estado de Jalisco. (n.d.). *Regiones de Jalisco*. Retrieved November 20, 2022, from https://www.jalisco.gob.mx/es/jalisco/regiones

Sandoval Moreno, A., & Ospina Parra, C. E. (2011). Sustentabilidad ambiental en el manejo del agua y del suelo en la producción de berries: los casos de México y Colombia. *Ambiente y Desarrollo, ISSN-e 0121-7607, Vol. 15, Nº. 28, 2011, Págs. 99-122*, *15*(28), 99–122. https://dialnet.unirioja.es/servlet/articulo?codigo=3937720&info=resumen&idioma=SPA

Instituto de Medio Ambiente y Comunidades Humanas. - CUCBA. (n.d.). Retrieved November 20, 2022, from http://saludambiental.udg.mx/instituto-de-medio-ambiente-y-comunidades-humanas/

Suter, M. (2019). Macroseismic study of the devastating 22⇓23 October 1749 earthquake doublet in the northern colima graben (trans-mexican volcanic belt, Western Mexico). *Seismological Research Letters*, *90*(6), 2304–2317. https://doi.org/10.1785/0220190162

Suter, M. 2018. Macroseismic Study of the Devastating 22– 23 October 1749 Earthquake Doublet in the Northern Colima Graben (Trans-Mexican Volcanic Belt, Western Mexico) Seismological Research Letters Volume 90 (6). pp 2304- 2317. https://doi:10.1785/0220190162

ISSN-On line: 2444-4987