International Journal of Geosciences, 2015, 6, 1367-1385
Published Online December 2015 in SciRes. http://www.scirp.org/journal/ijg
http://dx.doi.org/10.4236/ijg.2015.612108

Scientific Research Publishing

Atypical Variations of Water Conductivity Prior to Tectonic Earthquakes

Fidel Martínez-García[1,2*], Arturo Colín-Cruz[2], Salvador Adame-Martínez[3], Jorge J. Ramírez-García[2]

[1]Center of Proposed Drafts of the South Pacific, Federal Electricity Commission, Cuernavaca, Morelos, Mexico State, Mexico
[2]Faculty of Chemistry, Autonomous University of Mexico State, Toluca de Lerdo, Mexico State, Mexico
[3]Faculty of Urban and Regional Planning, Autonomous University of Mexico State, Toluca de Lerdo, Mexico State, Mexico
Email: *fidel.martínez@cfe.gob.mx, *fmg1376@yahoo.com.mx

Received 5 November 2015; accepted 26 December 2015; published 29 December 2015

Abstract

Within the framework of precursor events related to earthquakes, this paper analyzes the possible effect on the aquatic environment of the surrounding energy that accompanies earthquakes, particularly in the area where oceanic and continental plates collide (Cocos Plate and North American Plate, south of Mexico). As a preamble, the types of precursor events, characteristics, and their possible origin are described. A project was designed under the assumption that in areas with high frequency and intensity seismicity there is an electrical and electromagnetic potential promoter which is detectable and assessable indirectly by measuring water conductivity behavior, which also may have atypical variations of data; the outcome of intensive conductivity monitoring in different settings, natural as well as manmade (wellsprings, artesian well and a cistern), are presented herein. The results of the conductivity monitoring for seven months, highlight two patterns in data behavior: one pattern shows the subtle dependence of data behavior on the geographic location of data monitoring instruments, revealing that could have a slight relationship between areas with increased seismic frequency and intensity and the presence of atypical conductivity variations. Another pattern reveals the possible relationship between atypical variations in conductivity and subsequent earthquake events; a total of 241 seismic events were analyzed and 59 of them are provided as evidence related with patterns mentioned.

Keywords

Earthquakes, Precursor Events, Natural Water Conductivity, Subduction Plates, Cocos Plate, Electromagnetic Fields, Earth's Electromagnetic Pulses

*Corresponding author.

How to cite this paper: Martínez-García, F., Colín-Cruz, A., Adame-Martínez, S. and Ramírez-García, J.J. (2015) Atypical Variations of Water Conductivity Prior to Tectonic Earthquakes. *International Journal of Geosciences*, **6**, 1367-1385.
http://dx.doi.org/10.4236/ijg.2015.612108

1. Introduction

Frequently, phenomena linked to earthquake are associated with the interaction of the electric and electromagnetic energy emanating from the Earth's interior with surrounding natural environment. The power of energy ionization upon reaching the surface through faults or unstable areas is manifested by low frequency electromagnetic waves [1]-[5]; alterations of the local ionosphere [6]-[14]; luminous phenomena in the local atmosphere [15]-[17]; and the formation of aerosols and clouds [1] [2] [4] [5] [18]-[20]. Energy flow and electromagnetic fields also strengthen and promote the attraction of surrounding radiation issuing from each fracture of rock, thus intensifying the presence of ionizing energy, similar to the phenomenon that occurs near power transmission lines [21] [22].

Usually, these types of phenomena are associated with various origins: one is apparently related to the internal dynamics of the Earth's deep layers which cause electric and electromagnetic energy pulses that interact with the external layers by lithosphere fractures [1] [2] [18]. Another possible origin is mechanical and relates to the endogenous forces generated in the fault zones, particularly due to the movement of the Earth's crust [2] [23]; these phenomena have also been associated with the natural decay of unstable radioactive isotopes such as uranium, radium, radon, polonium, lead, and bismuth [7]-[9] [11] [12] [24]-[26]. A further cause, also mechanical in nature, is linked with endogenous forces that develop in the tectonic faults and their effect at the molecular level, specifically on the minerals that make up the rock, which results in the formation of an electric and electromagnetic potential flowing within a radius of several kilometers [27]-[32]. This energy has the ability to interact with surrounding water bodies, affecting the behavior of terrestrial and aquatic life prior to and subsequent to an earthquake [31]-[33]. A recently published example is the behavioral changes found in some amphibians due to disturbances among K^+, Na^+, Cl^-, and Ca^{2+}, ions present both inside and outside the cell membrane [31] [32]; the presence of an external electric field triggers an ionic oscillation or vibration which exerts a strong internal pressure in terms of electric charge [34].

Based on the above considerations, research relying on two hypotheses was designed. The first one states that such electric and electromagnetic potential is indirectly detectable and calculated with conductivity measuring instruments, particularly in areas where oceanic and continental plates collide and where seismic activity is frequent and intense. The second one is that the natural energy emanating from the surrounding environment (electromagnetic field and electric potential) could interfere with the normal functioning of the instruments being used, causing unusual variations in conductivity measurements, possibly by interrupting ionic conduction. According with this, a series of measurements to monitor conductivity in aquatic environments were performed in two different settings: a natural setting consisting of wellsprings, and a semi controlled setting using a cistern (tank) and an artesian well.

2. Study Area Description

After Japan, Indonesia, Chile, Papua New Guinea and Turkey, Mexico is one of the countries with the most seismic activity in the world, and data about its territory and its history on the subject dates from 1460 to the present day [35], **Figure 1**. Based on this frame of reference, monitoring sites were selected within the states of Guerrero, Oaxaca, and Morelos close to areas with a significant seismic history. These sites were located in the C and D seismic regions of the Mexican national territory (**Figure 1**), associated with the subduction process of the Cocos Plate, which moves beneath the North American Plate at a rate of six centimeters per year, and shifts 300 kilometers almost horizontally to enter the mantle with a 55˚ inclination angle [36].

For the development of this research, painstaking monitoring of the conductivity was carried out in an aquatic environment by a brief series of time, monitoring 90 days using two different settings: a natural setting, consisting of wellsprings and, a semi artificial setting using a cistern and an artesian well. The chosen wellsprings are located at coordinates 17˚33.606'N, 99˚24.583'W and 18˚28.697'N, 99˚9.209'W, **Figure 2** and **Table 1**. The first site is located in the town of Tixtla in the state of Guerrero, Mexico, and it belongs to a recreational center called "Teoixtla" in an area having a geology of sedimentary volcanic rock and gypsum from the Neogene period [37]. The second site is located in the town of Tlaquiltenango in the state of Morelos, Mexico. It is also a recreational center, called "Los Manantiales", having a geology of Paleogene rhyolites [38]. The semi artificial site corresponds to an artesian well of 1 × 1 × 6 meter located at the geographic coordinates 16˚14.180'N, 98˚11.406'W (**Figure 2**) in the community of "Corralero", a municipality of Pinotepa Nacional in the state of Oaxaca, Mexico, site located in a region with the largest number of earthquakes per square kilometer. The geomorphology and

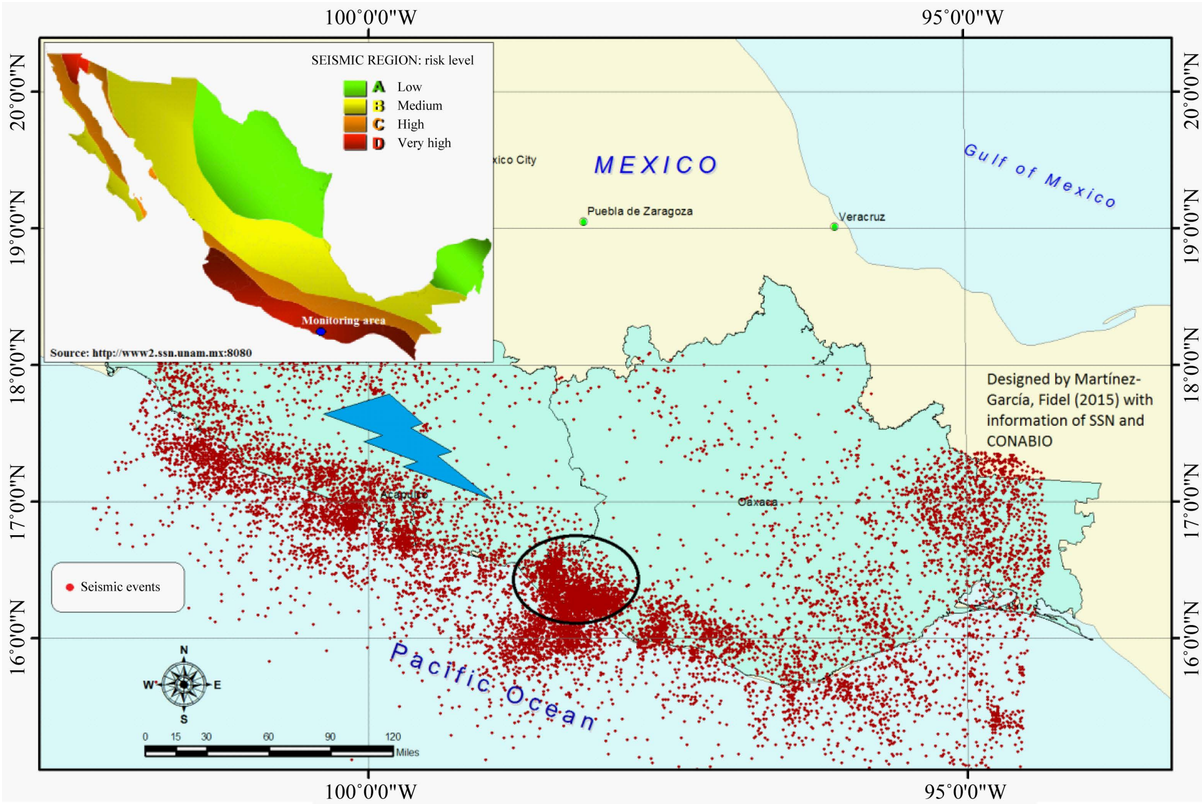

Figure 1. Study area location as regards the seismic regions of Mexico. The area has the highest number of earthquakes per km^2, corroborated by processing 12757 seismic events (red points) in a geographic information system, occurred in the states of Guerrero and Oaxaca, Mexico, from 2006 to 2014 with a range of magnitude between 3.5 to 7.4 Mw. Additional Mapping information was obtained of National Commission for Knowledge and Use of Biodiversity (CONABIO: http://www.conabio.gob.mx).

Table 1. Monitoring periods of selected sites.

Site	Start date	Date ending	Monitoring period (days)
Teoixtla	22/09/2014	28/09/2014	6
Teoixtla	29/09/2014	05/10/2014	6
Teoixtla	06/10/2014	12/10/2014	6
Los Manantiales	13/10/2014	19/10/2014	6
Cistern	04/11/2014	10/11/2014	6
Cistern	15/11/2014	21/11/2014	6
Cistern	06/12/2014	12/12/2014	6
Cistern	13/12/2014	19/12/2014	6
Corralero	19/01/2015	26/01/2015	14
Corralero	26/01/2015	02/02/2015	14
Corralero	03/02/2015	10/02/2015	14

geology of this area correspond to a coastal plain with Quaternary alluvial material. Another semi artificial setting corresponds to a cistern located at coordinates 18˚53.377'N, 99˚12.293'W, with no specific geology. This site corresponds to a 2 × 2 × 1.8 meter reservoir; its liquid content was in contact with the field's surrounding environment through a grounded electrode, using an iron bar buried 60 centimeters deep.

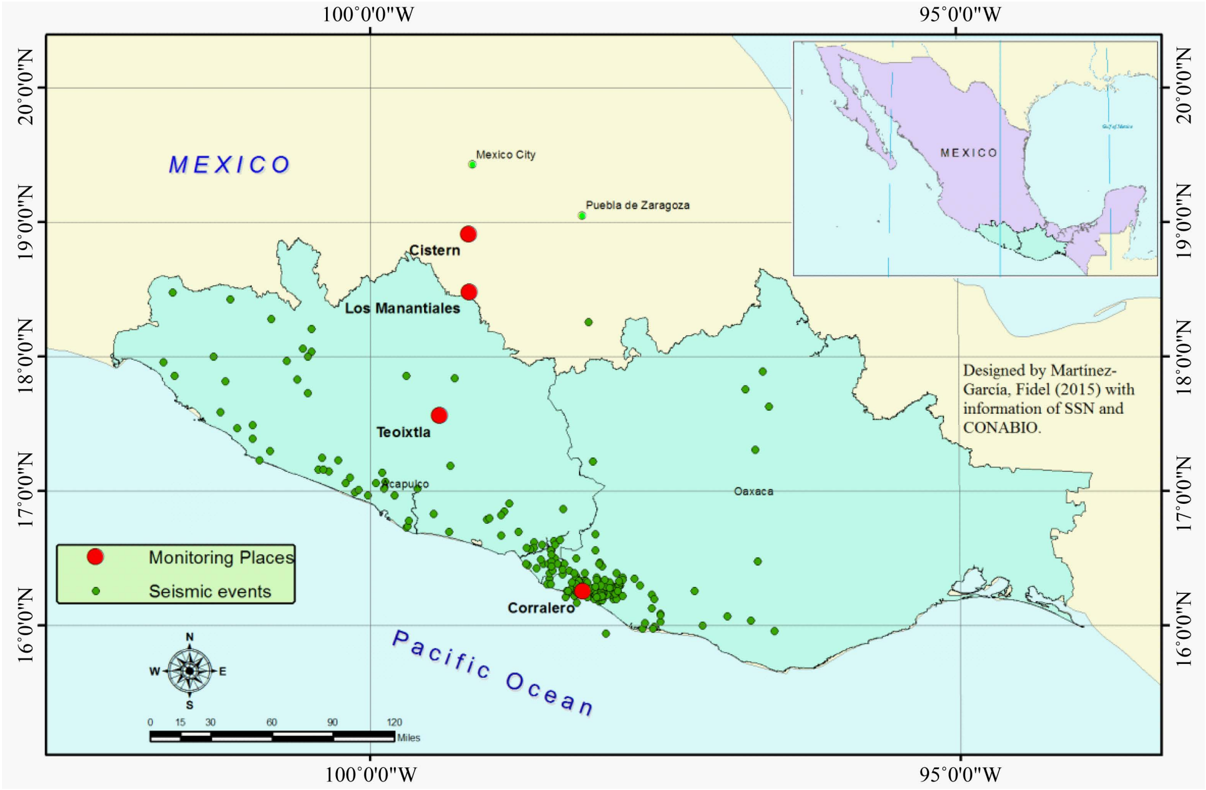

Figure 2. Study area location of the monitoring sites. Seismic events used corresponded to 241: 25 events for "Teoixtla", 9 events for "Los Manantiales," 101 events for "Cistern", and 106 events for "Corralero".

3. Materials and Methods

Intense monitoring in the sites above mentioned ware conducted using by submersion, a HOBO U24-001 Data Logger to determine conductivity (μS/cm), complementarily a HI 9828 multiparameter meter was used, to determine water quality (**Figure 3**). Each site was continuously monitored at a sampling frequency of 45 seconds on average, representing a total collection of 18,550 data per monitoring period obtained at least during two weeks per each campaign. Readings of basic water quality parameters of ˚C, pH, Dissolved Oxygen (ppm), and salinity were determined every second with the HI 9828 device for a period of 30 minutes, from which the average value was calculated; monitoring periods for each of the settings are included in **Table 1**.

Information of all >Mw3.0 earthquakes occurred within each monitoring period was gathered, particularly within the territorial limits of the states of Guerrero and Oaxaca, Mexico. Data was obtained from the National Seismological Service (SSN: http://www2.ssn.unam.mx:8080/index.html) of Mexico. Concerning the well-springs, only information of seismic events located within a radius not greater than 220 kilometers was gathered. Seismic events obtained for the cistern were located at a distance not greater than 320 kilometers. In both cases, the magnitudes of the earthquakes were normally not higher than 4.5 degrees; however, any earthquake with a magnitude of 5 or greater was addressed regardless of its distance from the location where the conductivity Data Logger had been installed. Regarding the seismic data obtained for the artesian well, the distance was not greater than 50 kilometers, taking in a count that this site is located in a place with the highest seismicity of the region. The general criteria employed to vary the distances was the instrument's geographic position in relation to seismic events occurring in the surrounding area as well as the speed and distance of seismic wave propagation in the ground and the area of influence.

Tabulated data of seismic events obtained from SSN were imported to a geographic information system (GIS) for spatial distribution. The position in geographic coordinates of the Data Logger were taken as reference to filter seismic data according to the place of monitoring (**Table 2**), and the distance of each seismic event was determined in relation to the Data Logger position. The resulting table was edited, removing events located in

Figure 3. Equipment used: (a) HOBO Conductivity Logger U24-001 and (b) HI 9828.

Table 2. Quantification of seismic events used during the study at each site.

Filtered seismic events			
Site	Starting	Ending	Events
Teoixtla	Sept/22/2014	Sept/27/2014	8
Teoixtla	Sept/29/2014	Oct/04/2014	6
Teoixtla	Oct/06/2014	Oct/11/2014	11
Los Manantiales	Oct/13/2014	Oct/18/2014	9
Cistern	Nov/04/2014	Nov/11/2014	18
Cistern	Nov/15/2014	Nov/22/2014	24
Cistern	Dec/06/2014	Dec/12/2014	12
Cistern	Dec/13/2014	Dec/20/2014	47
Corralero	Jan/19/2015	Jan/25/2015	14
Corralero	Jan/26/2015	Feb/01/2014	36
Corralero	Feb/03/2014	Feb/09/2014	12
Corralero	Feb/10/2014	Feb/15/2014	14
Corralero	Feb/16/2014	Feb/22/2014	14
Corralero		Mar/01/2014	16
		Total	**241**

the marine environment as well as those located beyond the distances set in the aforementioned criterion. Information was plotted for each of the locations listed in **Table 2**, using the 18,550 conductivity data obtained with the HOBO conductivity U24-001. Every seismic event shown in the list resulting from the filtering process was positioned in each chart according to the day and time it occurred; this process was replicated for each of the monitored locations.

4. Results

For the wellsprings, cistern and the artesian well, variations in the frequency of the monitoring sampling did not represent any significant changes at the time of processing and plotting the results. Another aspect that distinguished the chosen sites, besides their geological conditions, was their geographical position (**Figure 2**), both that of the instruments as that of the seismic events that occurred in the surrounding area. The monitoring sampling was during a 90 day period, from September 22, 2014 to March 1, 2015: 18 days corresponded to the "Teoixtla" site, 6 to the "Los Manantiales" site, 24 to the "Cistern" site, and 42 to the "Corralero" site, although they were short periods of time it was detailed monitoring. The assessment period for the "Los Manantiales" site was the shortest with one week; more monitoring time was considered unnecessary due to the presence of excessive "interference or noise" detected at the time of plotting data (**Figure 4**). Noisiness may have been due to two possible causes: a) the Data Logger operation was interfered with by a strong drift or movement, the device being located in a place with an intense current flow; or b) the possible presence of an underground river located relatively close to the wellspring being monitored, the undercurrent being located at approximately 1500 meters, its influence could be due to the continuous aquifer recharge and the presence of ions and possibly radioactive gases like radon [5] [39]-[41]. The most intensive sampling took place in the location called "Corralero" as this site is characterized by intense seismic activity. Historically, the surrounding area is where the greatest number of earthquakes per square kilometer occurs, **Figure 1**. During monitoring, seismic events occurred as close as one kilometer away from monitoring instruments.

The location of each seismic event in the Data Logger chart showed an interesting series of patterns. The first pattern observed was the dependence of the atypical readings of conductivity on the geographic location of the monitoring instruments, revealing that there is a possible relationship between areas with greater seismic frequency and intensity and the occurrence of higher atypical conductivity drops behaving such as pulses. As the distance between the Data Logger and the area with the greatest seismic frequency and intensity was reduced, data showed more atypical and more defined conductivity changes. Therefore, the spatial variation of conductivity (μS/cm) at the "Los Manantiales" site has a very confusing pattern (**Figure 4**), it was very regular at the

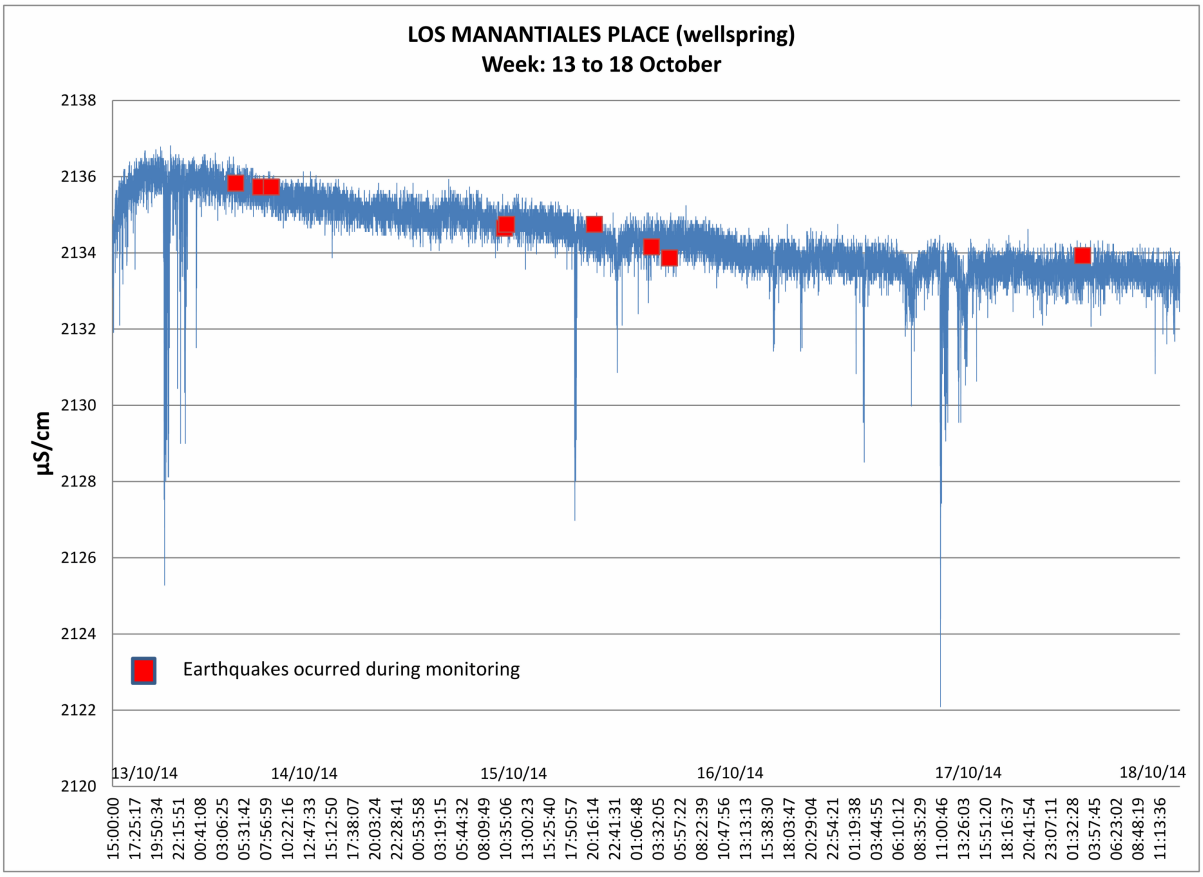

Figure 4. Conductivity pattern behavior in the "Los Manantiales" site. Its monitoring was suspended for reasons mentioned above. The average values of the quality of water obtained with HI 9828 were: Temperature (˚C) 29.18 pH 6.57; 0.97 ppm Dissolved Oxygen and 0.91 salinity.

"Cistern" site (**Figures 5-8** and **Table 3**), and it had a very erratic character at the "Teoixtla" site (**Figures 9-11**). The "Corralero" site showed the greatest variation, having a more defined pattern as well as an average of seven conductivity incidents per week, **Figures 12-17**.

Another pattern reveals the probable relationship between changes or atypical conductivity drops and the subsequent occurrence of earthquakes. According to these two patterns, one of the most notably changes observed occurred first at the "Teoixtla" site (**Figures 9-11** and **Table 4**).

Based on the two patterns observed, the "Corralero" site differed from the other sites used for monitoring conductivity; one similar patterns had already been observed at the "Teoixtla" site described in previous paragraphs. Variations in conductivity measurements were more perceptible at the "Corralero" site as the Data Logger was closer to the area with the greatest number of earthquakes per square kilometer. During the week of January 19 to 25, six major variations occurred, two of them very close to each other (21/01/15); five of them preceded five seismic events. During the week of January 26 to February 1, six variations occurred; five of them were preceded by six seismic events. Details of atypical conductivity drops in these periods are shown in **Figure 12**, **Figure 13** and **Table 5**.

During the weeks from February 3 to 9 seven of atypical conductivity behaviors occurred, respectively, as shown in the **Figure 14** and three variations occurred in a single day (07/02/15). In the first week, **Figure 14**, three of the variations were preceded by seismic events; from February 10 to 15, four atypical variations occurred, two of which were preceded immediately by seismic events, **Figure 15** and **Table 6**.

For the period of the week from February 16 to 22, nine atypical readings occurred with three major preceding seismic events, **Figure 16**. During the week from February 23 to March 1st, nine atypical readings occurred, four of which were preceded by four nearby earthquakes, **Figure 17** and **Table 7**. At the "Corralero" site, aver-

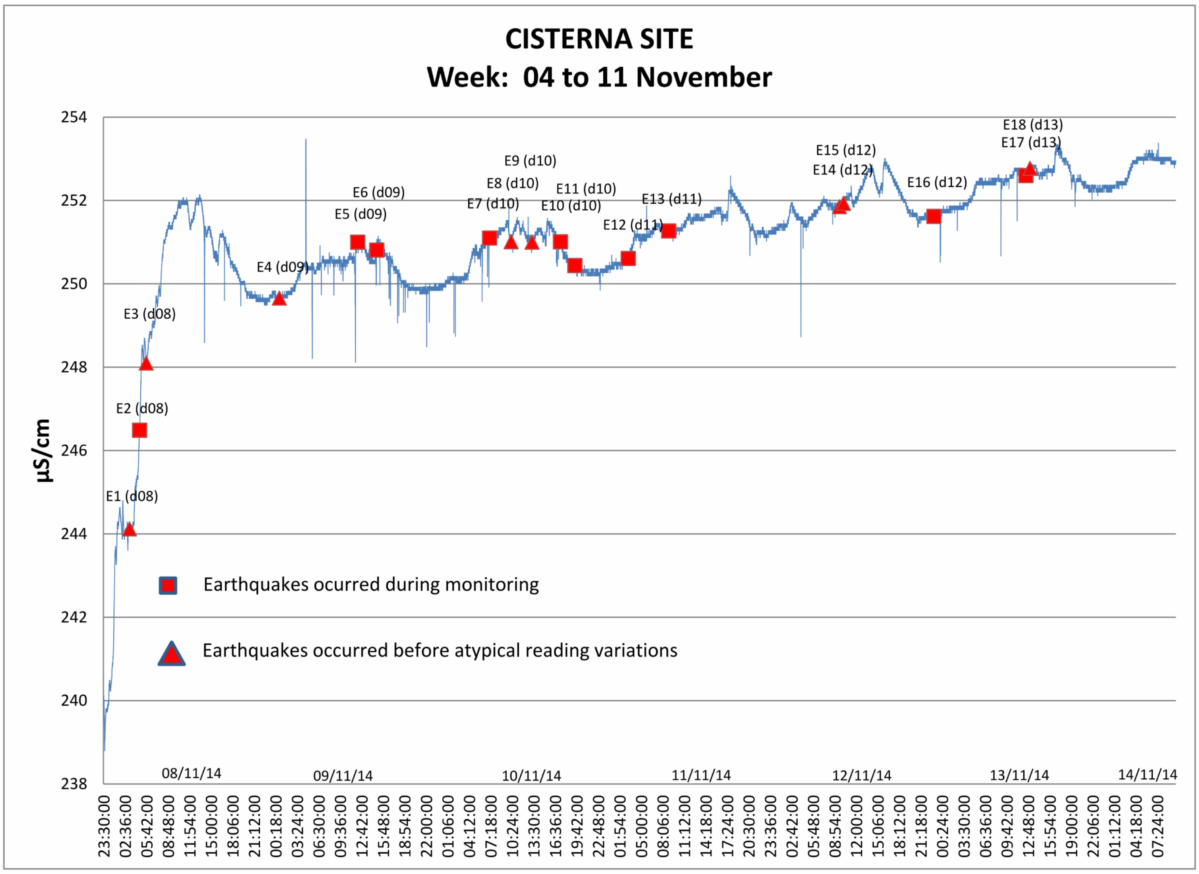

Figure 5. Conductivity pattern behavior in the "Cistern" site, period November 04 to 11. Total seismic events recorded during monitoring: 18. The average values of the quality of water obtained with the HI 9828 were: T (˚C) 24.35 pH 9.31, 5.51 ppm OD and 0.16 salinity.

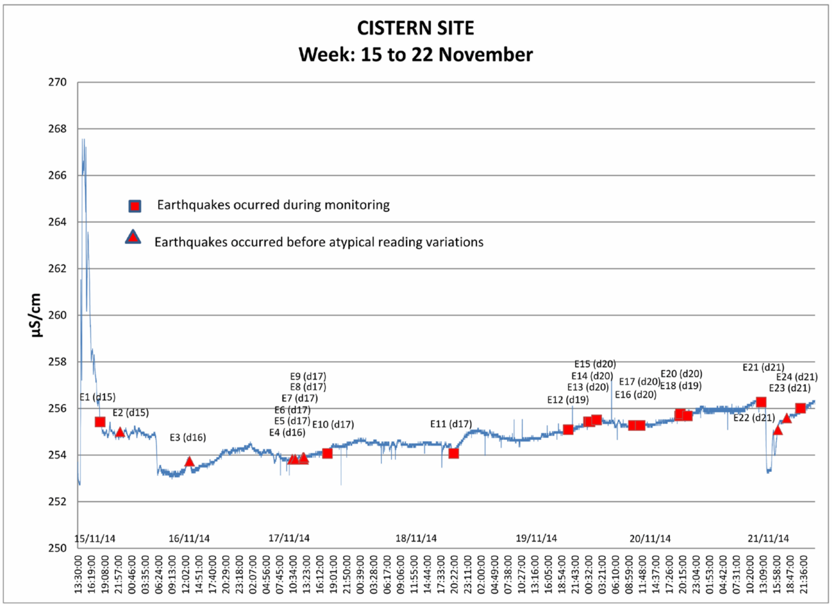

Figure 6. Conductivity pattern behavior in the "Cistern" site, period November 15 to 22. Total seismic events recorded during monitoring: 24. The average values of the quality of water obtained with the HI 9828 were: T (˚C) 24.35 pH 9.31, 5.51 ppm OD and 0.16 salinity.

Table 3. General characteristics of most notably seismic events in the "Cistern" site.

Event	Date	Time	Lat	Long	Depth	Magn.	Zone	Figure
1	11/08/14	03:14:23	16.23	−97.61	9	4.0	Southwest of Tataltepec, Oaxaca State	5
3	11/08/14	05:40:10	17.96	−101.76	52	4.0	East of Lázaro Cárdenas, Guerrero State	5
4	11/09/14	00:51:06	16.68	−98.09	18	3.6	East of Ometepec, Oaxaca State	5
8	11/10/14	10:16:25	18.43	−101.19	58	3.8	Northeast of Zihuatanejo, Guerrero State	5
9	11/10/14	13:17:39	16.00	−97.18	23	3.7	Northwest of Puerto Escondido, Oaxaca State	5
14	11/12/14	09:36:18	16.30	−97.88	23	3.6	East of Pinotepa Nacional, Oaxaca State	5
15	11/12/14	10:11:40	17.19	−99.32	51	3.6	Northeast of Tierra Colorada, Oaxaca State	5
18	11/13/14	13:04:18	17.86	−99.69	57	3.9	Southeast of Chilpancingo, Guerrero State	5
2	15/11/14	22:23:02	17.89	−96.66	71	3.7	Southwest of Tuxtepec, Oaxaca State	6
3	16/11/14	12:56:40	17.30	−100.85	49	3.5	Northwest of Tecpan, Guerrero State	6
4	17/11/14	10:28:21	16.47	−98.05	25	3.7	North of Pinotepa Nacional, Oaxaca State	6
5	17/11/14	11:01:54	16.31	−98.24	20	3.6	West of Pinotepa Nacional, Oaxaca State	6
7	17/11/14	12:44:15	16.25	−98.11	30	3.5	Southwest of Pinotepa Nacional, Oaxaca State	6
8	17/11/14	12:48:57	17.16	−100.44	40	3.7	South of Atoyac de Alvarez, Guerrero State	6
22	21/11/14	16:15:56	16.46	−98.49	14	3.7	Southwest of Ometepec, Guerrero State	6
23	21/11/14	18:08:25	18.28	−100.84	58	4.2	Southwest of Cd Altamirano, Guerrero State	6
9	12/09/14	23:27:03	16.70	−99.33	29	3.6	Southeast of San Marcos, Guerrero State	7
11	12/11/14	16:32:36	16.97	−99.79	38	3.6	Northeast of Acapulco, Guerrero State	7
2	12/14/14	20:47:15	18.06	−100.57	50	3.7	Southeast of Cd Altamirano, Guerrero State	8
3	12/15/14	08:51:06	16.42	−98.37	24	3.5	South of Ometepec, Guerrero State	8
4	12/15/14	18:38:19	17.76	−96.81	80	4.0	East of Tepelmeme, Oaxaca State	8
6	12/16/14	06:56:34	16.29	−98.02	28	3.6	Southeast of Pinotepa Nacional, Oaxaca State	8
12	12/16/14	17:15:39	16.25	−97.99	20	4.0	Southeast of Pinotepa Nacional, Oaxaca State	8
25	12/17/14	09:10:05	16.67	−98.89	30	3.6	West of Ometepec, Guerrero State	8

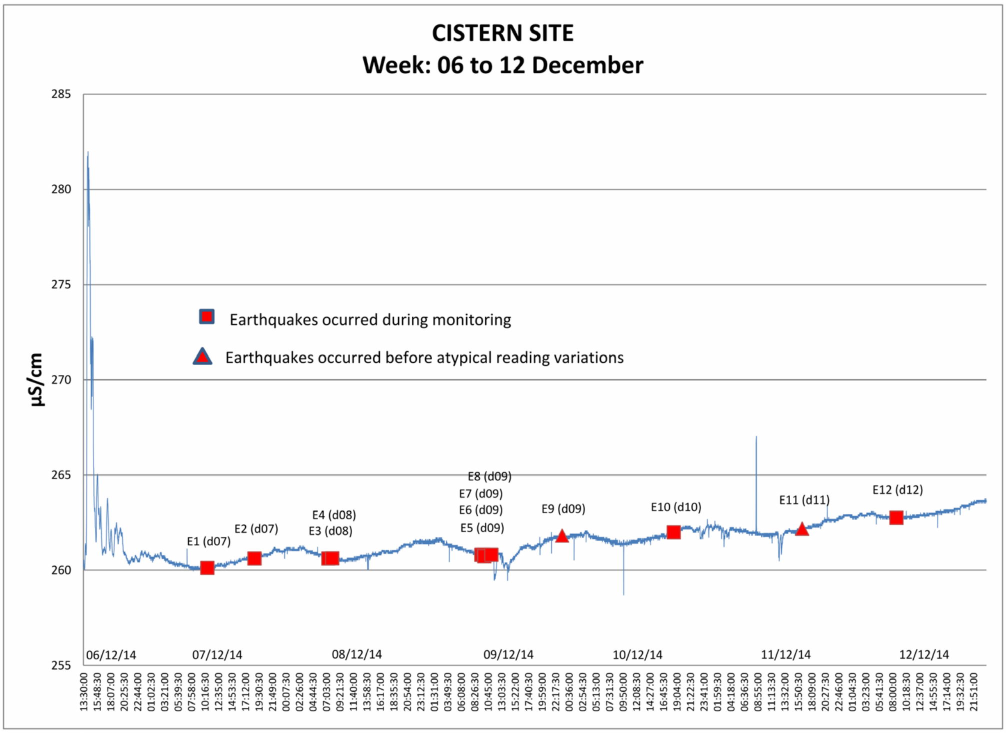

Figure 7. Conductivity pattern behavior in the "Cistern" site, period December 06 to 12. Total seismic events recorded during monitoring: 12. The average values of the quality of water obtained with the HI 9828 were: T (˚C) 24.35 pH 9.31, 5.51 ppm OD and 0.16 salinity.

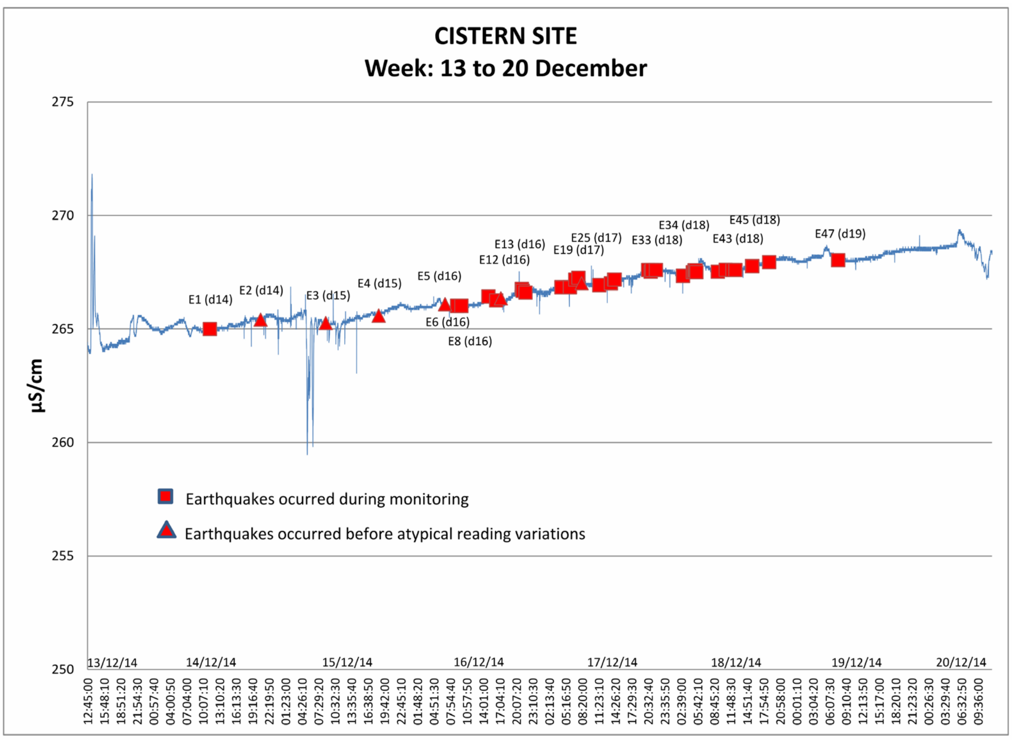

Figure 8. Conductivity pattern behavior in the "Cistern" site, period December 13 to 20. Total seismic events recorded during monitoring: 14. The average values of the quality of water obtained with the HI 9828 were: T (˚C) 24.35 pH 9.31, 5.51 ppm OD and 0.16 salinity.

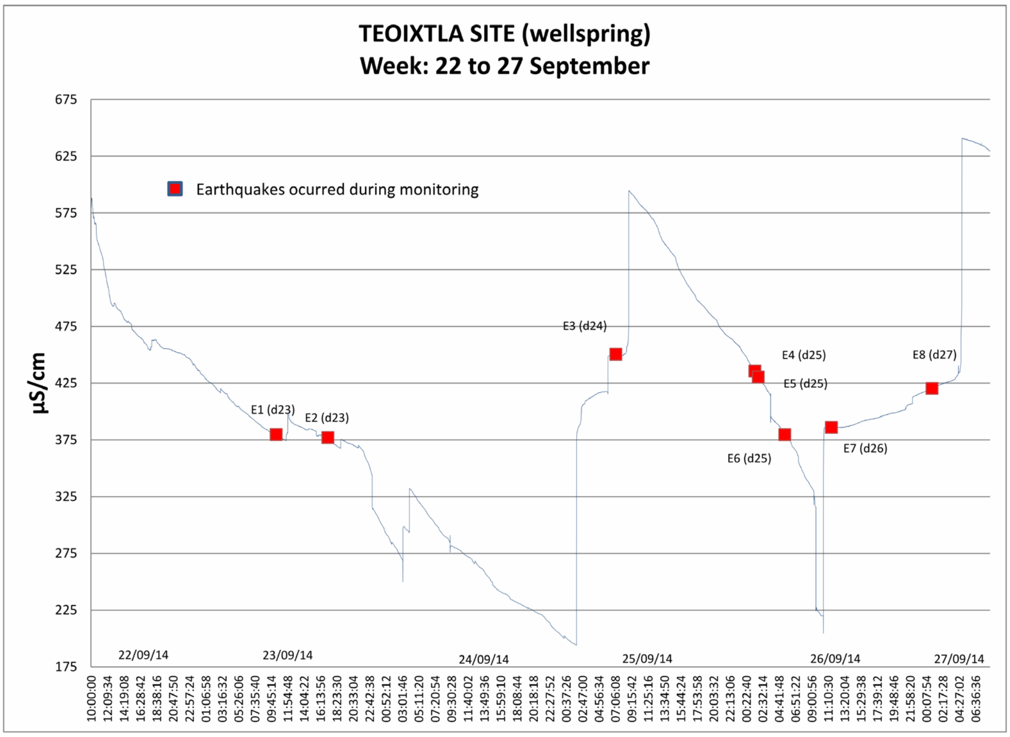

Figure 9. Conductivity pattern behavior in the "Cistern" site, period December 22 to 27. Total seismic events recorded during monitoring: 8. The average values of the quality of water obtained with the HI 9828 were: T (˚C) 24.35 pH 9.31, 5.51 ppm OD and 0.16 salinity.

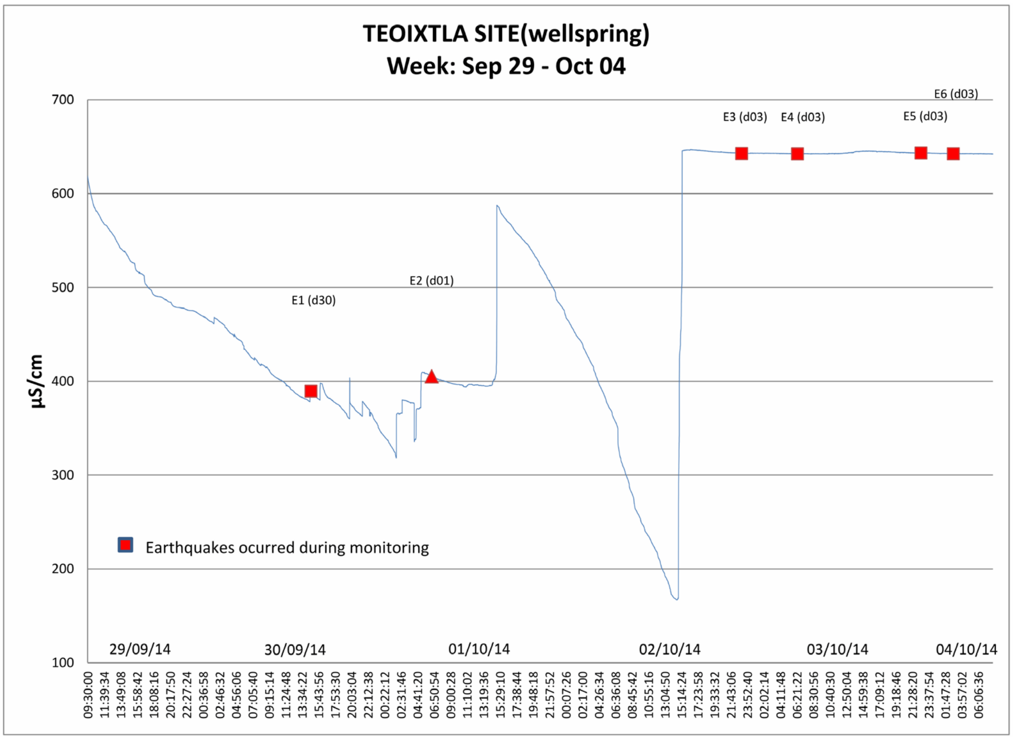

Figure 10. Conductivity behavior pattern of the "Teoixtla" site, period September 29 to October 04. Total seismic events recorded during monitoring: six. The average values of the quality of water obtained with the HI 9828 were T (˚C) 22.51 pH 7.18; 1.49 ppm OD and 0.28 salinity.

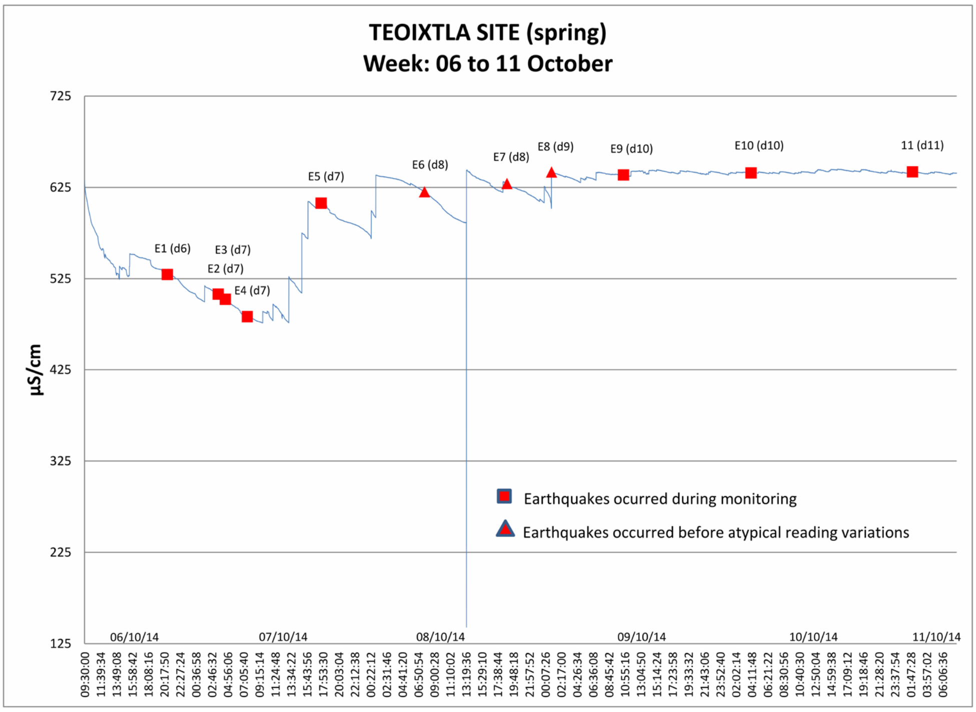

Figure 11. Conductivity behavior pattern of the "Teoixtla" site, period October 06 to 11. Total seismic events recorded during monitoring: 11. During this period a visible atypical variation of conductivity occurred on October 8. The average values of the quality of water obtained with the HI 9828 were T (˚C) 22.51 pH 7.18; 1.49 ppm OD and 0.28 salinity.

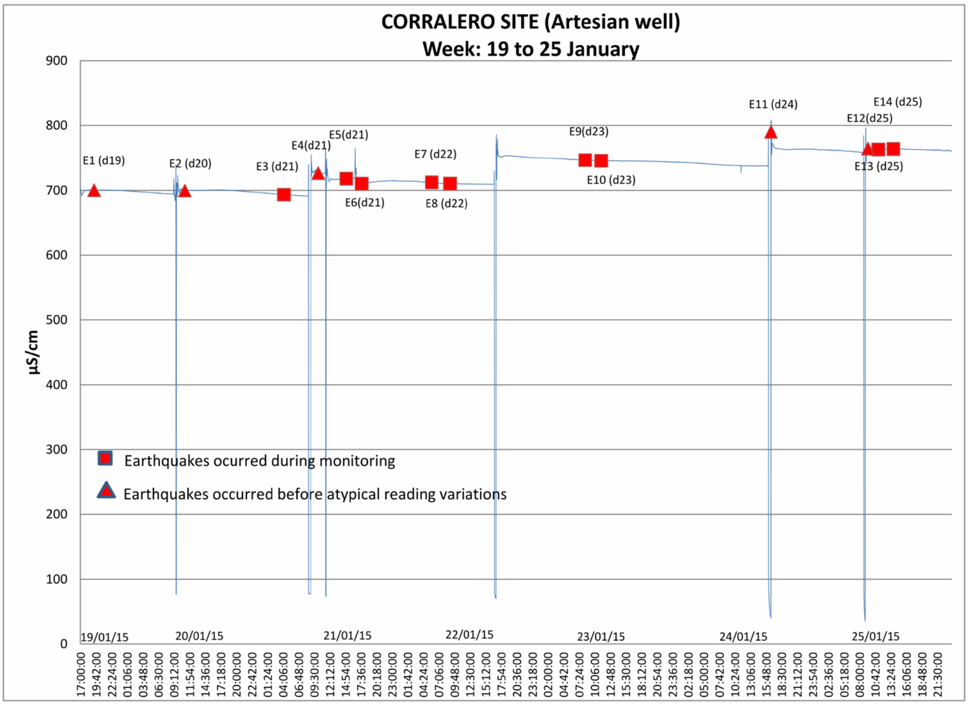

Figure 12. Conductivity pattern behavior of the "Corralero" site, period January 19 to 25: Total seismic events recorded during monitoring: 14. Five atypical variations preceded by seismic events occurred, first drop (E2 at 11:05:36 with Mw3.6); second and third drop (E4, E5 and E6 at 10:12:55, 15:03:45 and 17:44:27 with Mw 4.1, 3.8 and 3.6, respectively); fifth drop (E11 at 16:27:27 with Mw3.5); and sixth drop (E12 at 9:29:05 with Mw3.9.

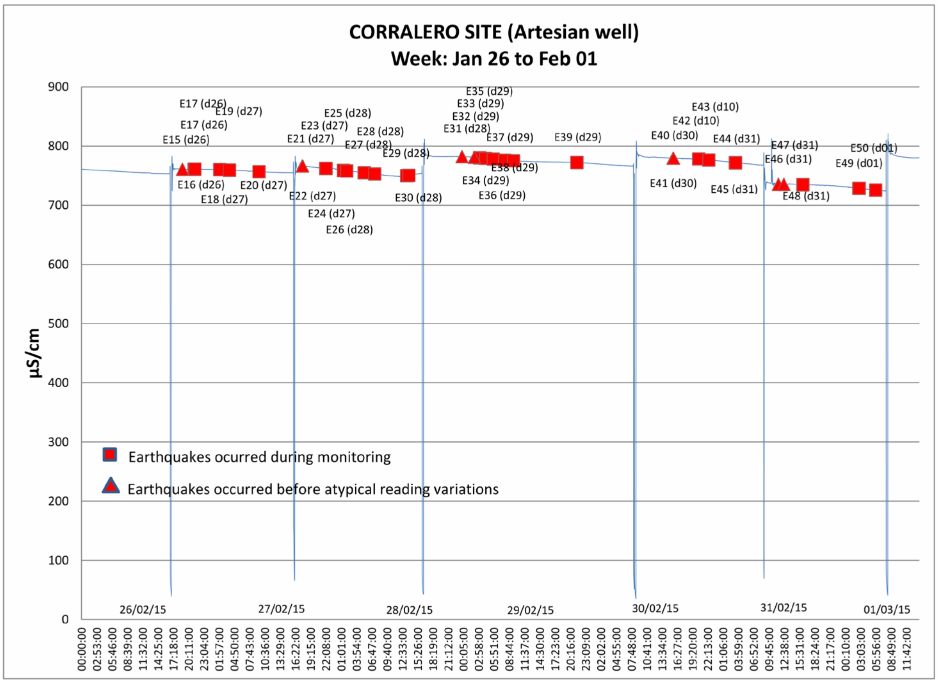

Figure 13. Conductivity pattern behavior of the "Corralero" site, period January 26 to February 01. Total seismic events recorded during monitoring: 36, almost all atypical readings were preceded of seismic events: first drop (E15 at 19:04:05 with Mw3.5; the second drop was preceded by earthquakes E21 with Mw3.7 at 17:40:35); third drop (E31 and E32 with Mw3.9 and Mw3.7, one at 23:51:23 on January 28 and another at 15:46:33 on January 29, respectively); fourth drop (E40 and E41 with Mw3.9 and Mw3.7, one at 23:51:23 on January 28 and another at 15:46:33 on January 29, respectively); fifth drop (E46 and E47, both with Mw3.5, at 11:33:44 and 12:35:22, respectively).

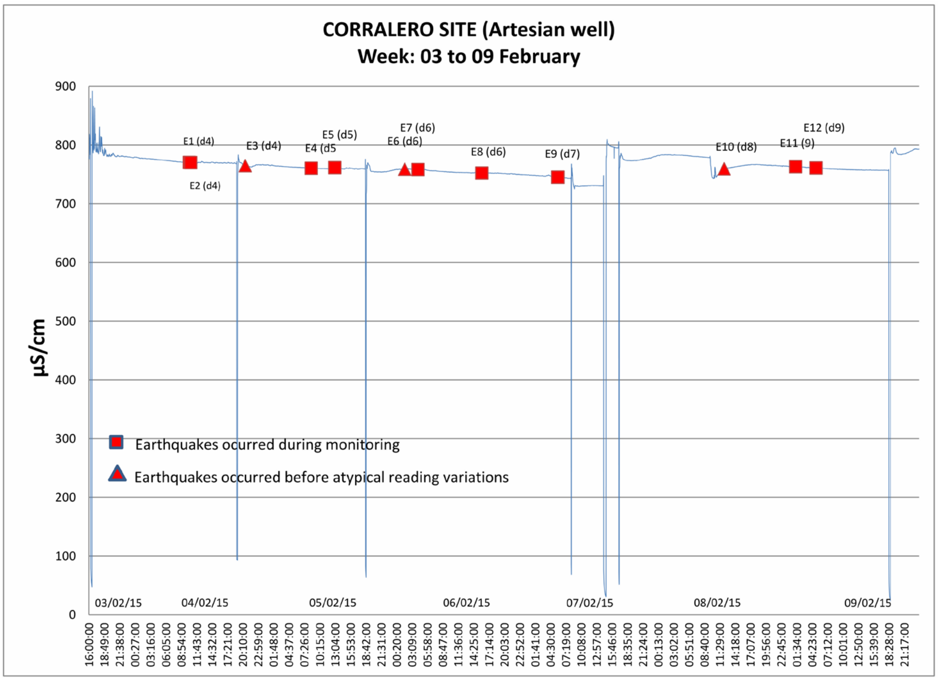

Figure 14. Conductivity pattern behavior of the "Corralero" site, period February 03 to 09. Total seismic events recorded during monitoring: 12. Three atypical readings preceded by seismic events occurred: first drop (E3 at 20:38:37 with Mw3.4); second drop (E6 at 1:50:12 with Mw3.5); fifth drop (E10 with Mw3.6 at 12:18:35).

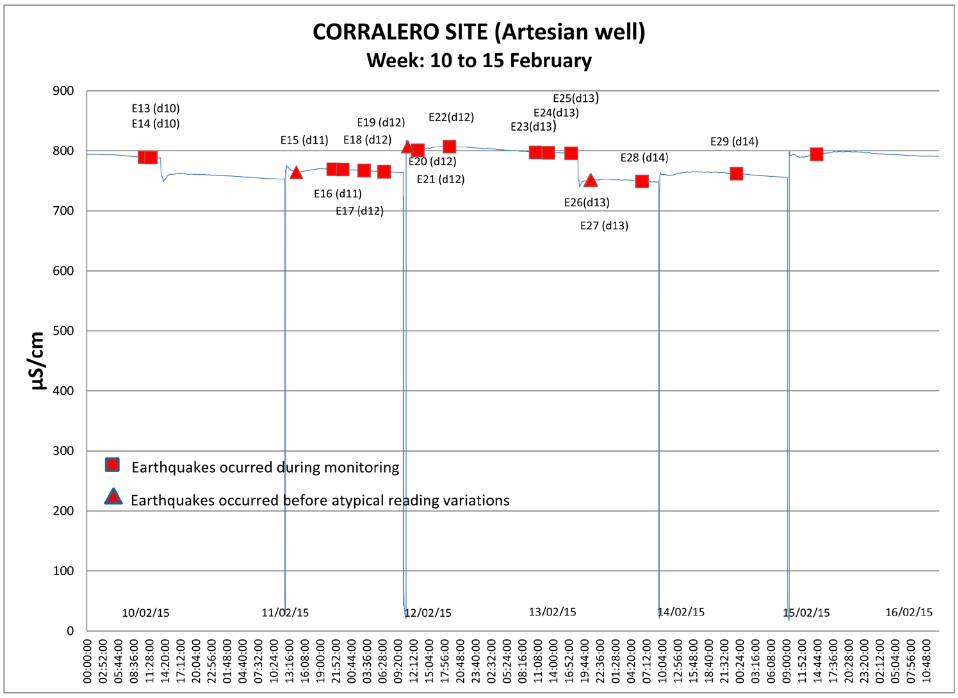

Figure 15. Conductivity pattern behavior of the "Corralero" site, period February 10 to 15. Total seismic events recorded during monitoring: 12. Three major drops preceded by seismic events occurred: first drop (E15 with Mw4.1 at 14:39:26); second drop (E20 with Mw3.5 at 11:10:20) and smaller third drop (E26 with Mw3.5 at 20:48:58).

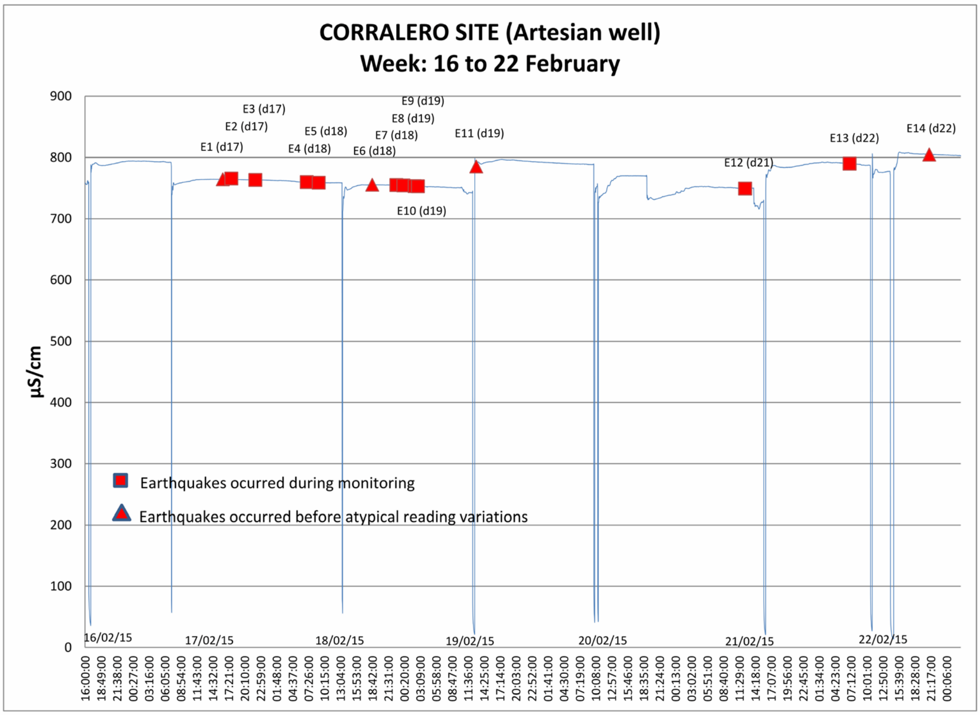

Figure 16. Conductivity pattern behavior of the "Corralero" site, period February 16 to 22. Total seismic events recorded during monitoring: 14. Four atypical readings preceded by seismic events occurred: second drop (E1 at 16:19:09 with Mw3.5); third drop (E6 at 18:42:07 with Mw3.7); fourth (E11 at 13:02:59 with Mw3.5). And ninth drop (E14 at 21:01:28 with Mw3.5).

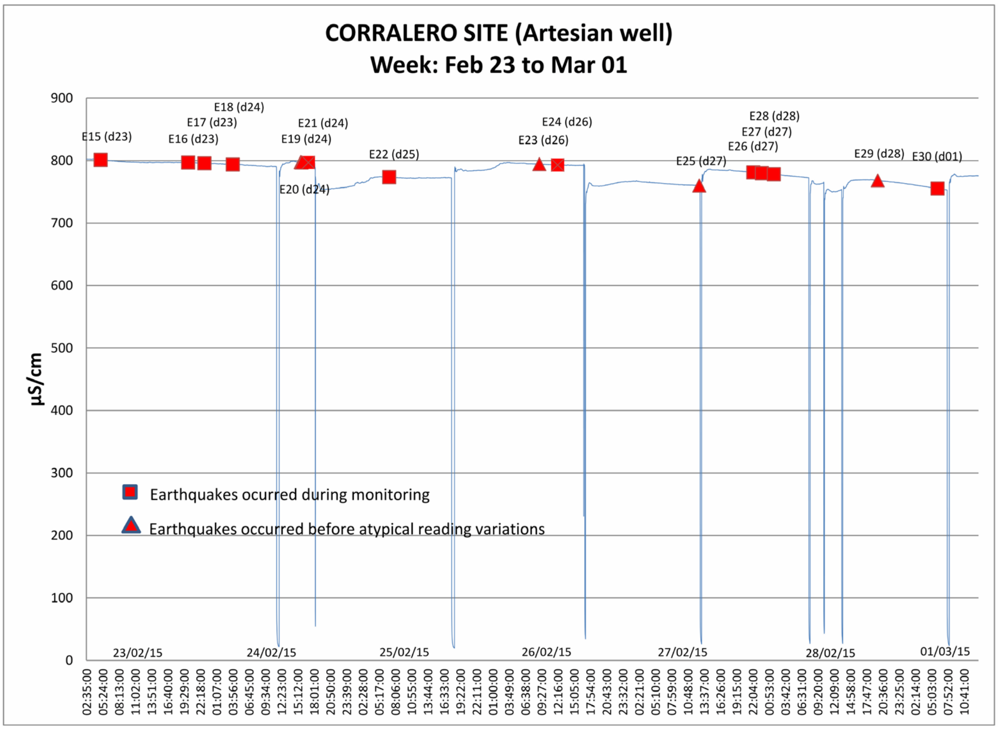

Figure 17. Conductivity pattern behavior of the "Corralero" site, period February 23 to March first. Total seismic events recorded during monitoring: 16. Four atypical readings preceded by seismic events occurred: first drop (E20 with Mw3.8 and E21 with Mw3.6 at 15:52:52 and 17:03:32, respectively); third drop (E23 with Mw3.6.); fifth drop (E25 with Mw3.6 at 12:46:53) and eighth drop (E29 with Mw3.7 at 19:42:42).

Table 4. General characteristics of most notably seismic events in the site "Teoixtla".

Event	Date	Time	Lat	Long	Depth	Magn.	Zone	Figure
1	23/09/2014	10:24:33	18.04	−100.50	57	3.5	Southwest of Arcelia, Guerrero State	9
5	26/09/2014	01:58:11	16.35	−97.76	45	3.5	East of Pinotepa Nacional, Oaxaca State	9
7	27/09/2014	00:52:07	17.06	−99.95	40	3.6	Northeast of Coyuca de Benitez, Guerrero State	9
8	26/09/2014	11:36:18	15.99	−97.59	20	4.0	West of Rio Grande, Oaxaca State	9
2	01/10/2014	06:32:26	17.59	−101.27	28	3.5	North of Petatlan, Guerrero State	10
6	08/10/2014	07:41:33	16.91	−98.82	13	3.7	East of Ayutla, Guerrero State	11
7	08/10/2014	18:55:19	16.30	−97.71	38	3.5	East of Pinotepa Nacional, Oaxaca State	11
8	09/10/2014	00:58:11	17.23	−100.27	25	3.5	Northeast of Atoyac, Guerrero State	11

age values of water quality obtained with the HI 9828 instrument were: 27.76 Temperature ˚C, 7.13 pH; 1.17 Dissolved Oxygen ppm, and 0.33 salinity.

5. Discussion

A total of 241 seismic events were analyzed and 59 of them were associated with atypical conductivity readings: 57 were superficial seismic events, and two were intermediate events; these latter with epicenters located 80 kilometers and 66 kilometers deep, respectively, but some quite distant from the Data Logger, 279 kilometers and 154 kilometers away, correspondingly. As expected, out of the 59 seismic events, 36 occurred in the Corralero site within the surroundings of the most seismically active area in the country, near the towns of Ometepec, state of Guerrero, and Pinotepa Nacional, state of Oaxaca, Mexico, likewise the notable conductivity variations occurred in this place (**Figures 12-17**).

Table 5. General characteristics of most notably seismic events in the site "Corralero", period 01/19 to 02/01, 2015.

Event	Date	Time	Lat	Long	Depth	Magn.	Zone	Figure
1	01/19/2015	19:22:34	16.28	−98.27	26	3.5	West of Pinotepa Nacional, Oaxaca State	12
2	01/19/2015	11:05:36	16.58	−98.61	7	3.6	Southwest of Ometepec, Gro.	12
4	01/21/2015	10:12:55	16.33	−98.06	13	4.1	Southwest of Pinotepa Nacional, Oaxaca State	12
11	01/24/2015	16:27:27	15.98	−97.69	20	3.5	West of Rio Grande, Oaxaca State	12
12	01/25/2015	09:29:05	16.30	−97.89	10	3.9	East of Pinotepa Nacional, Oaxaca State	12
21	01/27/2015	17:40:35	16.25	−98.12	20	3.7	Southwest of Pinotepa Nacional, Oaxaca State	13
22	01/27/2015	17:44:47	17.22	−98.11	57	3.5	West of H Tlaxiaco, Oaxaca State	13
31	01/28/2015	23:51:23	16.32	−97.88	10	3.9	East of Pinotepa Nacional, Oaxaca State	13
32	01/29/2015	02:10:22	16.43	−98.59	29	3.7	Southwest of Ometepec, Guerrero State	13
41	01/30/2015	15:46:33	16.24	−97.92	34	3.6	Southeast of Pinotepa Nacional, Oaxaca State	13
42	01/30/2015	20:30:49	16.60	−98.43	37	3.7	South of Ometepec, Guerrero State	13
46	01/31/2015	11:33:44	16.22	−97.86	10	3.5	Southeast of Pinotepa Nacional, Oaxaca State	13
47	01/31/2015	12:35:22	16.07	−96.97	39	3.5	Northeast of Puerto Escondido, Oaxaca State	13

Table 6. General characteristics of most notably seismic events in the site "Corralero", period 01/02 to 13/02, 2015.

Event	Date	Time	Lat	Long	Depth	Magn.	Zone	Figure
3	04/02/2015	20:38:37	16.34	−98.23	22	3.4	West of Pinotepa Nacional, Oaxaca State	14
6	06/02/2015	01:50:12	16.48	−98.46	27	3.5	Southwest of Ometepec, Guerrero State	14
10	08/02/2015	12:18:35	16.50	−98.25	27	3.6	Southeast of Ometepec, Guerrero State	14
15	11/02/2015	14:39:36	15.94	−98.00	20	4.1	South of Pinotepa Nacional, Oaxaca State	15
20	12/02/2015	11:10:20	16.23	98.03	5	3.5	South of Pinotepa Nacional, Oaxaca State	15
26	13/02/2015	20:48:58	16.46	−98.68	16	3.5	Southwest of Ometepec, Guerrero State	15

Table 7. General characteristics of most notably seismic events in the site "Corralero", period 02/17 to 02/28, 2015.

Event	Date	Time	Lat	Long	Depth	Magn.	Zone	Figure
1	02/17/2015	16:19:09	16.53	−98.46	10	3.5	Southwest of Ometepec, Guerrero State	16
6	02/18/2015	18:42:07	16.33	−98.23	14	3.7	West of Pinotepa Nacional, Oaxaca State	16
11	02/19/2015	13:02:59	16.23	−98.04	5	3.5	South of Pinotepa Nacional, Oaxaca State	16
14	02/22/2015	21:01:28	16.27	−98.25	13	3.5	Southwest of Pinotepa Nacional, Oaxaca State	16
20	02/24/2015	15:52:52	16.21	−98.08	11	3.8	South of Pinotepa Nacional, Oaxaca State	17
21	02/24/2015	17:03:32	16.31	−98.25	14	3.6	West of Pinotepa Nacional, Oaxaca State	17
23	02/26/2015	09:04:50	16.28	−98.14	13	3.6	Southwest of Pinotepa Nacional, Oaxaca State	17
24	02/26/2015	12:15:04	16.64	−98.39	42	3.5	Southeast of Ometepec, Guerrero State	17
25	02/27/2015	12:46:53	16.32	−98.16	19	3.6	West of Pinotepa Nacional, Oaxaca State	17
29	02/28/2015	19:42:42	16.29	−98.09	11	3.7	Southwest of Pinotepa Nacional, Oaxaca State	17

Energy manifestations and phenomena that occur before and after an earthquake can be grouped into two major categories: those events associated with the *MECHANICAL ENERGY* when blocks of rocks break their position of equilibrium, in this set are included events as terrain deformations or tilting [42]; changes in subsurface porosity, changes in water levels, as well as the release and presence of radioactive gases such as $Radon^{222}$ in the surface [2] [5] [43]-[47]. Other category is related to the *IONIZING ENERGY*, involve energy processes before the earthquake occurs, fog and cloud formation in areas near fault lines being among those frequently mentioned [1] [6] [18]; too changes in atmospheric electricity, temperature, and relative humidity [8] [24] [49] [50]; the presence of electromagnetic flux [48]; lights seen over ridges and mountaintops [16] [50]; and changes in animal and human behavior [2] [31] [32] [51]-[54]. All of these phenomena manifestations provide strong evidence of energy existence associated with earthquakes, but not of their exact origin. However, they should not be considered as merely curious, amusing, or even entertaining phenomena, such as the presence of lights or glares before and after an earthquake. Such phenomena should be of scientific interest because of the effects that predecessor earthquakes and their accompanying events have on the natural environment and on human settlements.

Atypical conductivity drops at the "Corralero" site (**Figures 12-17**) behaving as pulses, may provide indirect evidence of the presence of surrounding energy as presumed and mentioned in previous paragraphs. The subtle relationship between conductivity variations and earthquakes in aquatic environments near seismic areas and the energy emanating from the Earth's crust are evidence meant to further contribute to the understanding of these events and their preceding accompanying phenomena. As stated in the second assumption supporting this research, natural energy emanating from the surrounding environment would be sufficient to interfere with the normal operation of the Data Logger, interrupting the electric current or ionic conduction, causing unusual variations in conductivity; apparently, this interference appears to be a fact. This anomaly leads to two more assumptions: ion movement was directed towards a field of more intense energy, or the electric flux between the electrodes of the appliance was interfered with by the same field of natural energy (electromagnetic fields), altering the movement of ions.

In order to find a supported answer to these variations, one possibility mentioned in the literature is that changes in electric conductivity may be caused by the mixing (recharge) of different qualities of water because of the increases or decreases of ion concentration [55] or possibly also is due also to terrain compress or tilting [42] caused by very light earthquakes which increase internal water flow rising mixing. Mixing by natural processes of ground-water and surface-water interaction appears to be unsupported since the water of the "Corralero" site well does not seem to have an exchange with or to be renewed by a nearby wellspring or rainwater because sampling was conducted during the dry season of the year. An additional factors might be the temperature or the proximity of a coastal lagoon, inclusively with all due caution, others could be the Coriolis effect caused by Earth rotation movement or the Lunar influence by gravitational attraction, some of these possible answers would be matter of research. Indisputable conductivity variations do not follow a set pattern, as shown in the sampling site "Corralero", from week to week the number of variations is not constant, in a few hours can be presented two o three variations and the next week be more regular with one per day, **Figure 12** and **Figure 13**. In another period it can present a week with two very close variations in a few hours and the next week it can increase the number of variations, appearing two or three of them in very short periods of time, **Figure 16** and **Figure 17**.

A common element to the ions' change of direction or the interference of the instruments' electric field could be the presence of an electromagnetic field in the surrounding environment; in this case, electromagnetic pulses emanating from the Earth's crust or deeper layers, evidence of which is an anomaly in conductivity (**Figures 12-17**). This electromagnetic energy has often been detected and considered a precursor of seismic events by various authors and it is considered one of the anomalies with the greatest time interval of environment permanency; furthermore, it is characterized by an unusual increase of the electric potential near epicenters [3] [4] [7] [8] [12] [13] [48]. Therefore, the systematic monitoring of conductivity, preferably established in areas with frequent and intense seismic activity, may contribute more to understanding of this type of phenomenon. For this reason, it is a sustainable option and can be a preventive tool when considering the apparent relationship existing between water conductivity and subsequent earthquake occurrences.

6. Conclusions

According to the results described in this paper is concluded:

- The conductivity monitoring process of water in the wellsprings, the cistern, and the artesian well provide evidence of the possible existence of local energy that is manifested with drops or atypical conductivity readings in aquatic environments close to areas of frequent seismic events; as well as of the possible relationship to subsequent seismic activity. These variations are possibly due to the influence of energy emanating from inside the Earth's layers. Consequently, the first assumption upon which this research is based is apparently fulfilled, as monitoring the conductivity in areas with high seismic incidence and frequency indirectly provides a possible evidence of the presence of an electric and electromagnetic potential in the environment, energy that, as stated in the second assumption, could have interfered with the normal operation of the Data Logger, changing the movement of the ions dissolved in the aquatic environment towards a more intense field, resulting in reading variation of conductivity.
- Variations or atypical conductivity readings in existing water bodies located in areas with frequent seismic activity show a subtle connection with the subsequent potential occurrence of earthquakes (**Figures 12-17**).
- Conductivity readings in areas with high seismicity not follow a regular pattern over time, they are changing in short periods of time, registering up to three variations over a period of seven hours (**Figure 14** and **Figure 17**).
- Conductivity monitoring in seismic areas could be a sustainable option as a preventive measure for anticipating earthquakes. This can be achieved by placing measuring instruments in those areas where earthquakes historically occur.

Acknowledgements

The authors gratefully acknowledge to Engineer José Francisco Hernández Pérez, Head of the Center of Proposed Draft of the South Pacific, regional office of the Coordination of Hydroelectric Projects (CFE), for the logistics support provided. Transportation as well as human and financial resources were crucial for completing this research; visits to monitoring sites would have been extremely difficult without this support. Likewise to Andrés Suasto A., Oscar E. González A., Ricardo Vázquez H. and José H. Granados Z., for their support and solidarity during the trip.

References

[1] Asada, T., Baba, H., Kawazoe, M. and Sugiura, M. (2001) An Attempt to Delineate Very Low Frequency Electromagnetic Signals Associated with Earthquakes. *Earth, Planets and Space*, **53**, 55-62. http://dx.doi.org/10.1186/BF03352362

[2] Cicerone, R.D., Ebel, J.E. and Britton, J. (2009) A Systematic Compilation of Earthquake Precursors. *Tectonophysics*, **476**, 371-396. http://dx.doi.org/10.1016/j.tecto.2009.06.008

[3] Koshevaya, S.V., Pérez-Enríquez, R. and Kotsarenko, N.Y. (1997) The Detection of Electromagnetic Processes in the Ionosphere Caused by Seismic Activity. *Geofisica Internacional*, **36**, 55-60.

[4] Kotsarenko, A., Grimalsky, V., Koshevaya, S., Pérez Enríquez, R., Yutsis, V., López Cruz-Abeyro, J.A. and Villegas Cerón, R.A. (2008) Evidence of a New Electromagnetic Resonance Discovered at Teoloyucan Geomagnetic Station, México? *Geofisica Internacional*, **47**, 287-293.

[5] Omori, Y., Yasuoka, Y., Nagahama, H., Kawada, Y., Ishikawa, T., Tokonami, S. and Shinogi, M. (2007) Anomalous Radon Emanation Linked to Preseismic Electromagnetic Phenomena. *Natural Hazards and Earth System Sciences*, **7**, 629-635. http://dx.doi.org/10.5194/nhess-7-629-2007

[6] Bleier, T., Dunson, C., Alvarez, C., Freund, F. and Dahlgren, R. (2010) Correlation of Pre-Earthquake Electromagnetic Signals with Laboratory and Field Rock Experiments. *Natural Hazards and Earth System Sciences*, **10**, 1965-1975. http://dx.doi.org/10.5194/nhess-10-1965-2010

[7] Pulinets, S.A., Contreras, A.L. and Ciraolo, L. (2005) Total Electron Content Variations in the Ionosphere before the Colima, Mexico, Earthquake of 21 January 2003. *Geofisica Internacional*, **44**, 369-377.

[8] Pulinets S.A. and Dunajecka, M.A. (2007) Specific Variations of air Temperature and Relative Humidity around the Time of Michoacan Earthquake M8.1 Sept. 19, 1985 as a Possible Indicator of Interaction between Tectonic Plates. *Tectonophysics*, **431**, 221-230. http://dx.doi.org/10.1016/j.tecto.2006.05.044

[9] Pulinets, S. (2004) Ionospheric Precursors of Earthquakes: Recent Advances in Theory and Practical Applications, Terr. *Atmospheric & Ocean Science*, **15**, 413-435.

[10] Pulinets, S.A. (2009) Physical Mechanism of the Vertical Electric Field Generation over Active Tectonic Faults. *Ad-*

vances in Space Research, **44**, 767-773. http://dx.doi.org/10.1016/j.asr.2009.04.038

[11] Pulinets, S.A., Ouzounov, D., Ciraolo, L., Singh, R., Cervone, G., Leyva, A., Dunajecka, M., Karelin, A.V., Boyarchuk, K.A. and Kotsarenko, A. (2006) Thermal, Atmospheric and Ionospheric Anomalies around the Time of the Colima M7.8 Earthquake of 21 January 2003. *Annales Geophysicae*, **24**, 835-849. http://dx.doi.org/10.5194/angeo-24-835-2006

[12] Pulinets, S.A., Ouzounov, D., Karelin, A.V., Boyarchuk, K.A. and Pokhmelnykh, L.A. (2006) The Physical Nature of Thermal Anomalies Observed before Strong Earthquakes. *Physics and Chemistry of the Earth*, **31**, 143-153. http://dx.doi.org/10.1016/j.pce.2006.02.042

[13] Sarkar, S., Choudhary, S., Sonakia, A., Vishwakarma, A. and Gwal, A.K. (2012) Ionospheric Anomalies Associated with the Haiti Earthquake of 12 January 2010 Observed by DEMETER Satellite. *Natural Hazards and Earth System Sciences*, **12**, 671-678. http://dx.doi.org/10.5194/nhess-12-671-2012

[14] Shiro, B., Freund, F., Cagle, Y., Pilorz, S. and Hollis-Watts, P. (2012) Measuring Ion Currents and Electric Fields Caused by Earthquakes, Volcanoes and Lightning in the Mesosphere. *NSRC*, 27-29 February 2012, Palo Alto, 1-3.

[15] Araiza-Quijano, G. and Hernandez-del-Valle, M.R. (1996) Some Observations of Atmospheric Luminosity as a Possible Earthquake Precursor. *Geofisica Internacional*, **35**, 403-408.

[16] Heraud, J.A. and Lira, J.A. (2011) Co-Seismic Luminescence in Lima, 150 km from the Epicenter of the Pisco, Peru Earthquake of 15 August 2007. *Natural Hazards and Earth System Sciences*, **11**, 1025-1036. http://dx.doi.org/10.5194/nhess-11-1025-2011

[17] Straser, V. (2009) Luminous Phenomena in the Atmosphere: Signs of Uplift of the Earth's Crust? The "Lights" in Taro Valley (Italy) and Hessdalen (Norway). *New Concepts in Global Tectonics*, No. 53, 47-56.

[18] Biagi, P.F., Piccolo, R., Ermini, A., Fujinawa, Y., Kingsley, S.P., Khatkevich, Y.M. and Gordeev, E.I. (2001) Hydrogeochemical Precursors of Strong Earthquakes in Kamchatka: Further Analysis. *Natural Hazards and Earth System Sciences*, **1**, 9-14. http://dx.doi.org/10.5194/nhess-1-9-2001

[19] Guo, G. and Wang, B. (2008) Cloud Anomaly before Iran Earthquake. *International Journal of Remote Sensing*, **29**, 1921-1928. http://dx.doi.org/10.1080/01431160701373762

[20] Koren, I., Altaratz, O., Remer, L.A., Feingold, G., Martins, J.V. and Heiblum, R.H. (2012) Aerosol-Induced Intensification of Rain from the Tropics to the Mid-Latitudes. *Nature Geoscience*, **5**, 118-122. http://dx.doi.org/10.1038/ngeo1364

[21] Henshaw, D.L. (2004) Childhood Leukaemia and EMFs , Mobile Phones and Brain Tumours, Risks and Causal Pathways. Two Types of Fields from the Electricity Supply: Electric Fields (EFs) & Magnetic Fields (MFs). Doubling of Childhood Leukaemia Risk Increased Incidence of Chi. *The 7th Princess Chulabhorn International Science Congress*, 1-17.

[22] Henshaw, D.L., Ward, J.P. and Matthews, J.C. (2008) Can Disturbances in the Atmospheric Electric Field Created by Powerline Corona Ions Disrupt Melatonin Production in the Pineal Gland? *Journal of Pineal Research*, **45**, 341-350. http://dx.doi.org/10.1111/j.1600-079X.2008.00594.x

[23] Papadopoulos, G.A., Charalampakis, M., Fokaefs, A. and Minadakis, G. (2010) Strong Foreshock Signal Preceding the L'Aquila (Italy) Earthquake (M_w 6.3) of 6 April 2009. *Natural Hazards and Earth System Sciences*, **10**, 19-24. http://dx.doi.org/10.5194/nhess-10-19-2010

[24] Dunajecka, M.A. and Pulinets, S.A. (2005) Atmospheric and Thermal Anomalies Observed around the Time of Strong Earthquakes in Mexico. *Atmosfera*, **18**, 235-247.

[25] Pulinets, S.A. (2009) Physical Mechanism of the Vertical Electric Field Generation over Active Tectonic Faults. *Advances in Space Research*, **44**, 767-773. http://dx.doi.org/10.1016/j.asr.2009.04.038

[26] Virk, H.S., Walia, V., Sharma, A.K., Kumar, N. and Kumar, R. (2000) Correlation of Radon Anomalies with Microseismic Events in Kangra and Chamba Valleys of N-W Himalaya. *Geofisica Internacional*, **39**, 221-227.

[27] Freund, F.T. (2007) Pre-Earthquake Signals—Part I: Deviatoric Stresses Turn Rocks into a Source of Electric Currents. *Natural Hazards and Earth System Sciences*, **7**, 535-541.

[28] Freund, F.T., Takeuchi, A., Lau, B.W.S., Al-Manaseer, A., Fu, C.C., Bryant, N.A. and Ouzounov, D. (2006) Stimulated Infrared Emission from Rocks: Assessing a Stress Indicator. *eEarth*, **1**, 97-121.

[29] Freund, F.T. (2003) Rocks That Crackle and Sparkle and Glow—Strange Pre-Earthquake Phenomena. *Journal of Scientific Exploration*, **17**, 37-71.

[30] Freund, F.T. (2007) Pre-Earthquake Signals—Part II: Flow of Battery Currents in the Crust. *Natural Hazards and Earth System Sciences*, **7**, 543-548. http://dx.doi.org/10.5194/nhess-7-543-2007

[31] Grant, R.A. and Halliday, T. (2010) Predicting the Unpredictable, Evidence of Pre-Seismic Anticipatory Behaviour in the Common Toad. *Journal of Zoology*, **281**, 263-271. http://dx.doi.org/10.1111/j.1469-7998.2010.00700.x

[32] Grant, R.A., Halliday, T., Balderer, W.P., Leuenberger, F., Newcomer, M., Cyr, G. and Freund, F.T. (2011) Ground Water Chemistry Changes before Major Earthquakes and Possible Effects on Animals. *International Journal of Environmental Research and Public Health*, **8**, 1936-1956. http://dx.doi.org/10.3390/ijerph8061936

[33] Tong, W.K. (1988) Abnormal Animal Behavior. Faculty of the Department of Earth Sciences, Northeastern Illinois.

[34] Dologlou, E. (2010) Recent Aspects on Possible Interrelation between Precursory Electric Signals and Anomalous Bioeffects. *Natural Hazards and Earth System Sciences*, **10**, 1951-1955. http://dx.doi.org/10.5194/nhess-10-1951-2010

[35] Nava, A. (2002) Terremotos. 4th Edition, Fondo de Cultura Económica (FCE), México.

[36] Pérez-Campos, X., Kim, Y.H., Husker, A., Davis, P.M., Clayton, R.W., Iglesias, A., Pacheco, J.F., Singh, S.K., Manea, V.C. and Gurnis, M. (2008) Horizontal Subduction and Truncation of the Cocos Plate beneath Central Mexico. *Geophysical Research Letters*, **35**, 1-6. http://dx.doi.org/10.1029/2008GL035127

[37] Servicio Geológico Mexicano (SGM) (1998) Carta Geológico-Minera Cuernavaca E14-5. Secretaría de Economía, Cuernavaca, 1.

[38] Servicio Geológico Mexicano (SGM) (1998) Carta Geológico-Minera Chilpancingo E14-8. Secretaría de Economía, 1.

[39] Guangcai, W., Zuochen, Z., Min, W., Cravotta, C.A. and Chenglong, L. (2005) Implications of Ground Water Chemistry and Flow Patterns for Earthquake Studies. *Ground Water*, **43**, 478-484. http://dx.doi.org/10.1111/j.1745-6584.2005.0037.x

[40] Kumar, A., Walia, V., Singh, S., Bajwa, B.S., Mahajan, S., Dhar, S. and Yang, T.F. (2012) Earthquake Precursory Studies at Amritsar Punjab, India Using Radon Measurement Techniques. *International Journal of Physical Sciences*, **7**, 5669-5677.

[41] Sac, M.M., Harmansah, C., Camgoz, B. and Sozbilir, H. (2011) Radon Monitoring as the Earthquake Precursor in Fault Line in Western Turkey. *Ekoloji*, **20**, 93-98.

[42] Fielding, E.J., Lundgren, P.R., Bürgmann, R. and Funning, G.J. (2009) Shallow Fault-Zone Dilatancy Recovery after the 2003 Bam Earthquake in Iran. *Nature*, **458**, 64-68. http://dx.doi.org/10.1038/nature07817

[43] Chyi, L.L., Quick, T.J., Yang, T.F. and Chen, C.H. (2005) Soil Gas Radon Spectra and Earthquakes, Terr. *Atmospheric* & *Ocean Science*, **16**, 763-774.

[44] Chyi, L.L., Chou, C.Y., Yang, F.T. and Chen, C.H. (2002) Automated Radon Monitoring of Seismicity in a Fault Zone. *Geofisica Internacional*, **41**, 507-511.

[45] Singh, S., Kumar, A., Singh Bajwa, B., Mahajan, S., Kumar, V. and Dhar, S. (2010) Radon Monitoring in Soil Gas and Ground Water for Earthquake Prediction Studies in Northwest Himalayas, India, Terr. *Atmospheric* & *Ocean Science*, **21**, 685-695. http://dx.doi.org/10.3319/TAO.2009.07.17.01(TT)

[46] Thomas, D. (1988) Geochemical Precursors to Seismic Activity. *Pure and Applied Geophysics*, **126**, 241-266. http://dx.doi.org/10.1007/BF00878998

[47] Vaupotič, J., Riggio, A., Santulin, M., Zmazek, B. and Kobal, I. (2010) A Radon Anomaly in Soil Gas at Cazzaso, NE Italy, as a Precursor of an ML = 5.1 Earthquake. *Nukleonika*, **55**, 507-511.

[48] Namgaladze, A.A., Zolotov, O.V., Karpov, M.I. and Romanovskaya, Y.V. (2012) Manifestations of the Earthquake Preparations in the Ionosphere Total Electron Content Variations. *Natural Science*, **4**, 848-855. http://dx.doi.org/10.4236/ns.2012.411113

[49] Jin, X., Chen, Z., Ma, Q., Li, Y. and Pu, J. (2013) The Correlations between the Lightning Density Distribution of Sichuan Province and the Seismic Area. *International Journal of Geosciences*, **4**, 380-386. http://dx.doi.org/10.4236/ijg.2013.42036

[50] Sharma, D.K., Rai, J., Chand, R. and Israil, M. (2006) Effect of Seismic Activities on Ion Temperature in the F2 Region of the Ionosphere. *Atmosfera*, **19**, 1-7.

[51] Kirschvink, J.L. (2000) Earthquake Prediction by Animals: Evolution and Sensory Perception. *Bulletin of the Seismological Society of America*, **90**, 312-323. http://dx.doi.org/10.1785/0119980114

[52] Buskirk, R.E., Frohlich, C. and Latham, G.V. (1981) Unusual Animal Behavior before Earthquakes: A Review of Possible Sensory Mechanisms. *Reviews of Geophysics*, **19**, 247-270. http://dx.doi.org/10.1029/RG019i002p00247

[53] Deming, D. (2004) The Hum: An Anomalous Sound Heard around the World. *Journal of Scientific Exploration*, **18**, 571-595.

[54] Frohlich, C. and Buskirk, R.E. (1980) Can Fish Detect Seismic Waves? *Geophysical Research Letters*, **7**, 569. http://dx.doi.org/10.1029/GL007i008p00569

[55] Reddy, D.V. and Nagabhushanam, P. (2011) Groundwater Electrical Conductivity and Soil Radon Gas Monitoring for Earthquake Precursory Studies in Koyna, India. *Applied Geochemistry*, **26**, 731-737. http://dx.doi.org/10.1016/j.apgeochem.2011.01.031