WHITE PAPER

(Florida MUFON)

Earthquake Precursors
for
MUFON Field Investigators

C. C. Paulson (13110)
(Star Team - Field Investigator)
(Science Review Board)

Abstract

Its interesting that although UFO investigators have long been accused of misinterpreting earthquake precursors as UFOs for years, even seismologists do not yet agree what the precursors are. There is, however, enough science to use them as a probable sighting cause. At a minimum, accepting such a possibility allows the investigator the ability to explain why it was not the cause. This paper discusses some of the science behind earthquakes and what the MUFON investigator should be looking for.


MUFON
Mutual UFO Network

Most MUFON Field Investigators are not scientists. However there are many instances where a complete investigation requires knowledge of many different subjects. In terms of earthquakes, these subjects could include: geology, electromagnetism, atmospheric physics, astrophysics, animal psychology, seismology, and probably a few more.

Much of what follows will be seen to be more concerned with "earthquake precursors" than with the earthquake itself. That is because, all witnesses probably know what an earthquake (EQ) is unless it is far away. it would be the precursors that would be different and what witnesses would describe. This is particularly true when it is realized that EQs are not caused by a simple movement of the tectonic plates. They are caused by stress building up between the plates (or plate sections) due to no movement. When the stress builds to a large enough value, the EQ occurs as a sudden movement providing a release of this stress. The precursors also represent a relief of this stress, albeit smaller than a full EQ. One problem in noting precursors is that since they also relieve the stress, there are instances where regardless of their name, they are not followed by an earthquake

The body of the paper is broken into 3 sections: Introduction, Precursors, and Field Investigator. Since the paper was not written to prove a thesis, there is no Conclusion section. The Introduction section describes the US government agency US Geological Survey (USGS), and the types of precursors that will be discussed in the following 2 sections. Section 2 goes into each of the chosen precursor types and discusses how they are created and any proof of their existence. (It also contains some nice pictures.) Section 3 reiterates the precursors and discusses what the field investigator should look for. At the least it is suggested that Field Investigators read sections 1 and 3 and glance through section 2.

1.0 Introduction

"Earthquake" is the term used to describe vibrations in the earth. Typically these vibrations are the result of the release of elastic energy built up as stress in the tectonic plates in the Earth's crust*. The study of how these waves behave is called seismology. The governmental agency assigned to track and study them is the US Geological Survey (USGS). It is a division of the Department of Interior. It was created in 1879 but its initial mission was not earthquakes, it was the "classification of the public lands". Although it would seem reasonable to assume its responsibilities would have been expanded to include earthquakes following the M-7.8 (Magnitude 7.8) San Francisco quake in 1906, that would be incorrect. It wasn't until the M-9 earthquake in Alaska in 1964 that the USGS obtained those responsibilities. Its present mission is defined as obtaining and disseminating natural science information so as to minimize the loss of life and property from natural disasters.

Similar to MUFON's Computer Management System (CMS), the USGS has created a computer based searchable database[1] of worldwide earthquakes. Using that data investigators are able to create a hazard map of the world indicating the probability of an earthquake. Figure 1 is a portion of that map for the lower 48 states in the US. As was probably obvious to everyone before seeing the map, the maximum hazard area is the west coast.

---

*. Crust: A term that includes the tectonic plates and the rock and dirt above it

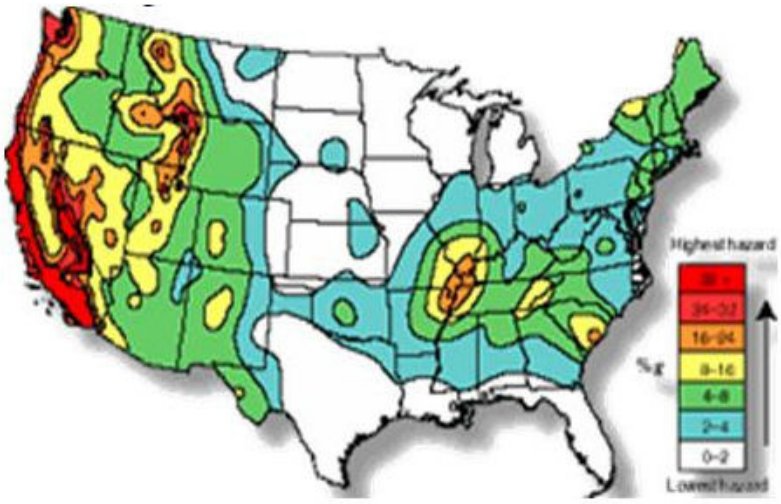


Figure 1: USGS - Earthquake Hazard Map

As stated. the database is searchable. Figure 2 was generated by the writer from the USGS earthquake archive for the year 2015. It covers what they call the Conterminous US[2]. Surprisingly it was found there were 4968 earthquakes with a magnitude greater than or equal to 2.5 during the year 2015. Again the largest number of quakes were along the pacific fault lines and the Rocky Mountains. As can be seen, there also was concentrations in areas that are not near plate edges. Although there are areas where no earthquake were reported (ex. Florida[3]) in some cases (not Florida) that may have been a result of limiting the search to a single year.

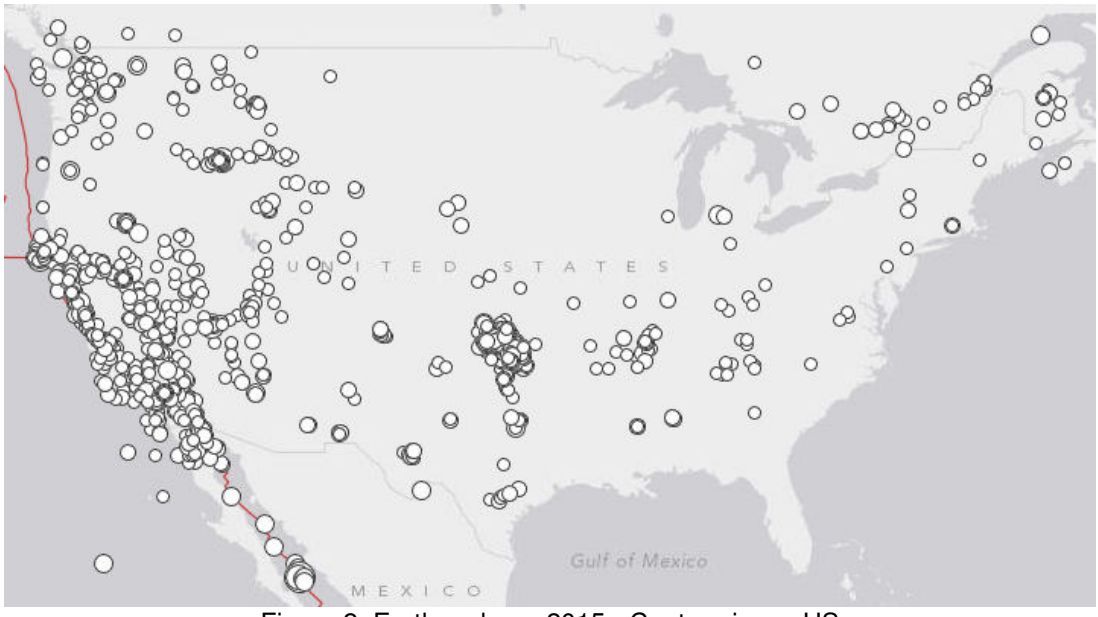


Figure 2: Earthquakes - 2015 - Conterminous US

In addition to knowing the possibility of an earthquake in any specific area, it is also known how earthquakes are generated and the types of ground motion (Appendix A) that can be expected. However it is not known when they will occur nor how dangerous they will be. Thus the holy grail of seismologists is

a precursor theory to provide a warning of impending EQs. Fortunately, the literature is replete with reports covering a range of possible precursors. This paper will be concentrating on those that could correspond to possible UFO characteristics. Specifically, the precursors to be considered are:

- Magnetic Field anomalies;
- Electromagnetic emissions;
- Luminous phenomena;
- Ionosphere phenomena; and
- Unusual animal behavior..

Until recently, due to lack of cause and effect, reports of pre-earthquake effects were anecdotal. Scientifically, the problems with most of those reports of odd things happening prior to earthquakes was a lack of a theoretical basis and reproducibility. It is, however, reasonable to assume that application of the same types of stress in a laboratory would give rise to similar electric, magnetic, and/or electromagnetic phenomena. That statement and in some cases luck have resulted in a rising level of research in many areas of the world.

A semi-complete listing of magnetic and electromagnetic precursors for the period starting in 1980 and ending in 1911 can be found in reference 29 (Table 1 in "Electromagnetic Pre-earthquake Precursors: Mechanisms, Data and Models - A Review"). It includes 89 entries. Each entry contains: earthquake details, detected emission type and frequency; instrumentation used; precursory time (time between disturbance and earthquake), and distance to epicenter. It should be noted that it is a listing of data that **had previously** been measured from earthquakes; not a listing of earthquakes nor a set of new measurements. Since there had been no standardized form for the data, it was not provided in a consistent manner. As an example, some reports separate frequencies and provide a precursory time for each; other do not. Additionally many do not separate electric and magnetic results. It is, however, the best listing this writer was able to find and the data is used throughout.

Figure 3: Tectonic Plates

Before looking at the specific characteristics some consideration should be given to the location this writer works in: Florida. As previously implied, the majority of earth tremors are associated with the edges of the Earth's tectonic plates. Fortunately for us Floridians, we are not very close to any of those edges.

As shown in figure 3[6], the closest one is far to the south. Coincidently, in a geological sense Florida is also a relatively young area. Therefore it is less likely to contain faults of any sort. The combination of distance from the edge of the plates and the young geological age result in a stable area in terms of earthquakes. However, regardless of Florida's lack of tectonic activity an Earthquake Seismograph Station was established at the University of Florida, Gainesville in 1977. As should have been expected, the station does not suffer from an overly hectic workload.

2.0 Precursors

2.1 Magnetic Field

Direct measurements have been made of ultra-low-frequency[4] (ULF) magnetic field variations occurring prior to, during, and following high magnitude earthquakes. Although it it is expected there should be signals covering the entire frequency spectrum, the higher frequency components are severely attenuated in the lithosphere[5] and do not propagate very far. The signals shown in Figure 4 are from the Loma Prieta (M-7.1) earthquake (18 Oct. 1989) in the Santa Cruz mountains. They were collected by researchers from Stanford University on 2 devices designed to help the US Navy detect enemy submarines. Luckily one of the devices had been placed almost directly over (7 km away) the earthquake epicenter.

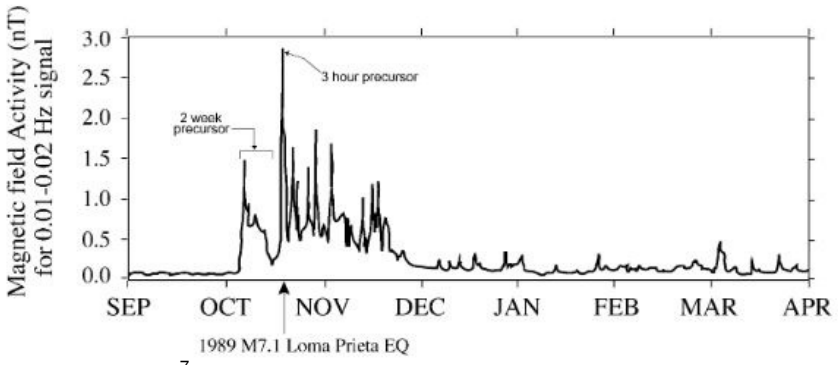


Figure 4[7]: ULF Magnetic Field - Loma Prieta Earthquake

It was stated there were 2 signals collected by the researchers. One was in the Ultra Low Frequency (ULF) range (0.01 - 10 Hz) and the second in the Extremely to Very Low Frequency (ELF-VLF) range (10 Hz - 32 kHz). Together they covered 25 frequency bands. The first signal related to the earthquake was on the ULF system and began on September 12 (~36 days prior to the EQ).

That initial signal cannot be seen in Figure 4. However, on 5 October there was a substantial increase seen on the ULF system. It was followed by an anomalous dip in the signal the day before the EQ. Finally 3 hours before the EQ the an extremely strong signal appeared. It should be noted the ELF-VLF system came alive with the EQ but did not show any precursor activity.

Although the signal shown above is very weak, it was stated it "broke" (exceeded the capacity of) the attached computer system. It should be noted that similar signals were also seen >75 km from the Spitak Armenia earthquake in 1988 and a number of others (Figure 5). In general these results seem to begin about 2 weeks prior to their related earthquake. It may also be seen in figure 5 that there have been earthquakes that did not show these signals. A reason for this dichotomy is not known.

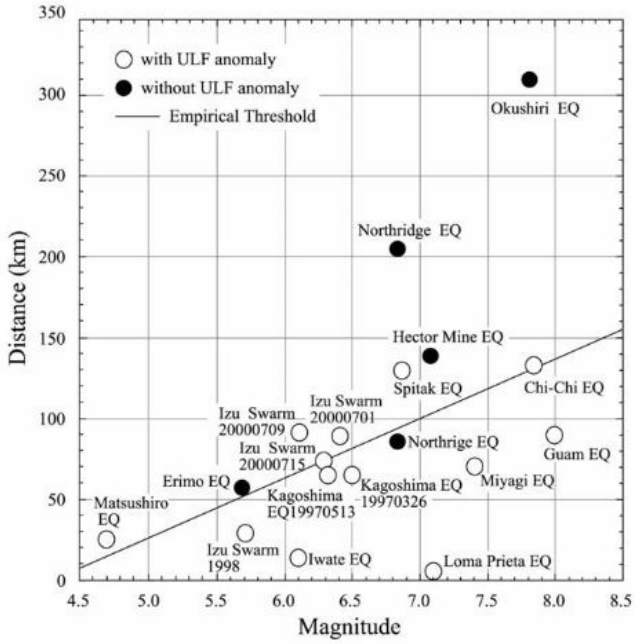


Figure 5[8]: Summary of Earthquake related ULF events

In September of the year following the Loma Prieta earthquake (1999), large earthquake instigated magnetic disturbances were seen from two sensors in Chi-Chi Taiwan. Since one of the sensors was close to the epicenter and the other was many kilometers away, researchers were able to eliminate background noise. They calculated the M-7.7 earthquake must have generated currents between 1 million and 100 million Amperes to create the magnetic field strengths seen. Additionally, the 8-station network in Taiwan recorded magnetic field magnitudes over 200 nano-Tesla (nT) in amplitude weeks before the earthquake.

To date the maximum measured magnitude seems to be approximately 250 nT (0.0025 Gauss). In terms of everyday objects that is not exceptionally high. As per Wikipedia ("Orders of magnitude (magnetic field)"), the magnetic field strength of a typical refrigerator magnet is approximately 0.5 mT or about 400 times stronger that the maximum quoted above. It is accepted that there is discussion on the internet concerning a connection between magnetic and/or electromagnetic fields and mood changes. There is, however, no proof as to its existence, nor if it does, how to quantify it. Due to a lack of any comments on the danger of refrigerator magnets, it is believed these earthquake fields should also be innocuous.

Since the Earth's magnetic field is also quite small, it is believed that a comment should be made about the ability of earthquake fields to affect it. Assuming the EQ field of 250 nT is all horizontal, it can be compared to the Earth's horizontal field (the portion of the field read by a compass). Since the horizontal field is minimum at the poles and gets larger the closer it is to the Equator, the minimum horizontal field in the US would be somewhere in Alaska and the maximum probably in Hawaii. Those values were found to be about 0.277 Gauss in Honolulu and 0.153 Gauss in Anchorage. It is easily seen that an EQ field of 250 nT is at most approximately 1.63% of the Earth's field. This is very small but it could have an effect by deflecting a compass needle. That can be determined by using the superposition principle for fields..

$$\mathbf{B}_{tot} = \mathbf{B}_{earth} + \mathbf{B}_{other} .$$

From geometry, the deflection angle (ϕ) of a compass needle due to the second field can then be calculated.

$$\tan(\phi) = \tan(\mathbf{B}_{other} / \mathbf{B}_{earth}) = 0.0001575 \quad \therefore \quad \phi = 0.009024 \text{ radians } (\approx 1.6°)$$

Thus, it is not credible that this would be noticeable.

2.2 Electromagnetic

In addition to the above magnetic emissions there are also higher frequency electromagnetic emissions associated with earthquakes. There are numerous reports in various places in the world of radio interference shortly before earthquakes. Most of these reports are from Citizen band (27 MHz - 11 meter) and amateur radio operators (Ham radio: 2 meter band 144-146 MHz; 6 meter band 50-54 MHz). Additionally in the In the Hollister, California area an increase (~10 db) in background noise on at 27 MHz and in the 6-and 2-meter bands was reported 12 to 24 hours prior to an M-5.2 earthquake.

Obviously the above reports are the anecdotal type discussed earlier. However, there has also been evidence of the effect from many locations. In 1980, the Sugadaira Space Radio-wave Observatory in Japan recorded (Figure 6) anomalous noise levels from the 31 March 1980 Kyoto earthquake. A half hour before the eathquake[9,10] they recorded an 81 kHz signal was which averaged 15 db higher than normal. The dashed line in Figure 6 represents the normal noise levels for frequencies shown. The solid line is the actual readings obtained. The area containing the anomalous noise due to the earthquake is seen between 0 and 1.33 kHz.

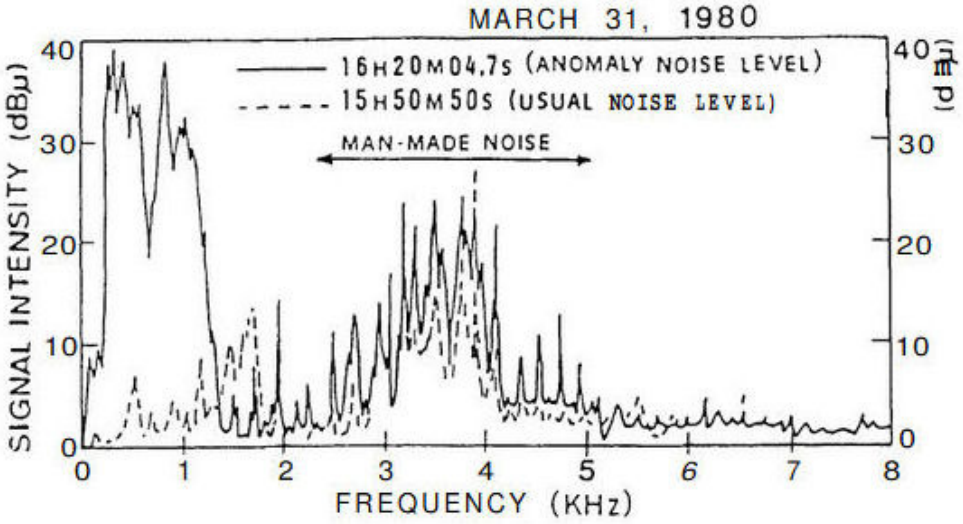


Figure 6[9]:

An 81 kHz signal was also detected at the same laboratory from the 25 September 1980 M-5 Tokyo earthquake. It is seen in Figure 7. Interestingly these figures not only support the theory that an electromagnetic field can be a precursor to an earthquake they also seem to show the fields can travel is a lot further than previously thought. The distance between the Tokyo and the Sugadaira observatory is approximately 290 km. .Finally the observatory also detected a similar 81-kHz signal were observed prior to M- 6 earthquakes in Tokyo Japan in January 28, 1981.

The Figure 7 earthquake also shows another interesting aspect. It can be seen that the signal drops precipitously with the onset of both the main-shock and after-shock. Since the signal drops with both, this cannot be considered a coincidence. Additionally it can be inferred that the source of the signal is not the earthquake itself. It must be the stress in the tectonic plates which is being relieved by the shocks.

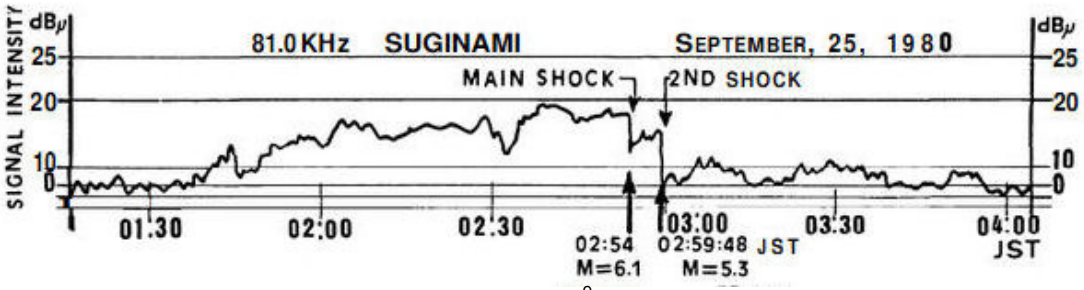


Figure 7[9]

In 1982 James Warwick[11] and others showed EM radiation emanating from micro fractures in quartz bearing rocks by piezoelectricity. It was believed that these microstructures were the proximate cause of the 18 MHz radio emissions from the Chilean fault that had been seen by widely separated radio astronomy receivers 8 days prior to the M-9.5 earthquake (16 May 1969). The theory, however, does not explain how a long range field can be obtained from randomly oriented quartz crystals.

2.3 (Near Earth) Luminous Phenomena

For centuries strange luminous phenomena have been reported before, during and following earthquakes. At times these reports have indicated discreet lights with unusual shapes and motions and other times glows or auras. Some of the reports describe lights very close to the ground while others describe the lights as high in the sky. Additionally there seems to be some correlation between the reports and the amount of seismic energy (earthquake magnitude) released and distance to the epicenter. However, there doesn't seem to be any correlation with the times of occurrence of the lights and the earthquake time. The lights have been reported during earthquakes; but they have also occurred prior to the earthquake and sometimes, after it..

The above disparities in size, report type, and temporal relationship led most people to consider these lights to be, at best, anecdotal (unscientific) or at worst apocryphal (fictitious). However with the advent of universal photography, the concept of earthquake lights has gained acceptance.

As stated, earthquake lights can manifest in a number of different ways. Sightings of floating spheres of light, strange blue glowing columns and lightning that reaches upwards instead of downwards have all been attributed to the phenomenon. The following are photographs illustrating a few of these.

Figure 8[12]: Peruvian EQ - 2007

Figure 8 shows 3 separate frames from a film during the 2007 earthquake in Peru. From the left the first fame shows the scene prior to the EQ, the middle frame shows the scene during the EQ; and the right frame shows the scene after the EQ. (There are sources which declare the middle frame to be airglow in

the ionosphere. However, it looks too bright to be seeing the ionosphere low on the horizon (very far away). It is also the wrong color. Figures 9 and 10 are other pictures of types of earthquake lights.

Figure 9: Orbs above Tagish Lake - 1970

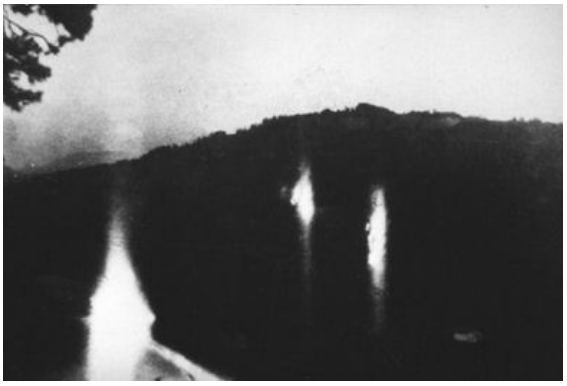


Figure 10: Light Streaks in Romania - 1977

Finally in 2014 a study[13] by Robert Theriault, et.al. was published in the Journal of Seismological Research Letters (JSRL) journal explaining these "fictitious" displays. Although it is mainly a compendium of sightings and related earthquakes, it is an interesting paper. (There were a couple of comments in JSRL to this paper discussing earlier similar papers however there were no criticisms of the work or results.) The real importance of this paper is its validation of both the sightings (and the reporters) and the earlier work of its third author; Dr. Friedemann Freund.

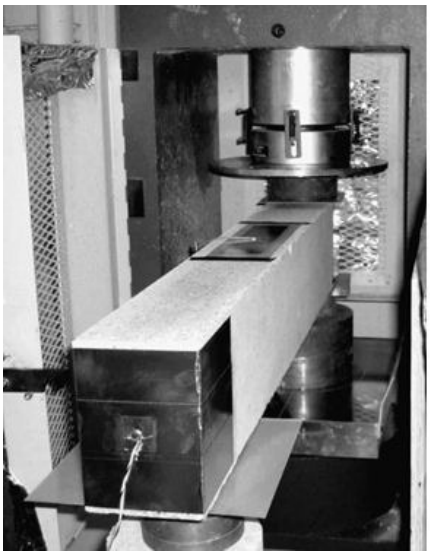
In terms of the sightings, the discussed results of the Theriault paper were:

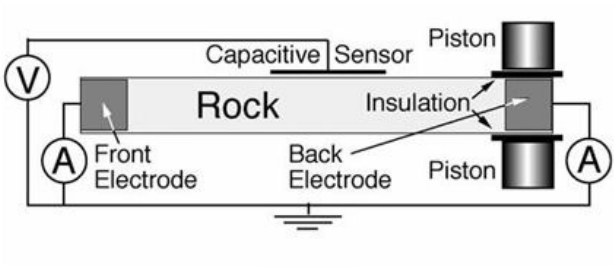
1. Earthquake Lights (EQL) are generated in association with earthquakes over a wide range of magnitude from ~3.5 to >9;
2. Most EQLs were observed from a few seconds to a few weeks prior to the EQ;
3. The processes responsible for their formation are related to a rapid buildup of stress prior to fault rupture and to rapid stress changes during the actual fault movement. EQL have been seen as far as 600 km from any given epicenter; and
4. Most (~90%) of EQL sightings are reported for INTRA-plate seismic events.

Since the generation of any luminous effect involves a generation and propagation of electrical energy in and above the earth, a source had to be determined. That source had previously been determined by Dr. Freund[14]. In multiple prior papers he posited that the Earth's crust works like a battery (or p-type semiconductor) driven by pressure.

Dr. Freund found, that there are two charge carriers in the crust, electrons and positive holes (p-holes). Each are activated when rocks are subjected to stress (see Figure 11). To complete a circuit these 2 charge carriers have to flow through the Earth. Since the earth is comprised of resistive materials (which is shown in Appendix B to decrease in value with depth), the conduction current (electrons) flows downward in the lower resistance path. However the p-holes constitute a polarization current which is not affected by the resistivity. It can flow upward. As stated by Dr Freund, these charges act more like a plasma that can then travel at very high velocities and at the surface, emerge as electric discharges in the air.

In the conclusion of this paper Dr. Freund estimated that with a reasonable cross section of stressed crustal rock, there would be enough charge available to generate a huge (not quantified) amount of current. Thus even allowing for losses there should be enough current to produce the surface and atmospheric effects seen.





A block of granite fitted with Cu electrodes at each end is compressed generating the currents.

Figure 11

Figure 12[15] is a cartoon showing the circuit proposed by Dr. Freund. The bottom portion shows the electron current traveling down to the mantle*. By definition, the mantle is a silicate rocky sheath between the Earth's core and the plates. The uppermost portion of the mantle and a portion of the crust is referred to as the lithosphere.

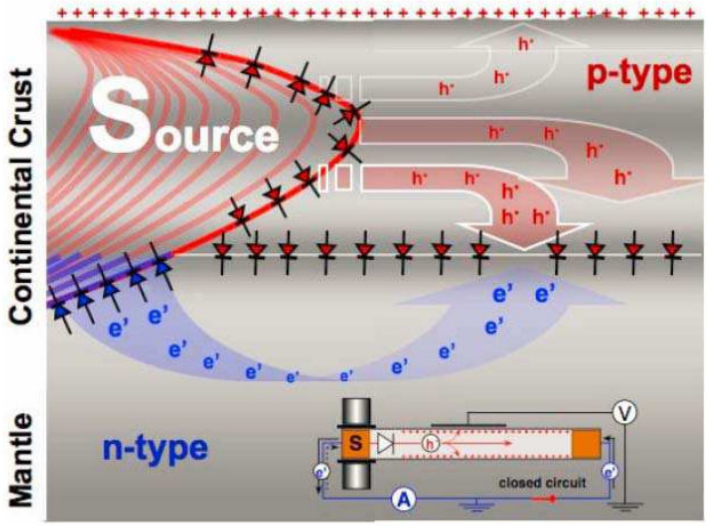


Figure 12: Cartoon of Dr. Freund's Crustal Circuit

---

* Mantle: The region of Earth between the core and the crust. The plates slide on top of the mantle.

2.4 Ionospheric Phenomena

Earth's atmosphere contains a series of regions that due to impingement of cosmic rays is largely composed of a neutral plasma of positive ions and free electrons. As a group, these regions are collectively called the ionosphere. Although they are located far from Earth's surface (about 100 km to over 900 km above the Earth) they are connected via the atmosphere. The plasma is electrically coupled to the Earth and thus can affect and reflect many things occurring on and/or beneath the surface. It has been agreed that the mechanism for this is called "Lithosphere-Atmosphere-Ionosphere" coupling. Unfortunately there is not the same complete agreement as to how all of the pieces go together.

The most obvious connection is electrical. As stated, the ionosphere is a neutral plasma and as such is capable of carrying an electrical current. It was shown in the previous section that a stress in the earth's crust can create an electric potential on the Earth's surface. Since the plasma electrons are much lighter than the ions, the ground potential will also cause the charges to separate and thus the densities of each in any particular volume to change. The density of interest in this section is the electron density. Simultaneously the ground potential will also cause some ionization of the air molecules near the surface thus allowing a current to flow between the earth and the ionosphere. From satellite data of the atmosphere prior to a Japonese earthquake it was determined[16,17] that the concentration of electrons in the ionosphere increased in the days prior to the earthquake. Additionally It was also shown by many[18,19] that the same stress that caused the electric potential also causes a release of radioactive radon gas to the air adding to the ionization and to the current.

While the above process is occurring, the ionosphere electric field will also excite atoms of the air (neutral oxygen and nitrogen) around it. When those atoms later de-excite they produce a glow in the ionosphere. While the lines of nitrogen are primarily in the in the ultra-violet region and create a blue tinge to the ionosphere, it is the 2 lines of oxygen[20] (5,577 Å {green} and 6,300 Å {red}) that are mostly seen as airglow. Example of a these 2 airglows is provided in figures 13 and 14.

Figure 13: ???

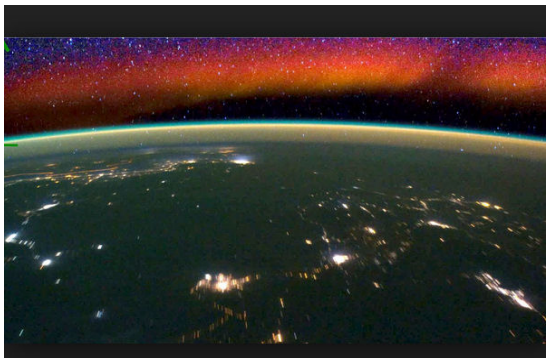


Figure 14: NASA (ISS - 2017)

A word of caution to MUFON Field Investigators. The only difference between the airglows discussed in this paper and the Aurora Borealis is the initiator. If the glow is seen at a low Latitude, it would be safe to assume it has a terrestrial source. Conversely, a high Latitude would probably be initiated by the sun.

Due to the relative proportions of atoms at each specific altitude and the energies involved, when seen together, the red (6,300) line will always be higher than the green (5,577) line and the blue higher than both. The plots in figures 15[21] and 16[21] are both from data collected by rocket borne photometers launched in Natal Brazil. The data for the figure on the left was obtained 11 December 1985. The data for the figure on the right was obtained 31 October 1986. It is not known which direction was being observed to obtain the data.

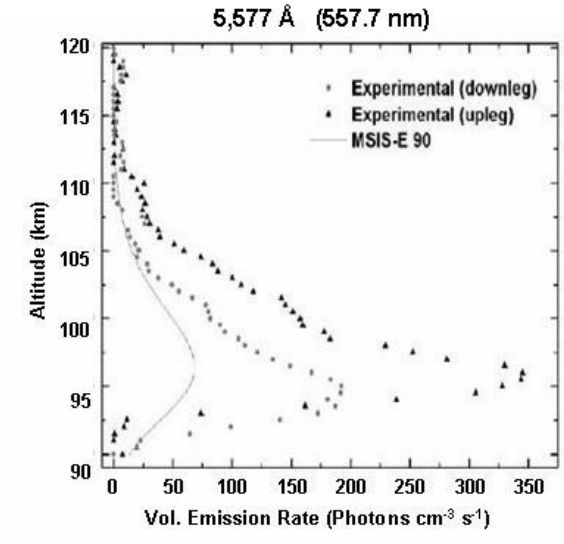


Figure 15: Altitude of Green Oxygen Line

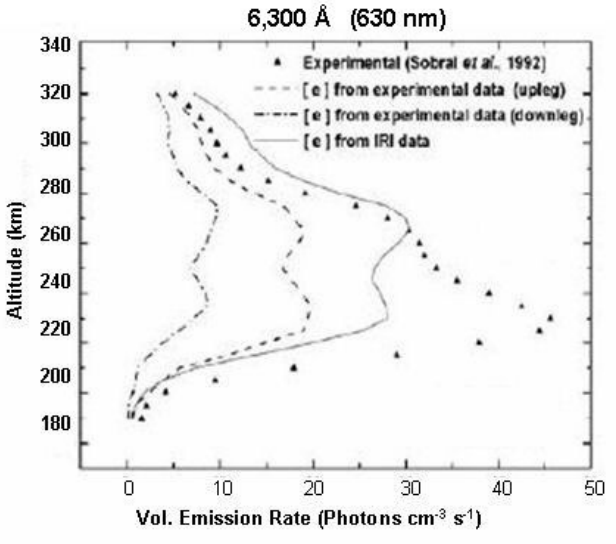


Figure 16: Altitude of Red Oxygen Line

There is a second effect in the ionosphere that can be initiated by stress in the Earth's crust. (The crust is a term that includes the tectonic plates and the rocks, dirt etc. above the plates.) Rayleigh waves (see Appendix A) propagate along the Earth's surface with velocities ranging from 3 to 4 km/s. Since that is approximately 10 times faster than the speed of sound, the compression (pressure) waves generated in the atmosphere will propagate almost totally vertically[22]. Assuming an idealized atmosphere (isothermal and shear free), the air density decreases approximately exponentially with height { e^{-az} }. Therefore by conservation of energy, the wave amplitude would **increase** exponentially with height as the square root of the density { $e^{-az/2}$ }[23]. Using that scaling, even a 1 mm amplitude wave on the surface of the Earth would result in a huge wave in the ionosphere. Specifically at an altitude of 100 km, the unnoticeable 1 mm surface wave would be larger than 7 km.

The above wave would dramatically change the electron distribution[24] in the ionosphere and could thus affect any system that relies on transmitting electromagnetic waves through it. Ionospheric Scintillation is caused by oscillations of the electron along the signal path and is the result of interference via refraction and/or diffraction of the signal's waves. The one ubiquitous item in today's society that can be affected by this would be the GPS[25] systems. Severe scintillation conditions (Large earthquakes) could prevent a GPS receiver from locking on to the signal and can make it impossible to calculate a position. Less severe scintillation conditions (small earthquakes or tremors) could reduce the accuracy and the confidence of positioning results. It is unlikely that anyone would connect (or even notice) a small error in their GPS receiver to a UFO report. Not locking on however would be noticed and may be reported. Since this depend on the line of sight between the GPS satellites and the receiver, it is possible the witness could be far from the earthquake site. However an exceptionally large earthquake even one a long distance away should be noted by the investigator.

2.5 Animal Behavior

Reports of unusual animal behavior near or following earthquakes are easily found on every continent and throughout the centuries. Since these reports cover widely divergent communities and times, this cannot be a result of communal reinforcement. To not investigate the concept is equivalent to ignoring

what could be a very important precursor to disaster that could save many lives. To use animal behavior as a prediction transducer there are 3 assumptions that must be true for it to be effective..

1. Earthquake precursors must be reliably perceived by some animals;
2. The animals have to show unusual behavior in response to the precursors; and
3. People must be able to recognize those unusual behaviors above the background of other possibilities.

It is believed that that it is the last of these that is the hardest to show.

It is well documented that numerous animals are very sensitive to subtle mechanical, chemical, and electromagnetic stimuli. However, reports about sensing earthquakes tend to be anecdotal and retrospective. Normally data only exists for what happened after the earthquake. Documentation of behaviors prior to the earthquake is rare. Therefore, statistics of what changed is also rare. Additionally the few studies that do exist are either incomplete, have data that cannot provide an unequivocal result; or use eusocial groups (ants, wasps etc.).

Many sources[26] single out eusocial groups as subjects of studies for this effect due to ease of monitoring and controlling their environment, The problem is, eusocial groups are absolute collectives. They tend to respond to external stimuli as a single super-organism rather than as individuals. Unless an ecological occurrence would affect the society as a whole, individual members would continue with their function and ignore the occurrence. It therefore would not be surprising that such studies would return conclusions of "no effect".

An interim report of one study[27] that looked into the effect of earthquakes on 10 Pocket Mice (Perognathus) was found. It used two facilities (Morongo Valley, San Bernardino County {about 106 miles east of LA} and Stone Canyon, San Benito County {~37 miles East of Monterey) in California and monitored the animals from November 1979 through the end of 1980. Although specifically written for the USGS, no mention of it could be found on the USGS pages. There was also no final study found. The study monitored gross motor activity (running in a wheel or passage through a switch gate). These activities were chosen because they exhibit fairly regular and predictable patterns. Those patterns can therefore be electronically monitored and are amenable to both qualitative and quantitative analyses.

The report stated that changes were observed in activity patterns in both facilities during the days immediately preceding and following commencement of a 1980 earthquake swarm. It was, however, believed that not all of the changes could be associated with the earthquake swarm. The report concluded that the data supported for the premise that animal activity increases in the period prior to an earthquake. However the authors stated it was, at best, weak support.

This is an example of a study that is not complete. Data for 6 (not 10) subjects (mice) is supplied but there are multiple problems with it and its analysis.

- First, the data for each mouse was not normalized to minimize any systematic bias that may exist in the data sets. This would have probably eliminated some of the equivocation stated about changes not associated with the earthquake swarm.
- Second the only analysis supplied was a single linear regression of the total activities of all of the mice. Each mouse should have been analyzed independently and followed by an analysis of correlations between their activities.
- Finally, the analysis covered a 3 month period (day 10 to day 102) which also contained (by their count) a total of 17 earthquakes, all with epicenters within 50 km. The study contained periods of earthquakes and periods of relative tranquility. It is unreasonable to assume the total period can be described by a single linear analysis, The study should have broken the period to smaller sections and done each separately.

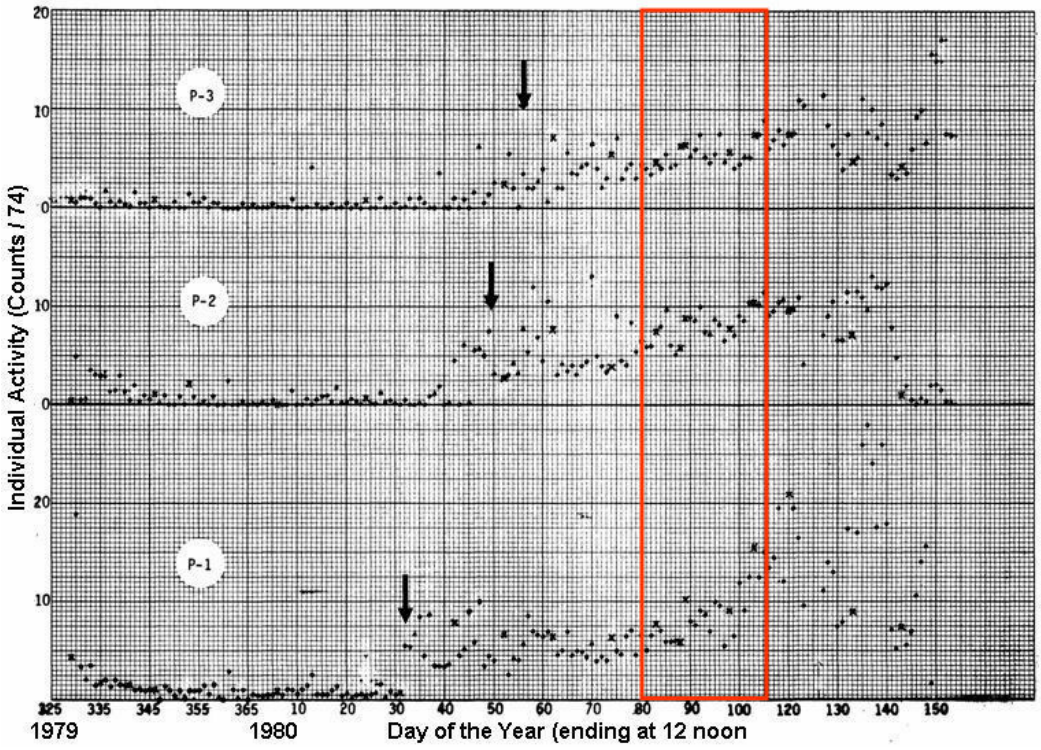


Figure 17: Individual Activity for P1, P2, and P3

Figure 17 (without the red box) is an example of how the data was presented in this study. As can be seen this graph covers many more days than the 92 days discussed above. In this period there were 37 earthquakes. It should be mentioned that the quiescent period to the left in the figure covers the winter months and the study subjects normally hibernate during those months.

The red box (25 days) was added by this writer to indicate a period of time that could be used to show the effect of earthquakes on animals. During this period there were 16 earthquakes in the testing area arranged as follows.

days 98 & 99	There had 2 small EQs (M 2.5 on day 98 & M 2.2 on day 99)
day 104	There were 6 small EQs ranging from 2.4 to 3.2 and 1 large EQ with a magnitude of 4.8
day 105	There was 5 small EQs ranging from 2.5 to 3.2
day 110	There were 2 small EQs (M 2.3 & M 3.0) .

Although this contains multiple quakes, they are mainly concentrated near the middle in days 104 and 105. Although it is fairly obvious by observation that there is a correlation between the 3 mice shown for this period. It is also easy to see that this correlation would cover the period prior to the main earthquake swarm as well as the periods during and after it. However it is not known if the earthquakes are the source of this correlation.

The following figure is a simple linear regression done by the writer for mice P1, P2, and P3 for the 7 day period (day 99 - day 196 inclusive) in the red box. The data for this graph was made by reading it by eye from figure 18. The small "r"s in the lower right corner are the calculated correlation coefficients (1.0 is perfect correlation) between the 3 graphs. As expected there a large correlation.

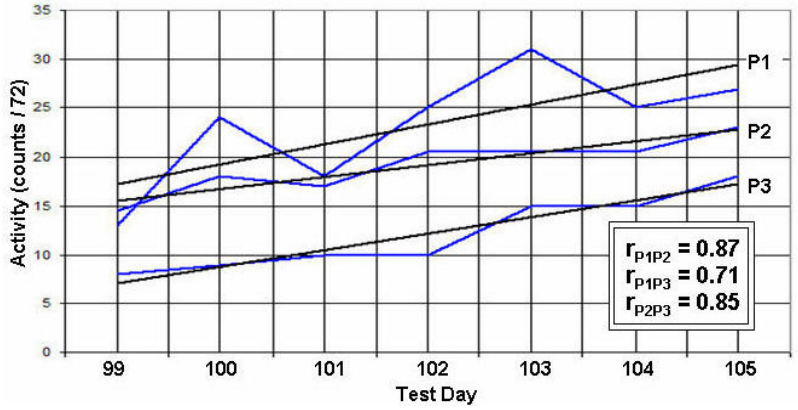


Figure 18: Linear Regression of P1, P2, P3

It is understood that the above results do not answer any of the questions concerning the possibility of animals sensing coming earthquakes. It doesn't even prove these 3 mice reacted to an earthquake or something else. However it does show they seemed to react together to something and it is known an earthquake swarm existed during the days 104 and 105. It also shows that humans would be capable of discerning this reaction. It is unfortunate that a final report for this study could not be found. It may have partially answered some of the questions that remain. Proof, however, will require multiple studies. It is also understood that even if this could unequivocally show that the mice reacted prior to the earthquakes this would not be a complete answer, It doesn't answer the question of mechanism.

As was stated above, the study of the effect of earthquakes on Pocket Mice was done for the USGS, but the USGS does not reference it. It therefore has to be assumed that if there was a final report, the authors did not add in the types of statistical analysis discussed above. In general the USGS only states that they agree the "keen senses" of animals could allow them to sense the earthquake's compression or "P" wave (see Appendix A) prior to the much larger "S" wave. While it is true the S wave will arrive sooner and animals may react to it, the travel time between waves is much to short (Figures 19[28] and 20[28]) to be the source of the above results.

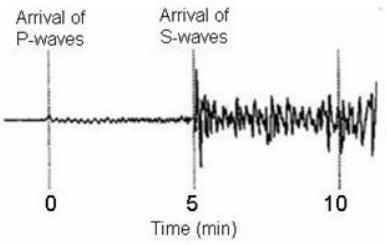


Figure 19

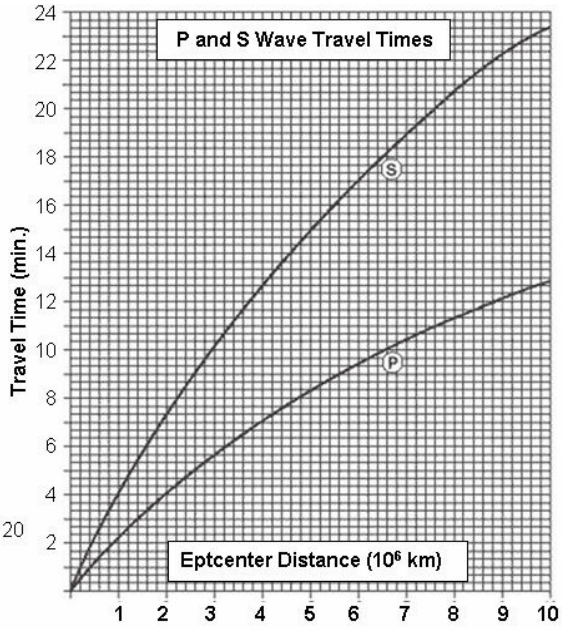


Figure 20

3.0 Field Investigator

Although earthquakes themselves are chaotic events, there are patterns to their location as well as causation and functioning. However this paper is not really concerned with the earthquakes per-se. For a MUFON Investigator, the concern is with secondary effects that are normally called precursors. Additionally since it is mostly stress or its release that causes the precursors it has to be remembered that the effect may occur without any earthquake noted. It is, however, believed that the effects should become more pronounced for higher magnitude earthquakes. This implies that while the precursor may exist without an earthquake, it should be of lesser degree than a similar type of precursor with an earthquake.

It is also probable that precursors would have larger effects close to the epicenter of an earthquake.. It is therefore believed that if the witness has, in his mind, separated the earthquake and the effect he is probably far from the epicenter or the precursor was minor. It is, of course, up to each investigator to determine what constitutes "far" for each effect considered.

3.1 Magnetic Field anomalies

This is a relatively easy pecursor to discuss since it was shown in Section 2.1 that the maximum field strengths (250 nT) measured to date are too low to be noted by anyone without specialized equipment. It was also shown that it is approximately 400 times weaker than the field of a typical refrigerator magnet and about 1.6% of the weakest horizontal field from the Earth measured in the US. Additionally in Reference 29 it was shown even with specialized equipment, the maximum distance from the epicenter recorded was about 600 km. and although there were a couple of reports for a precursory rime of about 1 week, the normal time was about 1 day (Hollister California). Finally once the stress in the Earth's crust is relieved by the EQ, the magnetic field should begin to reduce. In the Loma Prieta EQ, it took about 1 month to reduce back to normal. Finally it was stated in Section 2.1 that there is absolutely no proof of magnetic field of this magnitude altering the mood of a witness. It is therefore not considered realistic for a witness to have noted any effect from an earthquake magnetic field.

MUFON Field Investigator suggestions:

1. If told by a witness that they know there was a magnetic (not electromagnetic) field during the sighting (for whatever reason) it is probably not a function of an earthquake or stress in the Earth. Therefore look in another direction for the cause.

2. If told by a witness that their mood or consciousness was affected by an earthquake magnetic field, it is probably not a function of an earthquake or stress in the Earth. Therefore look in another direction for the cause. They, of course, can be affected by the quakes motion but that is a different subject.

3.2 Electromagnetic anomalies

Many laboratories have recorded electromagnetic emanations generated in the earth prior to earthquakes. It has also been proven that the same emanations can be obtained from granite slabs under stress in a laboratory. Since all of these emanations precipitously drop with the onset of an earthquake shock or any other stress release, the emanations are generated by stress in the rocks in the mantel. The earthquake itself is only a method of relieving that stress. Therefore these signals are complete **pre**cursors that basically end with an earthquake or aftershock. Since individual laboratories always seem

to record the same frequencies but differ from other laboratories, it has to be assumed that the emanations are actually noise (multiple frequencies) and the frequencies recorded are just a function of the laboratory equipment and settings.

Outside of laboratories, most reports of electromagnetic anomalies have been from Citizen Band (CB) or Amateur (Ham) radio operators. One reason for this is the fact that CB and amateur radios are mostly analog rather than digital (as most other systems are or are becoming). Distance also seems to be less important with these systems. Normally CB system are considered short distance radio while ham radios reach long distances. However each can reach thousands of miles in specific conditions (tropospheric ducting, multiple hop propagation, etc.). Therefore an investigator should not limit his investigation to nearby events..

As to coordination of electromagnetic interference with earthquakes, these effects seem to start hours to days prior to the EQ.

MUFON Field Investigator suggestions:

1. If the witness reports radio interference obtain information about the receiver. Digital receivers should not be subject to this type of interference.
2. Check "near and far" for similar reports. If an earthquake is the cause, it is likely, there would be multiple complaints.
3. Check the USGS site for earthquakes that occurred near the time the static was received. If no reported EQ can be found check the local newspapers for any local minor disturbances related to stress in the Earth. Do not be disturbed if none are found since the disturbance could be very far away.

3.3 (Near Earth) Luminous Phenomena

This section refers to discreet lights, upward directed or ball lightning, or glows (also described as auras) close to the observer and on or near the ground. (It should be noted that this does not refer to glows on the horizon. They are handled in the next section.) In terms of discrete lights, they can be orbs or oddly shaped lights.

All of these effects have a single source; electrification of the ground. It was shown in a laboratory by Dr. Friedemann Freund that blocks of granite could act like a battery when stressed. Placing a compression stress on one such block caused electrical currents to flow in an external circuit. However the existence of ground electrification could be from below (have a terrestrial source) or from above (an extra-terrestrial source).

In terms of earthquakes, the lights have been seen from distances up to 600 km from the epicenter and occurring seconds to weeks prior to the earthquake. One interesting item determined was that only 5-% of these sightings were inter-plate occurrences. Therefore most occur away from plate edges which is equivalent to saying, away from the majority seem to occur far from plate edges..

Since to note ground electrification the witness would have to be standing on or near the electrified surface. If on such a surface, the witness themslf may or may not also have been electrified. It is reasonable to assume that there could be some physiological effects that can be investigated. It is known that blood and lymph fluids contain free electronic charges that would react in response to an applied external electric fields. According to the World Health Organization (WHO), situations such as this can cause headaches, fatigue, anxiety, and prickling skin (among other things).

MUFON Field Investigator suggestions: (Note: There is no way to absolutely know the source, but the following could help.)

1. Check for a possible earthquake source. Remember an earthquake source may be many hundreds of kilometers away and weeks after this sighting. Since the earthquake should relieve at least a portion of the stress, it is unlikely a source earthquake would be prior to this sighting.
2. Determine if the witness had any odd feelings around the time of the sighting. Remember if there are person effects due to the electrification, that cause will have existed prior to the sighting and probably will still exist after it.
2. If the witness reports the above personal effects, check the shoes the witness had worn during the sighting. Check the manufacturer for information as to the conductivity of the soles (conducting, anti-static, non-conducting).
3. Determine if the witness had headaches or was fatigued afterwards.
4. Although more completely discussed in the following portion, check if the lights displayed any specific color. As will be noted later, air is mainly oxygen and nitrogen. Recombining oxygen atoms will glow red or green, while nitrogen glows ultra-violet / blue. Any other color would probably be from trace elements in the air.

3.4 Ionospheric Phenomena

There are really only 2 possible earthquake precursors relating to the ionosphere; its ability to interrupt electromagnetic transmission from satellites and airglow. Although the first can occur, it is not considered a realistic problem for a Field Investigator. The magnitude of the earthquake needed would be so high that the Field Investigator would have no problem connecting any report to the earthquake. The second, however, is quite common.

The ionosphere is a neutral plasma. Airglow occurs when the charging of the earths surface (from stress in the mantel) and a simultaneous release of radon gas (by the same stress) causes ionization of the atmosphere near the ground. It also causes the charges in the plasma to separate leaving an over-abundance of electrons at one level and an under-abundance at another. The conjunction of these 2 effects causes a current to flow between the ground and the ionosphere which subsequently causes additional ionization of oxygen and nitrogen atoms in the ionosphere. The actual glow is a result of the de-excitation of the nitrogen and oxygen ions.

The glow that results would be a bluish tinge from the nitrogen above a red glow from one of the possible oxygen de-excitation which is itself above a green glow from a second oxygen level de-excitation. It should be noted that the same glow can arise from an Aurora, The difference being the cause: sun or terrestrial. Although it is very rare to see an Aurora at a longitude of 40° N (NYC) or lower, it is possible. It is suggested the Field Investigator always check solar activity. Intense solar winds can cause a "Geomagnetic Substorm"[32] pushing the "Auroral Oval"[33] down.

MUFON Field Investigator suggestions:

1. Check the location of the airglow. Unless there are intense solar storms, if it is seen to be lower than ~40° N or S (approximately Philadelphia & Denver in the northern hemisphere) it is safe to call it airglow.
2. Check the colors seen of the airglow. Airglows will mainly be red and/or green.

3. Airglows will only appear to be low when they are being seen on the horizon. This means a green glow at a height of 97 km is a minimum of ~604 km away and a red glow at an altitude of 260 km is a minimum of ~1841 km away.

5. Check for possible earthquakes or other seismic events that could the cause of an airglow.

3.5 Animal Behavior

Although there have been many reports of strange behavior by animals prior to and during earthquakes there is no or very little actual evidence. It is almost certainly true, however it remains apocryphal. This, however, is not a disqualifying problem when investigating UFO sightings. Absolute proof also rarely exists for UFOs. Thus most conclusions can only be what is most probable.

Rating the response of animals to earthquake or their precursors requires reasonable answers to 3 questions.

1. Can some animals reliability perceive earthquake precursors?
2. Will those animals show unusual behavior in response to the precursor?
3. Is it possible for the people arround the animal to recognize those behaviors?

Its reasonable to assume the animals that an investigator will encounter will not have been trained to anticipate an earthquake. The responses that seems to be universal in most animals are anxiety and fear. Specifically for the present situation it can be said that anxiety would be a generalized reaction (uncertainty) to the unknown while fear is the reaction to a known threat[34]. To some degree, both of these will probably be seen in a reaction to an earthquake precursor. The anxiety reaction would probably be an increase in what is normally described as being clingy with their master. If the situation got worse that reaction would probably change to fear. For some that would mean running away. For other the pet would probably attempt to get the master to go with them. It isn't realistic that the investigator would see these reactions but the master would.

It should also be remembered that animal reactions do not distinguish between sources of the unknown or danger. Therefore the reaction is expected to be the same to earthquakes, UFOs or a few others.

MUFON Field Investigator suggestions:

1. Watch the interaction of pet and master to determine a baseline response.
2. Attempt to determine a history log of the pet leading up to and during the report time.
3. Determine if anything else occurred that may have instigated the response.
4. Determine if the master knows of any other animal unusual

4.0 References

1. http://earthquake.usgs.gov/earthquakes/search/
2. The Conterminous US is defined as a rectangle enclosing the lower 48 startes and small portions of Mexico and Canada. The coordinates defining the rectangle are: Latitude 24.6 to 50; Longitude -125 to -65.
3. A check of the entire USGS data-base there was only 1 that could even be considered as being in Florida. It was a magnitude 3.1 quake on 5 May 1997 and was on the Florida-Alabama line.
4. In this instance, the ULF range refers to signals less than 10 Hertz.
5. The lithosphere is the solid outer section of the Earth.
6. Jennifer Young: http://www.decodedscience.org/florida-earthquake-history-tectonic-setting/52225 Image from USGS
7. Karakelian, D. et.al.: " Ultra-low frequency electromagnetic measurements associated with the 1998 Mw 5.1 San Juan Bautista, California earthquake and implications for mechanisms of electromagnetic earthquake precursors"; Technophysics **359,** (2002) 65-79
8. Hattori, "ULF Geomagnetic Changes Associated with Large Earthquakes"; TAO, Vol. **15**, No. 3, 329-360, (2004)
9. Gokhberg, MB; Morgounov, VA; Yoshino, T; Tomizawa, I: "Experimental Measurement of Electromagnetic emissions Possibly Related to Earthquakes in Japan": J. Geophys. Res.*,* **87** issue B9, 7824-7828
10. Yoshino, T: "Low-Frequency Seismogenic Electromagnetic Emissions as Precursors to Earthquakes and Volcanic Eruptions in Japan": Journal of Scientific Exploration; Vol **5**, issue 1, pg 121-144, (1991)
11. Warwick, J. W.*,* C. Stoker*, and* T. R. Meyer *(*1982*), "*Radio emission associated with rock fracture: Possible application to the Great Chilean Earthquake of May 22, 1960"*,* J. Geophys. Res.*,* **87** *issue* B4*,* 2851–2859, 10 April 1982*, doi:*10.1029/JB087iB04p02851
12. The picture shown is from "Electric Displacement by Earthquakes" by Antonio Lira and Jorge A. Heraud. They reference an excellent short film: http://www.youtube.com/watch?v=SHmHsP1gd8I
13. Theriault, R.T.; St-Laurent, F.; Freund. F.T.; Derr, J.S. "Prevalence of Earthquake Lights Associated with Rift Environments": Seismological Research Letters; **85** (issue 1), 159-178: January 2014
14. Freund, F.T.; Takeuchi, A.; Lau, B.,W.,S: "Electric Currents Streaming out of Stressed Igneous Rocks - A Step Towards Understanding Pre-earthquake Low Frequency EM Emissions": Physics and Chemistry of the Earth; **31**, 389-396, (2006)
15. Freund, F.T.: "Pre-Earthquake Signals - Part II: Flow of Battery Currents in the Crust": Natural Hazards and Earth System Sciences; Vol. **7**; 543-548; (2007)
16. Ouzounov, D.; Pulinets, S. et.al.: "Atmosphere-Ionosphere Response to the M9 Tohoku Earthquake Revealed by Multi-Instrument Space Borne and Ground Observations. Preliminary results": Earthquake Science, Volume **24**, Issue 6, pp.557-564 (2011): arXiv:1105.2841 [physics.geo-ph]
17. Ouzounov, D.; Pulinets, S.; Davidenko, D.: "Revealing pre-earthquake signatures in atmosphere and ionosphere associated with 2015 M7.8 and M7.3 events in Nepal. Preliminary results": arXiv:1508.01805 [physics.geo-ph]

18. Pulinets, SA; Alekseev, VA; Bpyarchuk, KA; Hegai, VV; Depuev, VK: "Radon and Ionospheric Monitoring as a Means for Strong Earthquake Forcast:: Il Nuovo Cimento; Vol. 22, N. 3-4; 621-627 (1999)
19. Pulinets, S.; Boyarchuk, K.: "Radon Emanation as Precursory Phenomenon": Sect. 1.2 (Pg10) Ionospheric Precursors of Earthquakes; Springer-Verlag, Berlin, Heidelberg: (2005)
20. Pilipenko, VA; "Relationship Between Night Airglow and Seismic Activity"; Annales Geophysicae; **3**, 6. 689-694 (1985)
21. de Meneses, FC; Miralikrishna, P; Clemesha, BR: " Height profiles of OI 630 nm and OI 557.7 nm airglow intensities measured via rocket-borne photometers and estimated using electron density data: a comparison": Geofísica Internacional **47** (3), 161-166 (2008)
22. Lognonné, P et.al.; "Seismic waves in the ionosphere"; EuroPhysicsNews; **37** No. 34, 11-14
23. Hines, CO: " Atmospheric Gravity Waves: A New Toy for the Wave Theorist": RADIO SCIENCE Journal of Research (NBS/USNC- URSI); Vol. **69D**, No.3, March 1965
24. Tiwari, R; Bhattacharyaa, S; Purohitb, PK;, Gwal, AK: " Effect of TEC Variation on GPS Precise Point at Low Latitude": The Open Atmospheric Science Journal, **3**, 1-12 (2009)
25. De Agostino, M.; Piras, M.: " Earthquake forecasting: a possible solution considering the GPS Ionospheric delay": Nat. Hazards Earth Syst. Sci., **11**, 3263–3273 (2011)
26 Lighton, J,; Duncan, F.: "Shaken, Not Stirred: A Serendipitous Study of Ants and Earthquakes": Journal of Experimental Biology: **208**; 3103-3107; (2005)
27 Lindberg, R.G.; Skiles, D.D.; Hayden, P.: "Can Animals Predict Earthquakes? A Search for Correlations Between Changes in Activity Patterns of two Fossorial Rodents and Subsequent Events"; USGS Contract No. 14-08-0001-17686
28 Regents Prep: Earth Science: The Dynamic Crust: Earthquakes: http://regentsprep.org/regents/earthsci/units/earthquakes/earthquakes.cfm
29. Petraki, E. et.al.: "Electromagnetic Pre-earthquake Precursors: Mechanisms, Data and Models - A Review": J Earth Science & Climatic Change, Vol. 6, Issue1, 2015
30. Magnetic Field Anomalies Recorded Prior to the M=7.6 Chi-Chi Earthquake in Taiwan, Inferred Ground Currents, and the Electrical Conductivity of Rocks
31. Horng-Yuan Yen, et.al.: " Geomagnetic fluctuations during the 1999 Chi-Chi earthquake in Taiwan": Earth Planets Space; **56**; 39-45 (2004)
32. Geomagnetic Substorm: A disruption of the Earth's inner magnetosphere caused by the impact of intense solar winds, such as those caused by flares and CME's.
33. Auroral Oval: The oval, centered on a magnetic pole, where auroral activity takes place.
34. Steimer, Thierry: "The biology of fear and anxiety-related behaviors": Dialogues in Clinical Neuroscience; **4** (3), 231–249; Sep 2002

Appendix A

Earthquake Waves

Earthquake shaking is the result of three basic types of elastic waves. Two of the three propagate within a body of rock. The faster of these body waves is called the primary or P wave. Its motion is the same as that of a sound wave in that, as it spreads out, it alternately pushes (compresses) and pulls (dilates) the rock. These P waves are able to travel through both solid rock, such as granite mountains, and liquid material, such as volcanic magma or the water of the oceans.

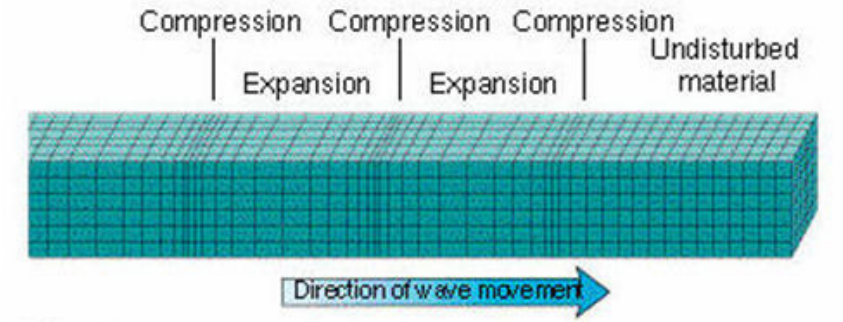


Figure A-1: Primary (P) Wave

The slower wave through the body of rock is called the secondary or S wave. As an S wave propagates, it shears the rock sideways at right angles to the direction of travel. If a liquid is sheared sideways or twisted, it will not spring back, hence S waves cannot propagate in the liquid parts of the earth, such as oceans and lakes.

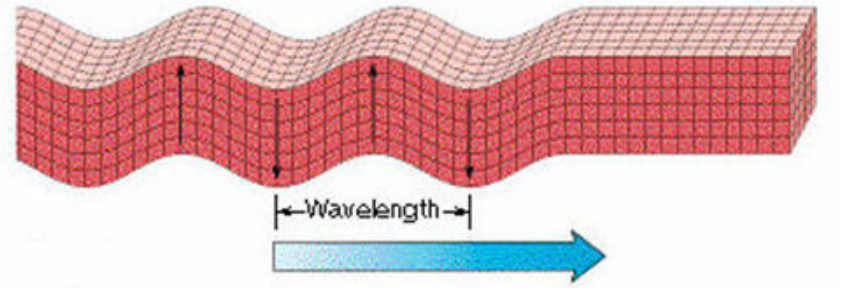


Figure A-2: Secondary (S) Wave

The actual speed of P and S seismic waves depends on the density and elastic properties of the rocks and soil through which they pass. In most earthquakes, the P waves are felt first. The effect is similar to a sonic boom that bumps and rattles windows. Some seconds later, the S waves arrive with their up-and-down and side-to-side motion, shaking the ground surface vertically and horizontally. This is the wave motion that is so damaging to structures. The third general type of earthquake wave is called a surface wave, reason being is that its motion is restricted to near the ground surface. Such waves correspond to ripples of water that travel across a lake. Surface waves in earthquakes can be divided into two types. The first is called a Love or L wave. Its motion is essentially that of S waves that have no vertical displacement; it moves the ground from side to side in a horizontal plane but at right angles to the

direction of propagation. The horizontal shaking of Love waves is particularly damaging to the foundations of structures.

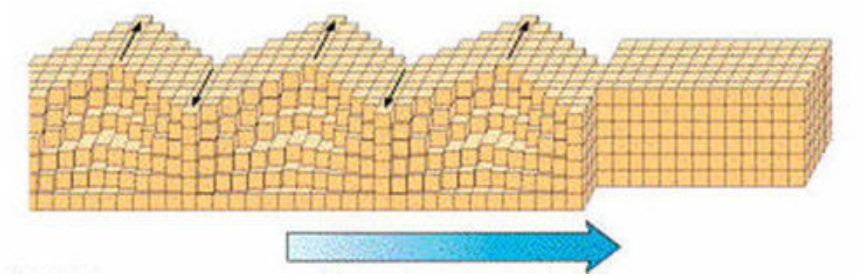


Figure A-3: Surface Love (L) Wave

The second type of surface wave is known as a Rayleigh wave. Like rolling ocean waves, Rayleigh waves wave move both vertically and horizontally in a vertical plane pointed in the direction in which the waves are traveling. :

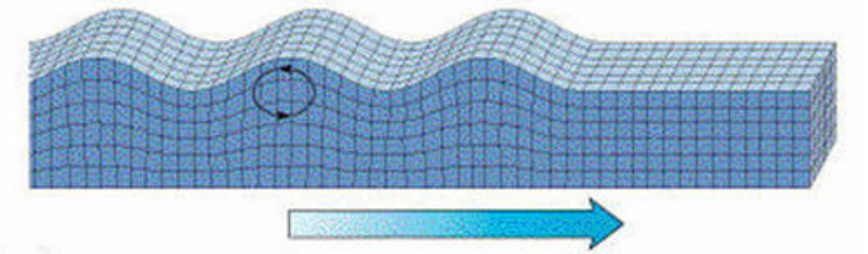


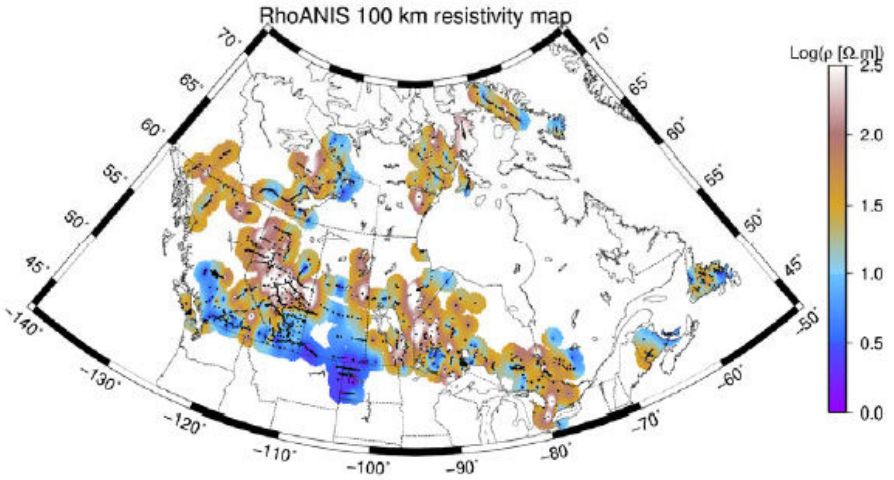
Figure A-4: Surface (Rayleigh - R) Wave

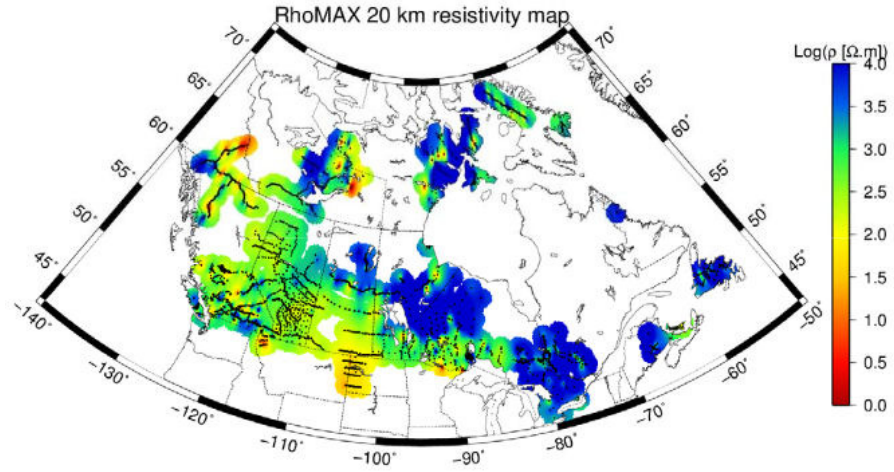
Surface waves travel more slowly than body waves (P and S); and of the two surface waves, Love waves generally travel faster than Rayleigh waves. Love waves (do not propagate through water) can effect surface water only insofar as the sides of lakes and ocean bays pushing water sideways like the sides of a vibrating tank, whereas Rayleigh waves, because of their vertical component of their motion can affect the bodies of water such as lakes.

Appendix B

Lithosphere Resistivity

"The electrical resistivity of Canada's lithosphere and correlation with other parameters: Contributions from LITHOPROBE and other programmes" Alan G. Jones et. al.: Canadian Journal of Earth Sciences: Vol. **51** no. 6: pg 573-617, (2013)





Choose a colored location easily located on both maps and read the resistivity.

		20 km	100 km
60°N	-140°W	~ 4.0 Ω-m	~2.0 Ω-m
47.5°N	-80°W	~ 2.0 Ω-m	~0.5 Ω-m

By inspection, the 20 km depths are mainly 2.5 - 4 ohm-m while the 100 m depths are 0.5 - 2.0 ohm-m. It is understood this is for Canada, however, it is not believed this tendency could depend on political divisions.

Appendix C

Comments on the Data Handling in:

"Can Animals Predict Earthquakes? A Search for Correlations Between Changes in Activity Patterns of two Fossorial Rodents and Subsequent Seismic Events"

Figure C1 was copied from the report. It shows The activity of 3 of the small pocket mice and covers a time span from (day 225) noon 13 Aug. 1979 to about (day 150) noon 29 May 1980. The mice are lodged independently in a three-level burrow system cage placed in/on the ground. The lack of activity on the left hand side is due to the fact that pocket mice hibernate for the winter. The arrows over each graph show the dates each mouse appeared above ground.

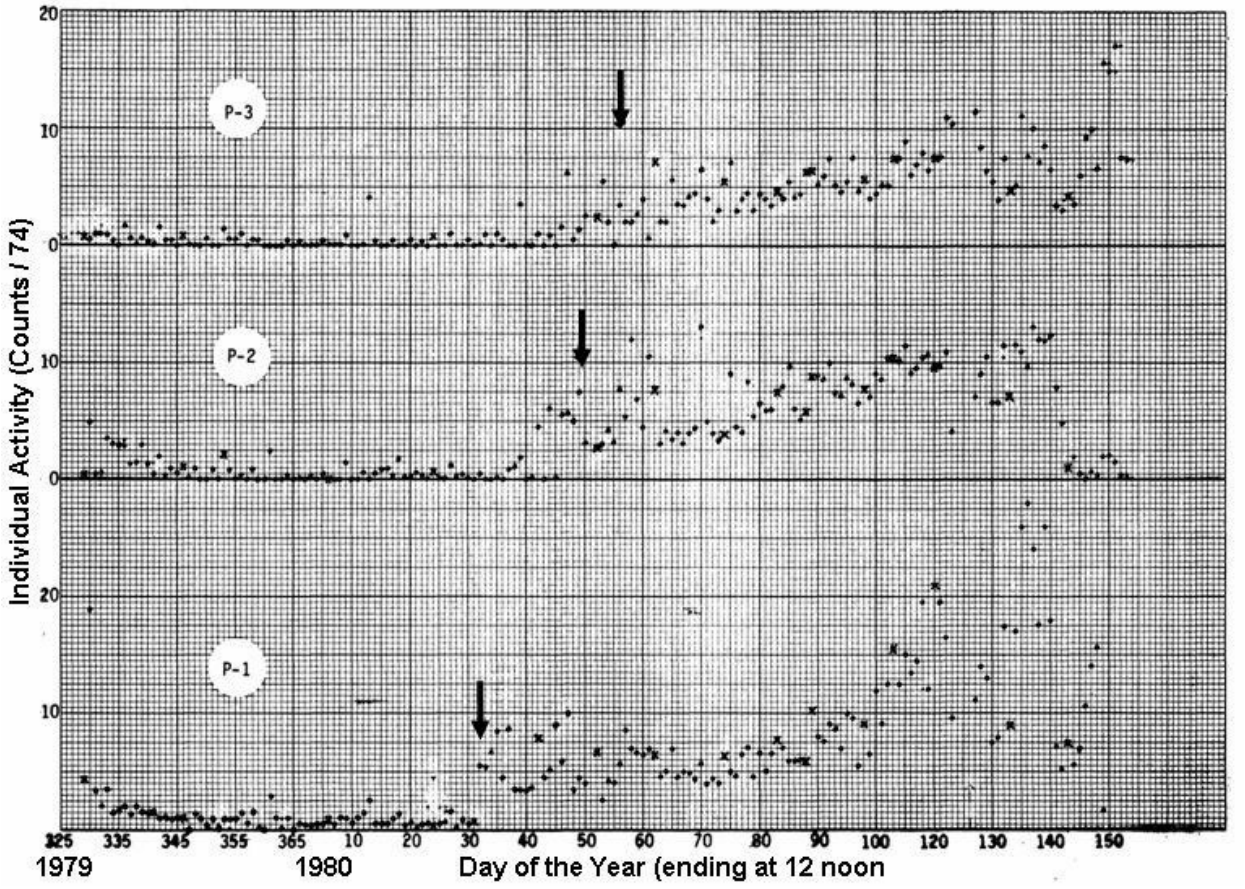


Figure C1: Individual Activity of P1, P2, and P3

As can be seen in Figure C1, the activity of mouse P1 basically starts when he emerges on the ground while P-2 and P-3 became more active prior to their initial surface activity.

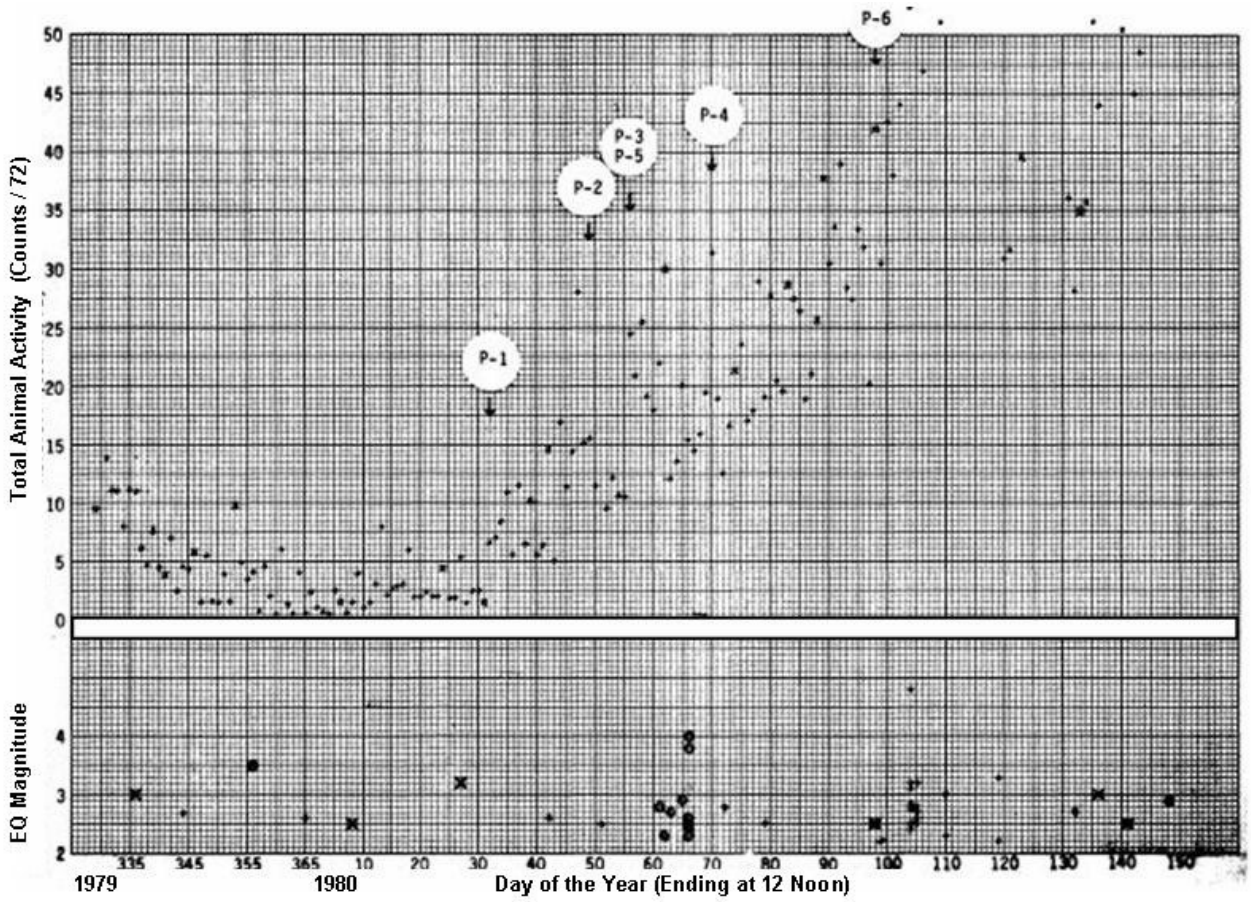


Figure C2: (top) Total Activity of P1 through P6 - (Btm)

Earthquakes with Magnitude - (same scale) It can be seen in the bottom portion of C2 that there were 7 earthquakes in the 5 day period starting on Feb. 29 and ending on Mar 4. This is the period referred to as the Landers 1 Swarm. On page 19 of the report it is started "... P-2 and P-3 became more active prior to their initial surface activity... Hence, the most obvious explanation for enhanced activity prior to the earthquake swarm is coincidence." The same statement was not made about P5. This statement seems to assume that there can be no earthquake precursor below ground. Since we do not know the mechanism involved, that assumption is not reasonable. It should be noted that the report did state that the activities of P2 on days 56-62 is significantly above the mean activity immediately preceding and following those days. **Data Problems:** The main problem with the data is that the above figures (C1 and C2) are examples of all that was done with it. The means and standard deviations for each of the mice were not normalized to equalize the effect of each mouse and to remove any unanticipated constant offsets due to non-earthquake sources. There was also no curve fitting or regression analysis attempted. Therefore any conclusions presented had to be from the data as shown and a best can be considered guesses.