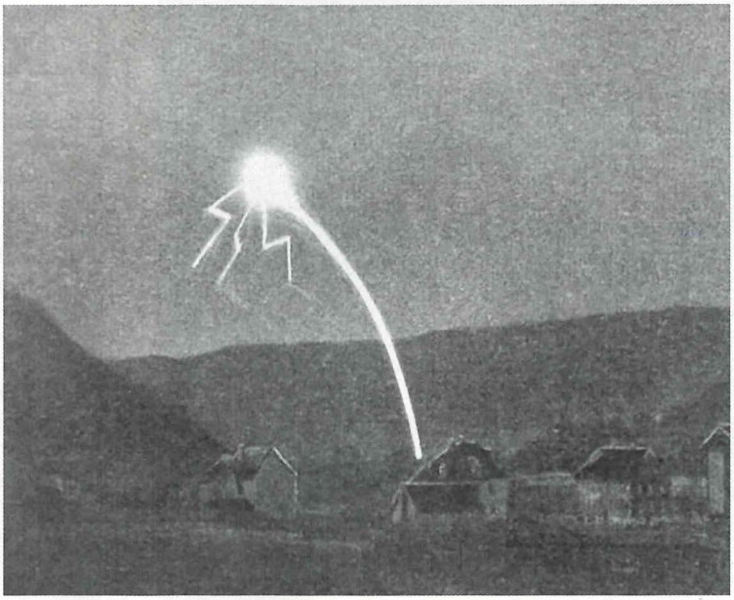
SHAKE, RATTLE AND GLOW

THE MYSTERY OF EARTHQUAKE LIGHTS

Anomalous luminous phenomena associated with seismic stresses, known as earthquake lights, are still not generally accepted as legitimate observations by modern seismologists. Will this fortean subject soon be explainable and its many witnesses vindicated? **SHARON A HILL** surveys the past, present and future of EQL research.



LEFT: Eyewitness recreation of a luminous event associated with the 1911 Ebingen earthquake.

COURTESY SHARON HILL

It was dark on 25 November 1988 at 18.46 when Joseph Dallaire, a trapper in Laterriere, Quebec, Canada, was leaving the coniferous forest near his home. The weather was mostly clear, cold, with a low wind. After exiting the woods, he headed across the open field to his house, 700m (765 yards) away, when he was startled by a crackling sound approaching from behind. This sound was followed by a 6-15m (20-50ft) high curtain of bluish light that passed him in about two seconds. Then, he felt the shaking from the magnitude 5.9 earthquake that had occurred in Saguenay, 19km (12 miles) away. Dallaire described the light to a researcher as hugging the ground as it moved past him, passing into the open field and disappearing to the north-west. He reported that the light was bright enough to illuminate his house nearby.

What can we make of this remarkable event? The crackling sound suggests an electric field build-up and discharge off the tree branches, and the curtain of light might have represented a coronal discharge at the ground-to-air interface travelling away from the direction of the Saguenay quake epicentre.[1] It was not the only luminous phenomenon noted in association with this unusual large earthquake, which took place within the continental land mass, far from a crustal plate boundary where the majority of large quakes occur. Forty-six good reports of luminous phenomena were collected during this swarm of 67 quakes in Saguenay, which also included light balls floating a metre off the ground, motionless "meteors" (some with streamers) popping out of the ground, and rays and bands across the sky. Though the Saguenay earthquake-related lights reports were relatively well-studied,[2] few seismologists refer to the Dallaire experience or mention earthquake lights at all.

The light was bright enough to illuminate his house nearby

The topic of earthquake lights, with their inherent spookiness, is popular with lay audiences and the media, but the potential mechanisms behind them are highly technical. Their ephemeral nature, unpredictability, and rarity, plus the lack of a solid mechanism to explain them, means that earthquake lights (EQL) remain unaccepted by most seismologists as a legitimate natural phenomenon. Detailed ideas and research on EQL are buried within specialised literature across multiple disciplines such as geology, geophysics, rock mechanics, and seismology, but accounts and social meanings related to sightings are found in natural history, folklore, and historic studies. Descriptions and explanations from mainstream news and entertainment sources following a seismic event are nontechnical, unverified, and often exaggerated or wrong.

EARTH LIGHTS

Lights originating from the earth (in contrast to those in the sky) have been reported for millennia.[3] "Earth lights" is a term that encompasses several different kinds of enigmatic phenomena that are frequently associated with paranormal and fringe ideas. Seismic stresses or geochemical processes that generate electric fields have been widely proposed as explanations for some floating balls of light, meteor-like streaks, and mountaintop glows. Locations of persistent anomalous luminous phenomena – such as in Hessdalen, Norway, and Brown Mountain in North Carolina – have been studied, yet investigations yield insufficient explanations. Earth lights as genuine natural phenomena remain controversial, often crossing over with descriptions of UFOs and ghost legends, meshing one mystery with another. Contrary to many statements by writers and proponents that earth lights are well known and real, none is scientifically well-established.

FT contributor and earth lights researcher Paul Devereux documented EQL reports from the UK.[3] His work was instrumental in popularising the idea of earth lights as an anomalous natural phenomenon and re-established EQL and strange lights as a fortean subject outside of the UFO framework.

SEISMIC-RELATED LIGHTS

Popular ideas about EQL spread in our modern society of social media and 24-hour news channels. Bright flashes that appear

COURTESY BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA, VOL 63, NO 6, PP.2177-87 PHOTOGRAPHER: T. KURIBAYASHI

ABOVE: The Matsushiro Glow. Probably the most famous photo said to show EQLs was taken by Mr T Kuribayashi and shows lights over Mt Kimyo, Japan, in 1968.
BELOW: Jim Conacher's 1973 photo of seven luminous orbs on the slopes of Lime Mountain in the Yukon, Canada. He thought he was seeing UFOs.

in the sky coincident with the shaking from a large earthquake are captured on surveillance cameras or mobile phones. Historically, however, EQL of widely varying descriptions have been documented long before today's modern electrified cities existed. They were also reported over the ocean or as luminous balls under the sea. Galli, an Italian priest, published 148 observations recorded between 89 BC and 1910 in Europe. [4] Montandon developed a system in 1948 to describe the lights,[2] including categories for aerial flashes, slow-moving floating globes, bands and rays in the sky, columns emanating from the ground, near-surface flames, and diffuse glows, usually over mountains. But those categories appear too limited, as the Daillaire event showed. Sparks and electricity crackling on high points have also been noted. [5, 6] Related effects – such as anomalies in the upper atmosphere (ionosphere), [7] clouds of unusual shape or colour, fog, electronic device malfunction, de-magnetisation of objects, radio frequency pulses, and anomalies in the ULF and ELF ranges [8-13] – have also been catalogued. Surface thermal anomalies 100-500 km (60-310 miles) across have been spotted via satellite a few days before major events. [8, 14] People on the ground reported feeling a rise in air temperature that was not reflected in the recorded local ground temperature. [6, 15, 16, 17] Fluctuation in groundwater levels and radon gas concentrations are well-documented effects of seismic events. [18, 19]

YUKON UFO SIGHTINGS ARCHIVE BY MARTIN JASEK. PHOTOGRAPHER: J CONACHER

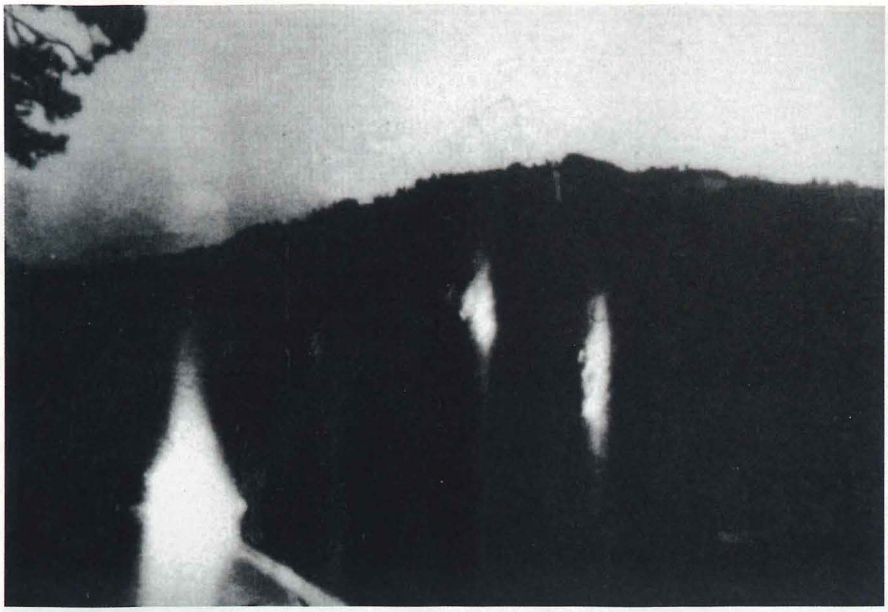
Folkloric precursors, such as strange animal behaviour, plant responses, and "earthquake weather", are dubious and highly unreliable, but not altogether discountable if they are associated with potential mechanisms for producing EQL, as discussed below.

EQL have been reported a few moments prior to, many weeks before, during, or shortly after shaking is felt, reportedly seconds to minutes in duration. While mainly associated with events above magnitude 5, there are several exceptions. One researcher estimates EQL may occur only in association with five to six per cent of all quakes. [4]

KEY OBSERVATIONS

The bulk of EQL evidence remains anecdotal and unconfirmed. Only in recent decades have cameras become ubiquitous and portable enough to better capture transient and rare natural phenomena. A handful of photographs exist that claim documentation of EQL. Though many Internet sources claim to show evidence of them, these often depict other phenomena like electrical arcing, exploding electric transformers, or iridescent clouds. What follows are some key events that spurred scientific interest or provided good evidence for further examination of EQL.

Matsushiro glow: From 1965-7, a swarm of quakes called the Matsushiro events occurred in Japan. Mr T Kuribayashi, a dentist and amateur photographer, took a series of photos during a 1966 quake, showing a sustained hemispherical glow over Mt Kimyo, lasting about 90 seconds, after which the glow diminished. This



ABOVE: The Brasov flames, photographed by Mihai Danciu in Romania in 1978, 100km (60 miles) from a quake. **BELOW:** Flashes recorded by surveillance cameras during the 2017 Mexico City quake.

striking glow was not coincident with the quake movement, indicating the lights were caused by something other than fault movement. Other glows observed associated with the same event lasted from 10 seconds to two minutes and the seismicity was accompanied by an anomalous increase in the total geomagnetic field. [20] One photo in this series is frequently featured as an example of EQLs. John Derr of the US Geological Survey, who developed a sustained interest in EQL and advocated that they be studied further, considered these photographs (published in 1973) as the best evidence for EQL so far. [5]

Lime Mountain orbs: While boating on Taglish Lake, Yukon, Canada, on a Canada Day (1 July) holiday weekend, Jim Conacher photographed seven luminous globes on the slopes of Lime Mountain. He thought he was seeing UFOs, reporting that the slow-moving orbs travelled in curious paths, sometimes upwards, unlike a solid object exhibiting ballistic motion. The Cross Sound earthquake, magnitude 6.7, occurred a few hours later on the suspected date of the photo in 1973. [21] There were no known causes for human-related lights to appear on the slopes. [4]

Brasov flames: Not widely circulated, a dramatic, spectral photo from Brasov, Romania, reportedly depicts bright flame-like lights near the ground. The photo was reportedly taken 100km (60 miles) from a magnitude 7.4 quake in the Vrancea Mountains in 1977. According to John Derr, some researchers believe this photo may represent defects introduced in photo processing instead of what the witness claimed to see. [22] Damage and loss of life occurred in Bucharest resulting from the vertical slip of a thrust fault. [4] Earlier

Eyewitnesses described the sky lit up by fireballs and beams of light

quakes in this location, in 1838 and 1940, also were associated with EQL reports.

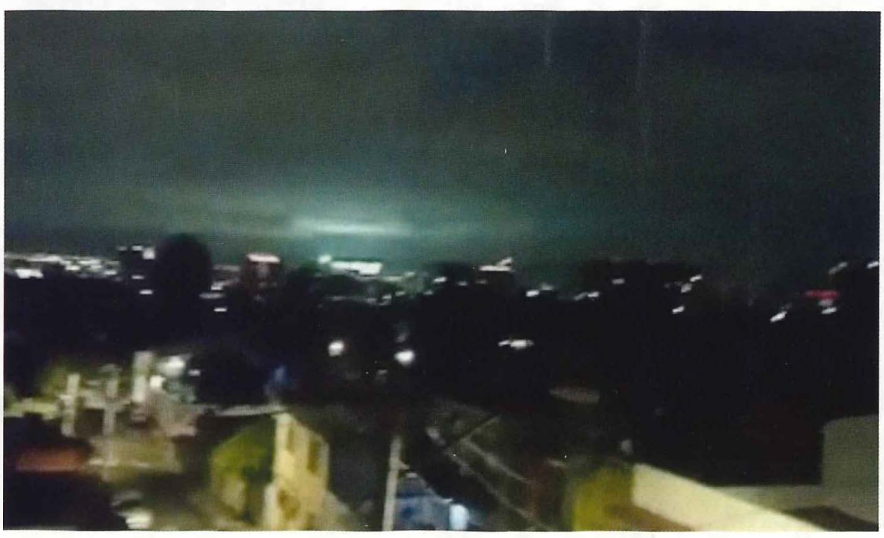
New Madrid, Missouri, catastrophe: The historic New Madrid quake of 1811 took place near the Mississippi River in an area of America sparsely populated at the time. An incredible 104,000km^2 (40,000 square miles) of land was affected by the estimated ~7.9 magnitude mid-continent quake. Luminous phenomena were seen in the epicentral area, including sparks from the earth, exploding flashes, and lightning in the sky. At a distance of up to 600km (373 miles) away, people also saw flashes from the direction of the quake and reported a glowing sky like "fires in the air". [4, 23]

Great Tangshan quake: Fireballs and flashes were seen 320km (200 miles) away from Tangshan, China, in 1976. The next night, a 7.8 magnitude quake occurred that killed an estimated 240,000 people. Changes in ground resistivity were recorded and there were some reports of fish acting strangely; [24] however, these events were not recognised as obvious precursors as they had been in the 1975 Haicheng quake, when Chinese scientists successfully predicted the quake and evacuated the city. The Tangshan quake was not preceded by foreshocks.

Sonora, Mexico/Arizona event: A 7.2 magnitude quake that occurred in 1887 in Sonora, Mexico, was very strong for this area with fault movement extending into Arizona. People apparently thought that volcanoes were erupting as they observed blazing craters on the mountains. [25] Scientists discovered scorched trees over the fault line. [5]

Idu peninsula: 1,500 reports of luminous phenomena were associated with the 1930 Idu peninsula quake in Japan. It occurred at 4.30am, and carefully recorded eyewitness reports included descriptions of the sky lit up by fireballs and beams and columns of light. A series of round lights in a straight line were seen moving through the sky. [5]

Kobe, Japan: Seconds before the 1995 magnitude 7.2 quake in Kobe, Japan, blue-white light streaks were observed issuing from the fault area. The longest lasted more than 30 seconds. White luminous hemispheres 100-200m (330-660ft) wide appeared near the ground and floated upwards. Flashes appeared at the same time as the shaking, even on the little-industrialised island of Awaji. At the surface exposure of the fault, plant roots were found



scorched, the minerals had been locally heated high enough to melt silicates in the rock. [26, 27]

L'Aquila, Italy: Fidani [6] published a study of observations from L'Aquila, Italy, in 2010. After several foreshocks, a magnitude 6.3 event occurred in April 2009. Eyewitness interviews resulted in the collection of 241 reports of luminous phenomena, among hundreds of other anomalies. Locals reported 10m (33ft) high flames emanating from the ground after the main shock and small flickers from poles and between the cobblestones just prior to it. The sky glowed red or orange before the quake, with violet clouds and fog appearing over the mountains. Sparks were emitted from rough or pointed surfaces. 71 flashes from a clear sky were catalogued before and during the main shock. Fireballs, glows, and streamers, similar to an aurora, appeared above. Carlo Strinella, a resident near L'Aquila, had heard the stories of strange lights before earthquakes. When he saw flashes, with one as intense as daylight, he took his family out of the house. Two hours later, the main shock hit. The Fidani survey was done after the event and the researcher declared one of his aims was to instruct the public about EQLs, so we must be cautious about taking these anecdotes at face value. Other than some photos provided to Fidani of glowing skies over L'Aquila, I can find no other recorded evidence of luminous phenomena.

VIRAL VIDEOS

Modern quakes get significant media attention and the effects recorded via security cameras and mobile phones are distributed across social media. Recording of lights, strange clouds, glows, and flashes appear on YouTube and Facebook videos, prompting interest in the idea of EQL from the public and the media. Three recent events have increased public interest and acceptance of the phenomenon.

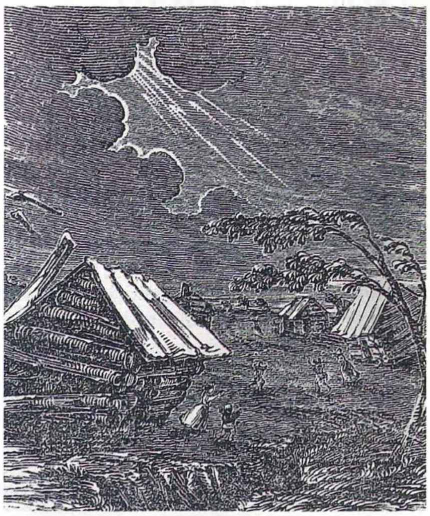
Lima, Peru, 2007: Security cameras caught light flashes as the shear waves passed from a magnitude 8 quake. A Navy officer reported blue columns of light bursting four times in succession from rocky outcrops in shallow water between his ship and the shore. [4]

Kaikoura, New Zealand, 2016: This magnitude 7.8 event occurred at night. Several people recorded green and blue flashes in the sky. Flashes were said to be over the sea, but that is not clear.

Mexico City, Mexico, 2017: Several light flashes in the distance were recorded from surveillance cameras and available on YouTube, labelled "Earthquake Lights".

These three visual events were called "EQL" but they are questionable. The light flashes look conspicuously like electricity transformers exploding or arcing, which

ABOVE AND BELOW: The New Madrid, Missouri, earthquake of 1811–1812 was felt over a huge area of the US and produced numerous luminous phenomena, both near the epicentre and far beyond.



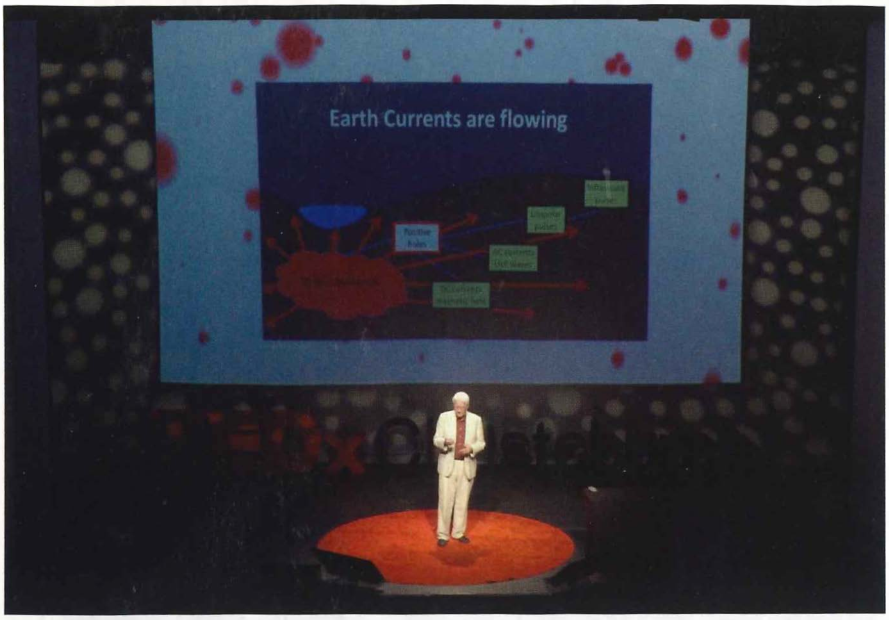
happens when overhead wires touch due to the motion of a quake. These events produce very bright white-blue light that will reflect off low clouds. It is more plausible that this is the explanation for these three particular incidents, because we know electrical system damage happens during large quakes in urban areas. Frustratingly, we have not seen recorded on video the more unusual forms of EQL such as glows, ground flames, fireballs, sparks and columns. Light pollution, the ubiquity of paved and developed areas, and lower population densities of land in a natural state suggests that subtle natural anomalies are masked or go unnoticed. Additionally, EQL will be far less noticeable during daylight. Balls of light may be interpreted as resulting from mundane sources. And, overall, the fleeting, unexpected nature of EQL that are non-coincident with the quake itself precludes adequate photographic or video documentation.

SCIENTIFIC SCEPTICISM

The scientific/seismological view of EQL remains one of scepticism, for good reason. Anecdotes can generally point to where to look, but contain noise and errors. How would scientists credibly record EQL? Earthquakes happen all over the world and within indeterminate time frames. The scale and scope of a network adequate to observe EQL and associated precursors would be prohibitively large. [8] Multiple variables would need to be measured across wide ranges of time and space. [1] Even for known seismically active areas, such a network would be expensive and risky. Not all faults will produce precursors, as subsurface regimes and quake mechanisms vary widely. Perhaps atmospheric conditions influence perceiving precursors. If real, EQL are obviously more of an exception rather than a typical phenomenon. The lack of a plausible mechanism inhibits research: if we lack a sound idea of how they could occur, it is far more difficult to plan to catch them.

Traditional research in seismology has been focused on mechanical observations – ground deformation and patterns of prior events. [17] The "father of seismology", Robert Mallet, mentioned EQL back in the 1850s in his volumes *On the Facts of Earthquake Phenomena*. In 1931, 1,500 reports existed, collected by professional researchers. [1] In 1973, Derr called EQLs "well established", based on the many documented reports. [5] Several scientists publishing on these topics repeatedly state that EQLs are accepted to exist. Officially, and in the larger framing of accepted geology, they remain notably controversial and widely dismissed.

From the USGS page on earthquake



LEFT: Friedemann Freund gave a 2016 TED talk laying out his peroxy effect theory of earthquake lights.
BELOW: Quakefinder in Palo Alto, California, is one venture using technology to gather better data.

lights: "Geophysicists differ on the extent to which they think that individual reports of unusual lighting near the time and epicentre of an earthquake actually represent EQL: Some doubt that any of the reports constitute solid evidence for EQL, whereas others think that at least some reports plausibly correspond to EQL." [28]

PROPOSED MECHANISMS

Various mechanisms have been proposed to explain the production of an electrical charge in association with seismic stresses. Ionisation of the surface air could produce coronal discharges, sparks, plasma emissions, and electromagnetic anomalies among other effects on the environment and organisms. But a mechanism for EQLs must be able to concentrate and maintain large charge densities that will reach the surface. This charge accumulation and movement from deep underground to the surface has been a hurdle to acceptance of EQLs. Several mechanisms to account for them, and associated phenomena, have been proposed, with the most commonly mentioned being piezoelectricity. [17] Some minerals like quartz, which is abundant, produce an electric charge when pressure is applied. However, this happens in a short span and decays quickly as the + and – charges cancel out due to random distribution of crystals. [29] Various other processes that could produce localised emissions may be occurring, but none seem to be able to produce what is reportedly observed as EQL throughout history.

The current best candidate for a mechanism is that of the peroxy defect theory. Freidemann Freund is the discoverer and promoter of this unifying theory – combining ideas from semi-conductor physics, chemistry, and rock physics into this framework to explain the generation,

Time and a bit of luck will be needed to amass enough evidence

concentration and movement of a charge cloud to the surface. In simplified terms, the idea is this: There is a percentage of "peroxy defects" in the minerals that make up rocks in seismic zones. The defects in the molecular structure occur when the oxygen molecules are not in their typical state but are instead connected by a weak oxygen-oxygen single bond. Under stress, these bonds break and release positive charge carriers that flow via grain to grain contact within the rock body. They move fast (200m/s) and far (several km). The plume of charged particles moves from high to low stress and upon reaching the surface, the theory goes, the cloud can generate local electrical fields that produce air ionisation causing coronal discharges or bursts of light.

As Dr Freund said to a general audience in Christchurch, New Zealand: "When we do nasty things to the crystals [in the rock], they fall apart and produce electric charge carriers." [30] Freund has demonstrated the charge concentration and movement on a small scale in the lab by stressing rocks. He reports that at around two seconds before the rock slab fails, a burst of positive ions is released from the surface of lower stress. The flow of positive charge carriers is away from the fault and, notably, towards high points – like mountains, or areas with rough or pointed surfaces. Peroxys are not very controversial, but this idea to explain EQLs and precursors is relatively new and has not received much attention from seismologists (who are mostly trained in geophysics, not solid-state physics or chemistry). [1, 4, 16, 17]

The peroxy defect theory has its problems – an obvious one is how to test it. We can't simply assume that rock slabs stressed in a lab are equivalent to conditions in nature. Real-world conditions will be far more heterogeneous and may not conform to the ideal conditions needed to allow for the formation of currents and the subsequent visual effects at or near the Earth's surface. Part of the peroxy defect idea suggests that charge flow may be focused in some areas and blocked in others due to the differences in the lithology and fault structure. If valid, however, this theory could account for luminous phenomena of various kinds, but also earthquake fog, strange clouds, thermal infrared anomalies, ionospheric perturbations, unusual animal behaviour, and even household device anomalies resulting from the mobilised cloud of charged particles at the ground-air interface. Perhaps the passing of seismic shear waves generated by the quake can even produce forces that activate the peroxy defects in the crystal structure of the rock, which may explain Dallaire's crackling curtain observation.

QUAKEFINDER

Dr Freund and colleagues are having a difficult time getting a forum with other seismologists who, generally, still do not consider EQL and other precursor reports to be important or meaningful. There are no statistically meaningful data sets yet. The non-interest in precursor research may be associated with the geological conditions of the US. Earthquake precursors, such as EQL, are not reported to be as prevalent in the US; 90 per cent of such reports are in rift areas in other parts of the world. [4] Therefore, greater interest in these anomalous precursors comes from researchers in China, India, Russia, Taiwan and Japan, and the resulting papers and discussion are not in English journals.

ESTABLISHING THE VALIDITY OF EQL

The primary task remains to establish the validity of EQL. More reliable data are needed. Monitoring networks and facilities to record EQL or other environmental anomalies are lacking. Considering the uncertainty of the next seismically stressed area to rupture in time and location, instrumentation must cover large areas and record various parameters. Systems designed to detect anomalous fields must be able to distinguish normal fluctuations in these fields. Quakefinder, in Palo Alto, California, is a private venture deploying magnetometers. Their goal is to obtain large data sets, determine local background measurements, look for statistical significance of anomalous readings, and get past the anecdotes.

Much related work is going on in earnest in other countries. Russian and Chinese scientists are actively working on recording ionospheric anomalies using remote sensing via satellites. [7, 10, 16, 31] The electrodynamic properties of the atmosphere are suspected to change as a result of the stream of positive charges released from the ground surface in relation to increasing stress from the fault. Though it sounds obvious to look for ionospheric perturbations, it is difficult to pinpoint them because of regular fluctuations from solar events and other typical causes of disturbance. Not all faults would produce this signal that would translate to the upper atmosphere, especially those underwater. [29] And not all faulted bedrock regimes will be conducive to produce, accumulate, and mobilise a charged stream that reaches the surface. Less obvious seismic areas that have been associated with luminous phenomena, such as the Mochras Fault in Wales, are complete mysteries regarding build-up of seismic stresses, as are the several (seismically quiet) well-established locations where earth lights are reported.

Time and a bit of luck will be needed to amass enough evidence to convince earthquake scientists that EQL are genuine. Until then, reports of EQL after major earth-shaking events will remain unconvincing to scientists but fascinating to the media and public.

A video of a talk on Earthquake Lights given by the author at NASA's Goddard Scientific Colloquium on 28 March 2018 is available at https://youtu.be/lkxrUlBcYQ8.

NOTES

1 F St-Laurent, JS Derr, and FT Freund, "Earthquake lights and the stress-activation of positive hole charge carriers in rocks", *Physics and Chemistry of the Earth*, 31:305-312, 2006.

2 F St-Laurent, "The Saguenay, Quebec, Earthquake Lights of November 1988-January 1989: A Comparative Study with Reference to the Geo-atmospheric Lights Classification Proposed by Montandon in 1948 and Description Put Forward by Yasui in 1968", *Seismological Research Letters*. 71:2, 160-174, 2000.

3 Paul Devereux, *Earth Lights Revelation*, Sterling Pub Co., Inc, 1990.

4 R Theirault, F St-Laurent, FT Freund, and JS Derr, "Prevalence of Earthquake Lights Associated with Rift Environments", *Seismological Research Letters* 85:1, 159-178 and electronic supplement, 2014.

5 JS Derr, "Earthquake Lights: A Review of Observations and Present Theories", *Bull. of the Seismological Soc of Am.* 63:6, 2177-2187, 1973.

6 C Fidani, "The earthquake lights (EQL) of the 6 April 2009 Aquila earthquake, in Central Italy", *Nat. Hazards Earth Syst. Sci.*, 10: 967–978, 2010.

7 SA Pulinets, "Seismic Activity as a Source of the Ionospheric Variability", *Adv. Space Res.* 22: 6, 903-906, 1998; SA Pulinets, & K Boyarchuk, *Ionospheric Precursors of Earthquakes*. Springer-Verlag, 2004.

8 T Bleier, C Dunson, M Maniscalco, N Bryant, R Bambery, & FT Freund, "Investigation of ULF magnetic pulsations, air conductivity changes, and infra-red signatures associated with the 30 October Alum Rock M5.4 earthquake", *Nat. Hazards Earth Syst. Sci.* 9: 585–603, 2009.

9 JL Kirschvink, "Earthquake Prediction by Animals: Evolution and Sensory Perception", *Bull. of the Seismological Society of Am.*, 90: 2, 312–323, 2000.

10 JW Warwick, C Stoker & TR Meyer, "Radio Emission Associated with Rock Fracture: Possible Application to the Great Chilean Earthquake of May 22, 1960", *J of Geophysical Research* 87:B4 2851-2859, 1982.

11 SK Park, MJS Johnston, TR Madden, FD Morgan, & HF Morrison, "Electromagnetic Precursors to Earthquakes in the ULF Band: A Review of Observations and Mechanisms", *Reviews of Geophysics*, 31:2, 112-132, 1993.

12 M Ikeya, *Earthquakes and Animals: From Folk Legends to Science*, World Scientific Publishing Co., Pte. Ltd, 2004.

13 C Johnston, "Light from seismic waves", *Nature*, 354:361, 1991.

14 AK Saraf, & S Choudhury, "Thermal Remote Sensing Technique in the Study of Pre-Earthquake Thermal Anomalies", *J of Indian Geophys Union*. 9:3, 197-207, 2005.

15 X Zhang, X Shen, & Y Mioa, "Electromagnetic Anomalies around Wenchuan Earthquake and Their Relationship with Earthquake Preparation", *Procedia Environmental Sciences*. 12A, 693-701, 2012.

16 FT Freund, IG Kulahci, G Cyr, J Ling, M Winnick, J Tregloan-Reed, & MM Freund, "Air ionization at rock surfaces and pre-earthquake signals", *J of Atmospheric and Solar-Terrestrial Physics*. 71, 1824–1834, 2009.

17 FT Freund, G Ouillon, J Scoville, & D Sornette, "Earthquake precursors in the light of peroxy defects theory: critical review of systematic observations", 2018. Available at https://arxiv.org/ftp/arxiv/papers/1711/1711.01780.pdf

18 William Corliss, *Remarkable Luminous Phenomena in Nature: A Catalog of Geophysical Anomalies*. Sourcebook Project, 2001.

19 AY Sidorin, "Search for earthquake precursors in multidisciplinary data monitoring of geophysical and biological parameters", *Nat. Hazards Earth Syst. Sci.* 3:153–158, 2003.

20 Y Enomoto, *et al.*, "Causal mechanisms of seismo-EM phenomena during the 1965–1967 Matsushiro earthquake swarm", *Sci. Rep.* 7:44774, 2017.

21 Theriault, *et al.* (electronic supplement) explains that Canada Day was on a weekend in both 1972 and 1973, and that earthquakes occurred in July in both years. It is assumed the photo was associated with the Cross Sound quake as noted but, since Mr Conacher is not certain of the year, this is unconfirmed.

22 Pers. comm. from John Derr, June 2019.

23 ML Fuller, "The New Madrid Earthquake", USGS Bulletin 494, 1912.

24 A Enriquez, "The Shining", *New Scientist*, 179:2402, 26–29, 2003.

25 www.tombstonetimes.com/stories/quake.html

26 Y Enomoto, & Z Zheng, "Possible evidences of earthquake lightning accompanying the 1995 Kobe earthquake inferred from the Nojima fault gouge", *Geophysical Research Letters*. 25:14, 2721-2724, 1998.

27 TV Losseva, & IV Nemchinov, "Earthquake lights and rupture processes", *Nat. Hazards Earth Syst. Sci.* 5, 649–656, 2005.

28 US Geological Survey. www.usgs.gov/faqs/what-are-earthquake-lights

29 DA Lockner, MJS Johnston, & JD Byerlee, "A mechanism to explain the generation of earthquake lights", *Nature* 302:5903 28-33, 1983.

30 TED talk "Using Semiconductor Physics to Forecast Earthquakes – Friedemann Freund" TEDxChristchurch https://youtu.be/B1yno8RjaFE

31 YJ Chuo, YI Chen, JY Liu, & SA Pulinets, "Ionospheric foF2 Variations Prior to Strong Earthquakes in Taiwan Area", Adv. Space Res. 27, 6–7, 1305-1310, 2001.

SHARON A HILL is a geologist who researches anomalous natural phenomena and paranormal culture. She is the author of Scientifical Americans: The Culture of Amateur Paranormal Researchers *(McFarland & Company, 2017) and the founder of spookygeology.com.*