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# Reproduced Earthquake Precursor Legends Using a Van de Graaff Electrostatic Generator: Candle Flame and Dropped Nails

Motoji Ikeya, Hiroshi Matsumoto

Department of Earth and Space Sciences, Graduate School of Osaka University, 1 Machikaneyama, Toyonaka, Osaka 560, Japan

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Some mysterious earthquake precursor phenomena depicted in Japanese legends and also reported retrospectively in the Kobe earthquake in 1995 have been reproduced in laboratory experiments using a Van de Graaff electrostatic generator. This suggests that pulsed electric charges appeared in the epicenter area. Folk stories of a reverse U-shaped candle flame on an altar and of iron nails dropping from a magnet were explained by the appearance of free charges produced by the depolarization of piezoelectricity for quartz grains in granitic rocks during seismic stress changes.

*Correspondence to*: M. Ikeya

Earthquake precursor phenomena, reported retrospectively or described in old folk stories, have been of interest in popular science journals but neglected as superstition by most scientists. Although scientists are skeptical about these statements because they were made under the abnormal psychological conditions accompanying natural disaster, human anthropology tells that frequently there are reasons for a taboo even in a primitive society. There must be some reason for proverbs about natural disasters.

Most such phenomena fall between disciplines, i.e., they are in an interdisciplinary field and also on the

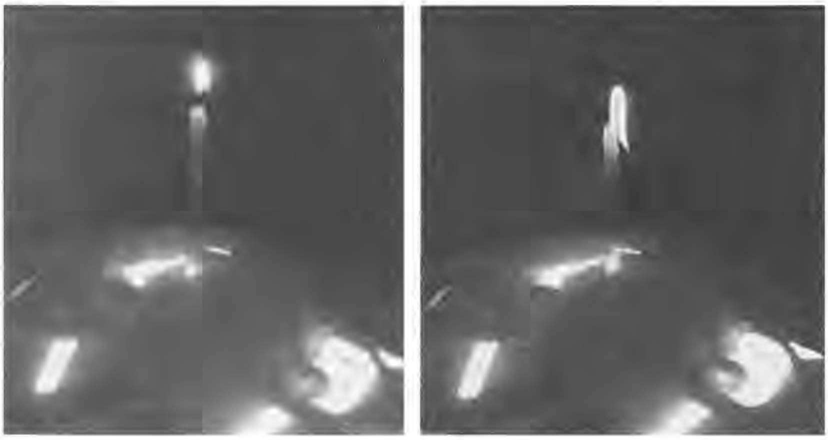

Fig. 1 a, b. Bending of a candle flame before a temple or shrine altar as a a precursor of an earthquake is a proverb in Japan. This is reproduced in an electrostatic experiment. a) A candle flame on electrically grounded sphere of a Van de Graaf electrostatic generator. b) The same candle after the sphere was charged to give 250 kV

boundary between reports of scientists and public or mass media. The retrospective approach – to collect statements from witnesses – may be one step to document the phenomena [1–4], but these observations must be explained scientifically based on a hypothesis and reproduced in an experiment.
This report demonstrates some anomalous phenomena – altered shape of a candle flame, faint lightning of a fluorescent lamp, and dropped nails before earthquakes – using a Van de Graaff high voltage electrostatic generator which produces 250 kV on its aluminum sphere.

## Mysterious Candle and Fluorescent Lamp

According to an old Japanese folk story, a candle flame deforming as a bent nail is a precursor to an earthquake. It was claimed that it was difficult to light a candle on a Buddhist altar before the Kobe Earthquake [1]. Chinese reports stated that a candle flame was suddenly extinguished and fluorescent lamps lit before the Tangshang earthquake which killed 240,000 Chinese citizens in 1976.
The flame of a candle placed on the sphere of a Van de Graaff generator as shown in Fig. 1a changed its shape upon charging as in Fig. 1b. Subsequently the candle was melted by the downward-pointing flame. When a grounded wire was brought close to the flame, the flame "danced" and was then extinguished.
The negatively charged sphere attracts positive ions in the candle flame plasma. Normally the flame plasma streams upward by convection but is pulled downward by an electric field because the positive ions are attracted downward. Positive ions pull light electrons downward, and the flame plasma is thus pulled downward. A slight tilt of the field for angle $\theta$ give a field of $F \cos \theta$ vertically and $F \sin \theta$ horizontally. Positive ions moving vertically upwards decelerate downward and change the direction while they move horizontally.
The difficulty in lighting a candle by the flame of a match, which was reported by an elderly religious woman, would result from the charging of the metallic candle stick.
A fluorescent lamp held close to the charged sphere of a Van de Graaff and to a plastic sheet charged by frictional electricity, also lit up, as occurred in a microwave oven. In nature, atmospheric lightning can light a fluorescent lamp. The faint lights in a fluorescent lamp before an earthquake would be due to the electric field produced by electromagnetic waves from the ground surface epicenter area where the seismic stress changes, not necessarily from the underground focus where bedrock granitic rocks rupture a head of earthquake.

## Dropped Iron Nails from a Magnet

A famous Japanese story (Ansei Chronicle) from 150 years ago recorded that large iron nails (15 cm in length) hanging from an iron magnet fell before the Ansei earthquake. This chronicle also tells of anomalous movement of catfish. An earthquake-prediction apparatus using a magnet was invented immediately after the earthquake, but it does not appear to have been useful. Even today the story is told by earthquake-predicting seismologists as evidence of magnetic anomalies, although the change in magnetic field intensity at the time or just before earthquakes is negligible.
Several nails were attached to a magnet hung above the Van de Graaff accelerator. When the high voltage sphere was electrostatically charged, the nails close to each other tilted and fell down. The iron magnet and nails acted as electrodes and were repelled each other when the image charges are induced by the charge of the sphere; they were attracted to the sphere. The electrodes were pulled to the sphere and the balance of the magnetic and gravitational forces was upset. The magnet and nails may also have charged leading to Coulomb repulsion with each other: a simple calculation can estimate the charge density required to produce the Coulomb force of the magnitude, $mg \sin \theta$, with the nails tilted at an angle $\theta$ from the vertical direction.
The Ansei story suggests that an intense seismic charge appeared on the ground in the area, although the possibility of nails dropping by the arrival of seismic P-waves still cannot be excluded. The story of a watch repair work in Italy in which a watch gear jumped up before an earthquake was also attributed to electrostatic charges by charged aerosol; dropping of nails was suspected to be due to seismic charges [4].
The well-known seismic anomalous animal behavior (SAAB) before an earthquake has been attributed to charged aerosol [4]. If an aerosol is indeed responsible for SAAB, violent movements of river catfish in Japanese legends cannot be explained. Intense electric-field pulses could affect animals and may also cause some

 

charged aerosol to collect in the epicenter area. Charged aerosols would be a result, and not a cause, of anomalies.

We found that catfish having electrosensory organs for capturing small fish are more sensitive to pulsed electric field than other fish; the violent movements start at 3–4 V/m. Eels are more sensitive than catfish, in agreement with another story in the Ansei Chronicle that eels had already disappeared when catfish were found violently moving in turmoil. Electromagnetic waves induced by sudden discharges between the sphere and ground wire surprised eels.

An electrostatic field intensity that produces a discharge spark between the electrodes, which surprises us at the door-knob, is about 3 MV/m. Seismic electric-field intensities of almost the same magnitude produces noises in television and radio signals due to discharges. The pulsed electric field in water would need to have been around 10 V/m before the Kobe Earthquake, as estimated from anomalous alignment behavior of fish. Lightning in nature and discharges by a Van de Graaff generator cause electric pulses with a peak intensity such that they cause anomalous behavior of some sensitive animals [7].

### A Model of Piezocompensating Charges for Precursor Phenomena

The physical reason for the occurrence of such intense charges at the epicenter is now discussed briefly. A possible mechanism for the intense charge generation at the epicenter is the release of piezocompensating charges by stress changes [5], although others such as frictional electricity and $\zeta$ potential of percolating water [6] cannot be excluded at the moment.

The bedrock in the Kobe area is granitic and contains piezoelectric quartz grains. Accumulated stress produces piezoelectric polarization of quartz grains in granite. The polarization is canceled almost simultaneously in a conductive earth by quick compensatory movement of free charges. It is these piezocompensating charges released by stress changes that caused earthquake-precursor electromagnetic phenomena. Precursory ruptures at the focus 10 km below the ground change seismic stress over a wide area close to the ground, leading to free charges and the generation of electromagnetic waves around the surface area of the epicenter [5].

An ensemble of electric dipoles of small dipolar free charges around quartz grains, $\Sigma p_i$, may be considered in a fault zone. In optics a light bulb consisting of $n$ excited atoms with dipole moment $p$ is approximated as a single dipole with the moment: $P=n^{1/2}p$. Similarly intense electromagnetic waves are generated from such a solid plasma at the fault zone. An intense charges of approximately $P/L$ might appear at the fault zone, with the length or the depth $L$ [7].

Note that this paper does not make a claim for earthquake prediction in observation of these phenomena. Deterministic earthquake prediction may not be possible, although alleged in the controversy over the seismic electric signal (SES) [8]. We only report that some mysterious phenomena, recited anecdotally by the public or in folk stories related to natural disasters, are not superstition but can be explained scientifically. Those related to earthquake precursors can mostly be explained as electromagnetic effects in nature similar to lightning-related phenomena. These natural SES appearing as precursor phenomena in our daily life at home might, however, be used as warnings in earthquake-prone countries if we can detect and interpret them properly [7, 9]. These simple experiments can easily be understood by a broad interdisciplinary audience and will be used as educational demonstration experiments in science courses for high school pupils and university students.

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