Thermo-mechanoluminescence as a new explanation for 2016 New Zealand earthquake luminosities

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ABSTRACT

Earthquake Lights (EQLs, also known as Earthquake-related luminous phenomena) occurred during 2016 New Zealand earthquake (Mw 7.8). We saw the incident of 11 different lights for New Zealand earthquake and we proposed that there is a connection between these lights and 13 surface ruptures of earthquake. We suggest thermo-mechanoluminescence (ThML) can be a new explanation of these lights and explain the conditions of their occurrence. We consider the necessary heat source to be frictional heating of faults. Feldspars, quartz and calcite are the main luminescence producers. Parallel to the heating and production of luminescence on the fault plane, the emission of luminescence due to the pressures and stresses (grinding, rubbing, cutting, cleaving, shaking, scratching, compressing) created on the fault plane is also significant. This kind of emission called mechanoluminescence (ML). Here, we have introduced for the first time ThML as a new cause for the EQLs.
Keywords: (Thermo-mechanoluminescence, EQLs, New Zealand earthquake)

INTRODUCTION

Earthquake light (EQL) that occurs just before, during, or right after an earthquake is a secondary phenomenon that has been reported with some major earthquakes (e.g. Torabi et al., 2018; Torabi and Fattahi, 2019). Torabi and Fattahi (2019) reviewed different aspects of EQLs and they concluded that the EQLs cannot be explained by a single theory and it seems that a set of different processes play role in the production of light. One of the last cases of the EQLs has been during the New Zealand earthquake in 2016. At 12:03 am local time, on November 14th, 2016, a moment magnitude (Mw) 7.8 (USGS) earthquake struck the Kaikoura region of South Island, New Zealand (Wang et al., 2018). At the location of this earthquake, the Pacific plate moves to the west-southwest with respect to the Australia plate at a rate of approximately 40 mm/yr (USGS). After the earthquake, the locals presented reports that showed they had seen strange lights during earthquakes. Also, a camera at Petone has recorded these lights (***https://www.youtube.com/watch?v=CjqxiSxhNCw***) at the moment of the earthquake.
This paper describes the New Zealand's EQLs and also includes a new theory for interpreting these lights.

METHODOLOGY AND DATA

After the earthquake, the locals presented reports that showed they had seen strange lights during earthquakes. Also, a camera at Petone has recorded these lights at the moment of the earthquake. By comparing the available videos from New Zealand's earthquake with reports of EQLs, these lights are definitely co-seismic EQLs. We saw the incident of 11 different lights in this video (Fig. 1). Setting and surface ruptures of the Kaikoura earthquake is show in Fig. 2. There are about 13 ruptures. It seems that there is a direct connection between these ruptures and the EQLs. Also, the number of surface ruptures is close to the number of lights (13-11). Another reason for the relationship between light and ruptures is the sequence of light events that follows the rupture model. This means that the lights that were created in the first few seconds are far away from the camera, and the light at the end have been closer to the camera (to the Petone in the Northeast of the region) that follows precisely the rupture process.

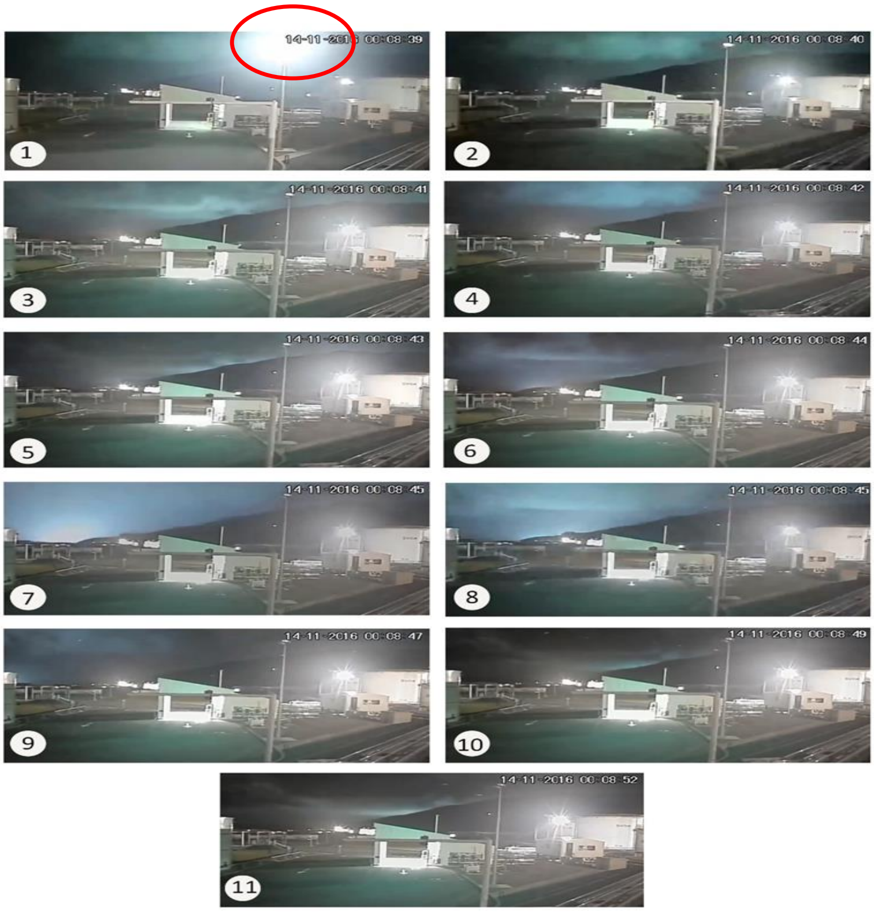

Figure 1. Screenshots of the Petone camera (*https://www.youtube.com/watch?v=CjqxiSxhNCw*). As you can see, the location of the lights in the first screenshots is far from the camera and gradually the light gets closer to the camera (compare 1-8) (view toward southwest). Red circle represents light bulb.

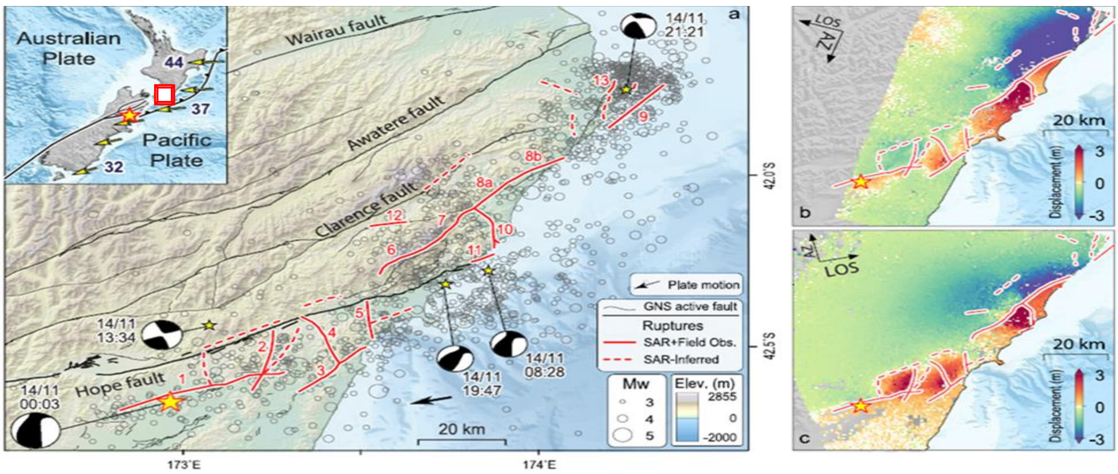

Figure 2. Setting and surface ruptures of the Kaikoura earthquake. The inset in a shows a simplified plate boundary of New Zealand, b shows image offsets along the satellite's direction of motion derived from ALOS-2 data. Warm colors represent southward movement. c shows image offsets in the satellite line-of-sight direction derived from Sentinal-1 data. Warm color indicates mainly uplift. (From Wang et al., 2018). Red box is the location of camera.

Based on joint inversion model by Wang et al (2018), rupture initiated on the Humps fault (the farthest point to the Petone in the southwest of the area- #1 in Fig.2), and then the rupture propagated to the Hundalee fault (#3 in Fig. 2) and then all the faults in the area are involved up to the north-east end, respectively. This means that the rupture has begun from the southwest corner and has continued to the northeast and on various faults (Fig.2). The camera in the Petone, which shows EQLs, has recorded the same process. First, the lights are seen at the end of the horizon, and then the lights come closer to the camera. Based on the view of the camera, the lights first appear at the end of the south-western horizon and then move to the north-east (Fig.2) which is exactly the same as the rupture process of the earthquake.
ThML can be a new explanation for the EQLs. Frictional heating on the fault plate is the heat source to stimulate the electron traps and release the TL signal (Fattahi, 2009). Consequently, surface ruptures will create the necessary heat and generate light. We have also assumed that the feldspar, quartz and calcite minerals will be the main producers of ThML signal due to their high abundance in the Earth's crust. Parallel to heating and TL, different type of excitation such as grinding, rubbing, cutting, cleaving, shaking, scratching, compressing, applied pressure, can trigger ML. Generally, it is accepted that ML originates from transitions of charge carriers at traps (Feng and Smet, 2018). The earthquake-induced mechanical stresses can help to detrap the carriers and on a large scale, such as the 2016 New Zealand earthquake’s surface ruptures, it seems this phenomenon will cause the emission of light in the location of ruptures whether through piezoelectricity, domain structures or the movement of dislocations which are the three main and accepted mechanisms in the production of ML (Feng and Smet, 2018).

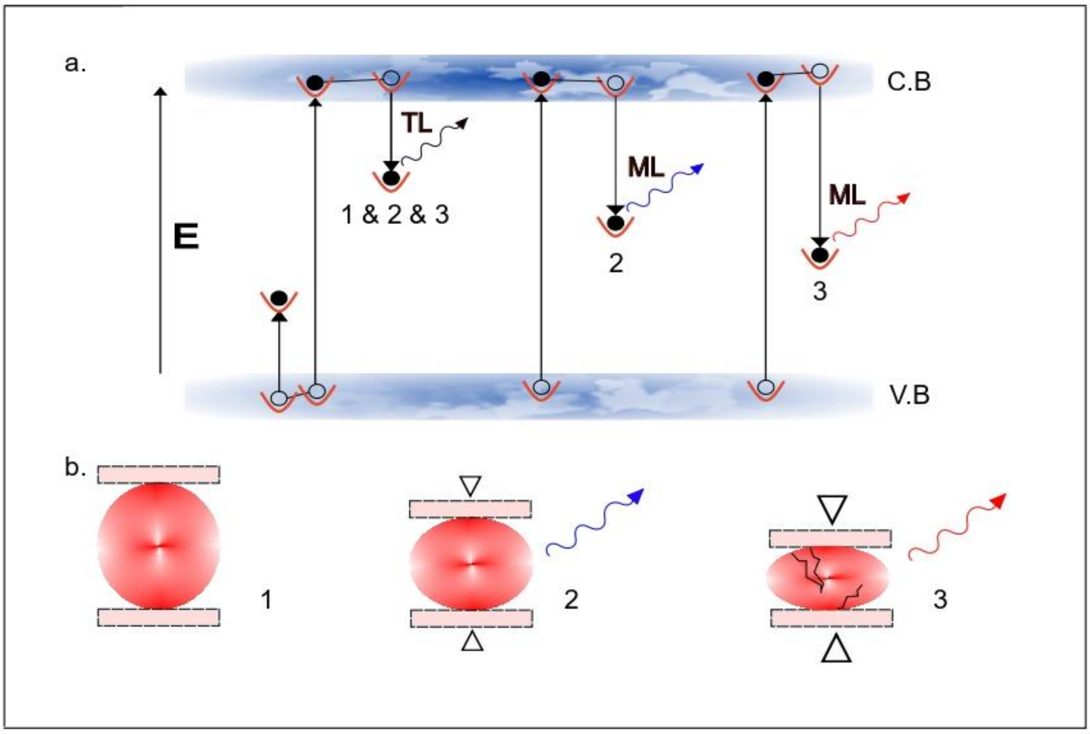

Figure 3. a) The TL and ML processes in quartzes. b) (1) natural Quartz in actual situation, (2) quartz has deformed under pressure and emitted blue light which is a kind of ML. (3) Quartz has fractured under more pressure and emitted red light which is another type of ML. The TL may occur in situations (1, 2 & 3) whenever the heat stimulates the electrons the luminescence will occur. The friction is the source of heat I (2 & 3). Note that these 3 types of luminescence can occur simultaneously.

Aman and Tomas (2004) also suggested that quartz particles under pressure can produce measurable ML signals and also lights. They showed that blue light impulses coming from plastic deformation zone and red light impulses coming from cracks.

ThML can also justify the moving object (EQLs) associated with some major earthquakes like 1995 Kobe earthquake (at 5:46 a.m. (LT) on January 17, 1995 around the Hanshin area in Japan, M 7.2 - Kamogawa et al.,2005). With the rupture event in the direction of the fault, the heat rapidly increases due to frictional heating, in the same direction on the rupture walls, the electrons in the electronic traps will be excited, the light will be emitted and move rapidly with rupture. Previous researchers have done an excellent job to provide theories to interpret EQLs in different part of the world. These include Piezoelectric, Friction-Vaporization, Positive Holes, Exo-elctron emission, and Tribo - or fracture electrification. Torabi and Fattahi (2019) reviewed major theories of EQLs and concluded that these theories have not succeeded in interpreting the phenomena associated with EQLs such as light spectrum and intensity, lithology, relation with active tectonic boundaries and amount of stress. The main reason for this is that, in our opinion, a single theory cannot explain the light produced in the Earthquake process. And therefore, the ThML has been proposed along with other theories and does not cause rejection of any of them.

CONCLUSIONS

EQLs were observed during the 2016 New Zealand earthquake (Mw 7.8). Our observations show the occurrence of 11 bright flashes of light (mostly blue and red) in the night sky based on images from a local camera. The earthquake rupture pattern shows that 13 faults in the area ruptured during the earthquake. According to the comparison of the pattern of faults and the rupture model, as well as the order of occurrence of lights in the video recorded by the local camera, the connection between lights and faults seems clear. We have presented the ThML as a new explanation in EQLs. Frictional heating during earthquakes will produce the necessary heat for emission of TL signals from electronic traps of quartz, feldspars and calcite as the most abundant minerals in earth crust. Parallel to the generation of TL signal, grinding, rubbing, cutting, cleaving, shaking, scratching, and compressing on the fault plane during rupture and movement of fault will result to emission of ML signals from different minerals. Our theory does not exclude other theories proposed for EQLs, and what we believe is that a series of physical processes in the fault plane cause light, one of which is the ThML.

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