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Research Article

# On the Role and Mechanism of Anomalous Heat Generation From Low Energy Nuclear Reaction (LENR) During Earthquakes

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**Abstract**

After going over the empirical study made by seismologists Jiwen Teng, Zuoxun Zeng, Jianguo Du, and Earth scientists Dewei Li, Guanghe Liang certain characteristics other than stress building up and rock slipping, of major earthquakes can be seen. And a reasonable heat producing mechanism is required. Based on pioneering research conducted by Song-Sheng Jiang, Wei-Yin Chen, Tadahiko Mizuno, Edmund Storms and other researchers, we believe that source cavities of these earthquakes may indicate a few possible scenarios initiating energy surge or energy increase, while depicting profiles of active environment that sustains thermal energy accumulation confined in a source cavity. In particular, the work of S.-S. Jiang, E. Storms and F. J. Mayer gave rise to the postulate that deep in Earth, nuclear reaction may take place due to the formation of a nuclear active environment (NAE) resulting in anomalous heat generation. Conditions for such reactions may foster similar processes to occur at shallower depth in source cavities of earthquakes: the deep fractures can serve as conduits for the transportation of species from deep Earth. An enclosed source cavity receives heat-producing substances, forming nuclear active sites generating excess heat on the fluid-solid interface within the media, leading to temperature and pressure accumulation, and subsequent melting of surrounding rocks. Accordingly, static electricity replenished from the atmosphere and formation of electron-proton composite (tresinos) and electron clusters thus formed within the source zone in the crust, may become contributors to the initiation of low energy nuclear reaction (LENR). Elements of H(D) may play a role in prolonged thermal energy generation responsible for energy surge in source zone, and electromagnetic/thermal energy anomaly close by an epicenter. Active lava flow on the Moon 2 billion years ago may indicate a similar energy generation mechanism. Finally, based on the field study in Fujian Province, southeast China, a twin relation between seismic events and geothermal energy release was proposed: Geothermal energy resource may bear great potential in understanding, diagnosing earthquake occurrence and even tempering hazardous seismic events by its conversion into a new paradigm of renewable energy.
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*Keywords:* Major earthquake, anomalous heat generation, heat producing mechanism, LENR

## 1. Introduction

For decades, state-of-the-art theories and hypothesis have failed to explain the fact that, for the interior of our planet as a dissipative system, strain and thermal energy seemingly follow a spontaneous pattern within a relatively small region to form seismic disasters. Theory of Isostacy, normal and strike-slip force by impounding reservoir, erosion and deposition, radioactive decay of heavier elements, Earth's rotation and cooling of the Earth Core, the gravitational influence from the other celestial bodies are flawed, because they do not form a coherent stress/heat generation mechanism to successfully explain both their spatial temporal distribution and the magnitude of energy released from major intraplate tectonic earthquakes.

Our quest to understand the correlation between earthquakes and geothermal energy starts from Fujian province. For the past ten years, abundant hot spring sites in this province have been found at regions where numerous active seismic events are recorded in the history, as if these earthquakes are well located beneath these hot spring complexes. Interestingly, a closer look at the mapping of the epicenters of previous earthquakes and hot spring locations show that they are not overlapped: In average the locality of the epicenters are 5 to 10 km away from the spots of hot spring manifestations. Such patterns can be applied elsewhere in China, for example, from 1900 to 1980 an 80-year period, where localities of epicenters of 3442 earthquakes are analyzed. For almost all the epicenters of destructive earthquakes with M$\geq$4.7, hot spring or other geothermal manifestations are missing [1]. Likewise, in active fault zones, the locations of most epicenters of destructive earthquakes deflect away from the actual observable faults.

Based on long-term observations of the source zone, seismologists have concluded that pattern of kinetic energy release during earthquakes exhibits more explosive behavior than faulting [2]. The presence of Low Velocity Zone (LVZ) underneath an epicenter [3], abnormal surface latent heat flux (SLHF) [4], earthquake lights, increased helium gas detected in geothermal wells prior to main shock of a major earthquake, are a few prominent precursors that pale the theories advocating the collision of tectonic plates, or activated fault zone as the cause of seismicity. Explosion of fluids (supercritical fluids, magma, etc.) have been widely proposed with highlighted discussion [5], which however further need a robust "heat source". As we go over all the possibilities of different types of energy generation, all forces, energy sources having "an outside origin" turned out to be much less able to account for the various phenomena during earthquakes. There must be another mechanism that actively causes a spontaneous upsurge of energy in a seismic or volcanic event. Such a mechanism, if it truly exists, needs to fulfill these criteria:

a) It can be demonstrated and replicated in empirical experiments.
b) It can accumulate to reach enough magnitude.
c) It has something to do with the local environment where the seismicity occurs.

## 2. The Possible Role of LENR in Seismicity

In addition to a few already known spontaneous energy surge phenomena, including sonoluminescence [6], pressure surge phenomena (PSP) [7], magnetic field amplification in ferrous medium, and its self-amplification within the vortex on a solid-fluid boundary [8], enhanced chemical reactions in photon and acoustically treated biochar for $CO_2$ capture and utilization [9], a nuclear reaction may also appear in deuterium/hydrogen loaded metals at much lower temperature and pressure – a unique process known as cold fusion or Low Energy Nuclear Reaction (LENR) first discovered in 1989 by Fleischmann and Pons [10]. These metals include Ti, Ni, Pd, Li and W [11], [12], [13]. As Jiang has proposed, the Earth's mantle and core have abundant Fe, Mg, Ni and Al, all of which are capable of absorbing hydrogen to form metal hydrides at high pressure and temperature [14]. Unlike hot fusion, cold fusion somehow lowers the Coulomb barrier, allowing for a faster rate of events for protium and deuterium to fuse [15]. Appreciable heat, $^4$He is produced with insignificant radiation and occasional neutron emissions. Unexpected nuclear products imply very different reaction channels than those of hot fusion. During the occurrence of cold fusion, the critical step towards the

**Table 1.** Major categories of LENR and their stimulation methods

| | |
|---|---|
| Electrolytic method | Electrolyte: $D_2O$ or $H_2O$ with solute of $H_2SO_4$, $K_2CO_3$, LiOD, $Na_2CO_3$, $Na_2SO_4$, KOH, $Li_2SO_4$, $C_2H_5OD$; Active substrates include: Pd, Ti, W, Ni, Fe and other functional metals used in conventional experiments of LENR and Lattice Energy Converter (LEC) [16]. Enhanced effects expected with specific surface morphology, high D(H)/metal ratio, increased temperature, co-deposition operation and applied magnetic field. |
| Gas loading method | Diffusion and saturation of pressurized $H_2$ or $D_2$ through metals like Ni, Pd, powder of Ni-Pd alloy, Cu-Ni-Zr-Pd alloy or metal composite [17]. Enhanced excess heat expected with cycles of gas loading-desorption treatment. Preparation of metal composite with smelting, and co-deposition may be crucial for successful replication. Better results with heating, high D(H)/metal ratio, applied magnetic field during experiments. |
| Stimulation methods | Sonic, Electrolytic, Electrodiffusion, Gas discharge, Laser irradiation |

formation of nuclear active environment (NAE) makes it special. Edmund Storms, in his insightful writings, suggests that the physiochemical environment in which very small length scale cracks in metal, such as Pd and Ni, are essential to create NAE that makes nuclear reactions occur. As nuclear scientists have pointed out, LENR shed light upon a broad way of causing nuclear reactions to occur since it has a couple of categories to start with. Categories given by Storms were shown as a reference.

By comparing the NAEs of LENR experiments with Earth crust, mantle and core, it can be shown that conditions for triggering LENR are not rare.

### 2.1. The Role of Water and H(D) Element

Around 70% of Earth surface is covered by water. The estimated deuterium content in oceans is enough for D-D fusion for billions of years. Water content also has sufficient abundance in porphyry deposits; At greater depth, water-rich magma can have a water content around 13%. Further down into the mantle, water abundance higher than expected has been found in transition zone as diamond inclusions [18]. Enough water can be carried down via the great subduction zone to reach Core-Mantle Boundary [19]. Water is compatible with Iron and can be stored within the core in great amount within the Earth core [20]. In short, H and D are readily available for nuclear reactions as long as a NAE is present and sufficiently robust.

Regarding the presence of large currents in major earthquakes [21], it is worth mentioning that surface water, ground water, brine or hydrothermal fluids having solutes dissolved as ions, are electrolytes. During their migration within seismic active zones when electricity is available, $H_2$ may be easily generated and trapped in confined space. $H_2$ may also be produced by Serpentinization of Olivine:

$$6(\mathrm{Mg,\ Fe})_2\mathrm{SiO_4} + 7\mathrm{H_2O} \rightarrow 3(\mathrm{Mg,Fe})_3\mathrm{Si_2O_5(OH)_4} + \mathrm{Fe_3O_4} + \mathrm{H_2} \quad (1)$$

This may be different from deuterium dispersed in sea water, since the great subduction zone may offer a particular structure for sea water to find its way to deep mantle and eventually the center of our planet, an intended “design” on a planetary scale for deuterium, protium and suspected NAE to meet at core-mantle boundary (CMB) [22], generating heat for the gigantic movement that keeps the entire planet geologically alive for eons, and serving for a planetary purpose, while fresh water in water reservoirs and natural water channels only migrate to moderate depth. Water migration may disturb the slippery effect among rocks and cause greater movement in places where stress concentration may be amplified. Hereby the state-of-art research on seismology has not been totally rejected. Rather, it is the possible presence of NAE for hydrogen element that inspires us to think twice about the role of common water in seismicity.

### 2.2. Role of Heat Producing Substance

Many scientists have ascribed the abrupt energy release to the explosive behavior of fluids. Among them, supercritical fluids have been proposed [23]. Sites of cryptoexplosion have been observed in line with the major fault zones across the mainland of China [5]. How can these cryptoexplosion gather enough energy to cause noticeable earthquakes simply by adding material transported over a long distance? From an incomplete review from thermodynamics and heat transfer, a supercritical fluid in general is not the ideal carrier of thermal energy. Its superb mass diffusivity is offset by its limited capacity for thermal energy storage, compared to steams formed by the same species. If expansion of supercritical fluid does trigger cryptoexplosion and subsequent seismicity it most probable falls into these categories: (1) the multi-phased fluids have enough enthalpy originally stored or supplied from latent heat from superheated steam blended within, which facilitates bubble growth during the dephasing. Thermal energy potential for generating volumetric work is maintained; or (2) they have carried radioactive elements as heat suppliers as they spontaneously decay; or (3) there are other heat producing mechanisms involved.

Most radioactive elements are found at a shallower depth, and if highly radioactive elements self-concentrate within the source zone, they may easily become visible when there are any fluids, e.g., vapor, gases, volatile matter escaping from the pressurized chamber. But reported high radiation background at sites around epicenters, or release of radioactive compounds, is rare. Likewise, volcanic veins and faults are control volumes for non-reversible thermodynamic processes, unless active sites for heat producing reactions are developed due to their specific material/morphological features favoring such reactions, which can be further confined by caprocks and maintained by the most abundant element in nature: hydrogen isotopes.

### 2.3. Static Charges May Well Exist in Deep Structures, Where Electrons May be Stored in Special Form

Graphitized carbon and formation of the dark brown pseudotachylite exhibiting large magnetic susceptibility and high Natural Remnant Magnetization (NRM) can be found at the shear plane of exhumed fossils from major earthquakes. The high NRM of pseudotachylite is due to large currents acting on the fine grains of magnetite during their fast cooling around 580°C. Clay samples found at the fault zone in Wenchuan Earthquake on May 12, 2008, for example, indicates temperature within the clay reached about 1100°C [23]. Strong graphitization of carbon, however, refers to a microstructural change that occurs in carbon exposed to temperature of about 425–500°C for several thousand hours. It can also be produced by applying strong direct electric current to the carbon due to the simultaneous heating effect of the current, which will be capable of raising the temperature of carbon to more than 2000°C [24]. Indication of varied, nevertheless very high temperature (higher than which can be expected from average local geothermal gradient) shown by pseudotachylite and graphitized carbon may denote the thermal energy generation and subsurface current flow as two individual events. The physicochemical mechanism behind the events deserves more attention.

Experts have searched for the origin of subsurface large currents present during major earthquakes. F. Freund and his co-authors have proposed electrons and p-holes as charge carriers. P-holes can spread out over the volume of rocks, while flow of electrons requires the circuit to be closed. The awakening of subsurface electric current occurs when conducting fluid travels further into the rock which closes the circuit between geological domains having different electric potential due to the application of stress to these domains. Their experiments had shown that every cubic kilometer of stressed igneous rock adjacent to the fault plane could deliver $10^3$–$10^5$ A. However, if the conservation of charges stays valid, it is not clear how such large current is maintained for an appreciably long time so that there is a remarkable influence on both the carbon and magnetite in pseudotachylite. Or spontaneous current may first appear due to the LEC effect within layers of metallic minerals and then merge to greater intensity [16].

Here we postulate a new hypothesis accounting for the origin of prolonged large currents within Earth. The argument made here is that Earth crust may play a very important role in storing negative charges and electrons. There has been hypothesis and conclusions that both the Earth core and the atmosphere carry positive charge. Then the negative charges have to be stored elsewhere, i.e., the mantle and crust. The fluids in Earth mantle carry electrolytes that conduct electricity. Only above the Moho-discontinuity electrons can appear as static electricity, thereby sustaining the electric potential similar to a capacitor. Lightning storms in the troposphere carry overall negative charges to the ground rated about 1800 amps [25]. These charges are assumed to go back to the atmosphere in fair weather, whereas a small fraction of them may be left within the complex of rocks and minerals, and replenish the cations in rocks when negative charges are released during a seismic event.

If the earth crust acts like a huge capacitor, why don't we detect the current flow when a borehole is drilled? Electrons may be stored in forms previously unknown to us, such as tresinos [26], and EVs, or electron clusters [27]. When their numerous presence is combined with the oxidized layers of valve metals, or moderated by the positive ions on the surface of minerals and crystals, their exhibited negative potential will be disguised by the special form of electrons [28]. Visible ball lightning formed during stormy weather has shown strong evidence involving elements from earth and sand [29]. In comparison, electron clusters may form micro-sized plasmoid [30] when they appear and interact with solids, suspected as the main trigger in LENR or cold fusion. Their appearance may contribute to more diverse distribution and accumulation of static electricity, disturbing local electromagnetic fields when negative charges migrate closer to the surface, leading also to the negative charge anomaly in the atmosphere [31] and flashes of light preceding an earthquake. The simultaneous production of transmuted elements, among which the enrichment of radioactive elements can also be expected.

Based on the model of E. Storms, we believe that cracks and fluid-solid interfaces down to the micro-meter to nanometre length scale along the main fault plane and connected veins may serve as the natural sites of electron accumulation in very large density, hence extremely intense electric field strength, for the initiation of LENR. Beta emission of radioactive substances contributes to a portion of electrons at shallower depth, but much less to the source zone at greater depth.

## 3. How Reactions May Happen

Here are some typical examples of heat producing nuclear reactions:

### 3.1. S.-S., Jiang and S. E. Jones

Geological evidence has demonstrated that the ratio of He-3/He-4 over the ratio found in atmosphere ($R/R_A$) of majority of hydrothermal samples fetched from hot fluids from the mid-ocean ridge of Atlantic Ocean, Rainbow, Lucky Syriky and circum-Pacific volcanic arcs has fallen into a very narrow band, about 8 times of the $R_A$. It is also found that the absolute content of He-3 from these hot fluids are linearly proportional to the temperature of these fluids. The results can be either by explained by existence of He-3 reservoir since the beginning of our planet, or as a stable supply of He-3 from a common mechanism related to thermal energy generation from interior Earth. Jiang *et al* from their findings of He-3 and Tritium concentration in excess of the atmospheric values in the deep waters of the volcanic Lakes Pavin (France), Laacher (Germany) and Nemrut (Turkey), had found strong evidence of the existence of nuclear reactions in deep Earth [14]. Possible equations of D-D fusion are given:

$$ {}_1^2\mathrm{d} + {}_1^2\mathrm{d} \rightarrow {}_2^4\mathrm{He(m)} + 23.8\mathrm{MeV(m)} \tag{2}$$

$$ {}_1^2\mathrm{d} + {}_1^2\mathrm{d} \rightarrow {}_2^3\mathrm{He}\,(0.82\mathrm{MeV})\,(\mathrm{m}) + {}_0^1\mathrm{n}\,(2.45\mathrm{MeV})\,(\mathrm{m}) \tag{3}$$

$$ {}_1^2\mathrm{d} + {}_1^2\mathrm{d} \rightarrow \mathrm{T}\,(1.01\mathrm{MeV})\,(\mathrm{m}) + \mathrm{p}\,(3.02\mathrm{MeV})(\mathrm{m}) \tag{4}$$

In Eq. (4), "m" stands for the active environment correlated to the lattice of metals, metal particles, or localities on metallic surface, shedding light upon an exciting joint area between condensed nuclear physics and Earth science. In our oceans, the natural abundance of deuterium is about 1/6500 of hydrogen atoms, and this value is subject to variations in different continents. The enrichment of deuterium may be achieved with some other reaction that will be shown below.

P-D fusion generating He-3 is also considered as the exothermic reactions inside Earth and Jupiter in S. E. Jones' paper. Although his empirical experiment produced no net excess heat [32]:

$$ {}_1^1\mathrm{p} + {}_1^2\mathrm{d} \rightarrow {}_2^3\mathrm{He} + \gamma(5.4\mathrm{MeV}) \tag{5}$$

### 3.2. P. L. Hagelstein and M. H. Miles

At room temperature, D-D fusion has been observed consistent with the reaction in a metal deuteride:

$$ {}_1^2\mathrm{D} + {}_1^2\mathrm{D} \rightarrow {}_2^4\mathrm{He} + 23.8\mathrm{MeV}\ \text{(heat)} \tag{6}$$

Production of helium in D-D fusion quantitatively correlated to excess heat in deuterated metals has been studied extensively and documented by the many, including M. H. Miles [33] and P. L. Hagelstein et al. [34].

### 3.3. E. Storms, Y. Iwamura and W.-S. Zhang

Apart from the equation (1) and (5), exothermic reactions may also take on distinctive channels when common hydrogen is involved:

$$ {}_1^1\mathrm{H} + {}_1^1\mathrm{H} + {}_{-1}^0\mathrm{e} \rightarrow {}_1^2\mathrm{D} \quad \mathrm{Q} = 1.4\mathrm{MeV} \tag{7}$$
$$ {}_1^1\mathrm{H} + {}_1^3\mathrm{T} + {}_{-1}^0\mathrm{e} \rightarrow {}_1^4\mathrm{H} \rightarrow {}_2^4\mathrm{He} + {}_{-1}^0\mathrm{e} \quad \mathrm{Q} \leq 20.4\mathrm{MeV} \tag{8}$$

Eq. (7) might give an example of deuterium enrichment resulting from the fusion of two hydrogen atoms.

HACONS (H stands for Hydrogen or Halogens, A for Alkalis, C for Carbon, O for Oxygen, N for Nitrogen and S for Sulfur Group) fluids are mainly composed of hydrogen, Na, K, Li, Rb, Cs, carbon, oxygen, nitrogen, and sulfur [35]. Interestingly, Cs involving nuclear reactions have been observed and replicated. Experiments by Iwamura et al. have demonstrated the puzzle of unknown mechanism for cold fusion on thin layer of deposition of CaO on bulk palladium, upon which 400 angstrom thickness of Pd were attached, with impurities of Cs as seeds for deuterium self-concentration. Geologically speaking, layers of mineral precipitation with metals and H(D) ions deposition may be realized by magmatic intrusion and redox reactions, and hence the naturally formed multi-layered metal composite well studied in LENR.

$$ {}_{55}^{137}\mathrm{Cs} + 4{}_1^2\mathrm{D} \rightarrow {}_{59}^{145}\mathrm{Pr} \quad \mathrm{Q} = 50.5\mathrm{MeV} \tag{9}$$
$$ 4({}_1^2\mathrm{H}) \rightarrow 4({}_1^1\mathrm{H}) + {}_2^4\mathrm{He} + \sim 21\mathrm{MeV} \tag{10}$$

Storms and other scientists, including W.-S. Zhang, H. Zhang from China, also found strong correlation between the ambient temperature and rate of excess heat generation [36], [37]. Accordingly, low temperature of aqueous environment may lead to a low reaction rate. When we apply the same principle to fluids supplied to source zone, the enhanced thermal energy dissipation, and a dilute or redistribution of the ions and key elements, whether through a natural hot spring, or geothermal power plant, may directly or indirectly lead to lessened rate of heat generation, since the NAE may be interrupted, the reaction channel changed, and positive feedback can be expected for the source zone to "calm down".

### 3.4. F. Mayer, J. Reitz and M. Fukuhara

$$\mathrm{d} + \mathrm{d}^* \rightarrow \mathrm{p} + \mathrm{t}^* + 4\mathrm{MeV} \tag{11}$$

$$\mathrm{d} + \mathrm{d}^* \rightarrow \mathrm{p}^* + \mathrm{t} + 4\mathrm{MeV} \tag{12}$$

$$\mathrm{d}^* +^3_2 \mathrm{He} \rightarrow \mathrm{p} +^4_2 \mathrm{He} + 18\mathrm{MeV} \tag{13}$$

Mayer and Reitz have formulated a tresino model, in which electrons can be stably combined with proton of matter. His model is able to calculate the consumption of three hydrogen isotopes p, D, and T, and rate of thermal energy generation, which is commensurate with observed rate of thermal energy generation within Earth. His model also predicts the slow change of D/H ratio on planet Earth versus other already cooled celestial bodies having no internal active heat generation, such as ice comet [38]. A theoretical model proposed by Fukuhara, has shown a possible unique reaction channel with He-4 production brought forth by neutral pion catalysis reaction under high pressure, high temperature conditions at the D-rich Earth core [39].

$$3^2_1\mathrm{D} \rightarrow 2^1_1\mathrm{H} +^4_2 \mathrm{He} + \overline{\nu_\mathrm{e}} + \mathrm{e}^- + 21.63\mathrm{MeV} \tag{14}$$

Recent eminent discoveries made by Chang E-5 lunar robotic spacecraft have proven the fact that lava flow still existed 2 billion years ago on the Moon, leaving a great mystery to planetary scientists: with contribution of radioactive heat generation and lessened melting point of rocks being ruled out, how could its geological movement stay alive for another 0.8 billion years [40]. Nuclear reactions such as Eq. (13) might well be involved to create heat and helium, thereby becoming the heat source for Moon earthquakes and prolonged volcanic activities.

### 3.5. A. Carpinteri and Q. Zhuang

A. Carpinteri and his team have empirically observed thermal neutron burst during loading process to rocks including Magnetite [41]. Fracture experiments on natural rocks demonstrate that the TeraHertz vibrations are able to induce fission reactions on medium weight elements accompanied by neutron emissions. These discoveries made it possible for thermal nuclear fission reactions to occur within upper crust where geologically induced species enrichment by supercritical fluid extraction and subsequent dephasing and deposition has reached the threshold similar to that of a nuclear power plant when neutrons burst are produced and become available to $^{235}$U at the moment of final collapse of rocks. Under extreme conditions, secondary neutron production from fission reactions of Uranium might trigger chain reactions similar to an atomic bomb, generating sufficient magnitude of earthquakes on Qinghai-Tibet Plateau for example, as was mentioned by Q. Zhuang [42]. However, much more evidence is needed to verify such claims.

## 4. LENR Products vs What Have Been Observed in Seismicity

Several possible features of seismic events are identified to be correlated with LENR in nature: Natural helium reservoir large enough to exploit; Increased helium production and/or heat flux close to source zone a couple of days before onset of major earthquakes; Micro crack development prior to the onset of main-shock. Abnormal regional droughts prior to major earthquakes [43]. Self-sustained heat production for months to years after its initiation in NAE enables the small scale cryptoexplosion of breccias. Eventually, immense energy can accumulate to generate work on a geological time scale. Large currents beneath the ground, earthquake lights, Ultra Low Frequency Radiation close to source zone may be related to the special forms of electrons for the initiation and maintenance of LENR. It is thus suggested that thermal effect coupled with electromagnetic effect of condensed matter nuclear reactions deserves study combined with physiochemistry in geological context.

## 5. Conclusion

It is argued that the thermal energy responsive to orogen, geothermal energy, and earthquakes should have an active energy component in addition to stable energy generation from radioactive decay. Among all the candidates of energy surge phenomena, anomalous heat generation from low energy nuclear reaction (LENR) is the most probable mechanism compatible with the intensity and scale of major earthquakes, and can explain many concurrent events during a seismic event.

It is also suggested that if the dynamic thermal energy input from LENR does have an impact on tectonic movement and earthquakes, its NAE should be responsive to human intervention. Geothermal energy exploitation, if properly applied, has the potential to offer a feasible way of releasing the strain/thermal energy accumulated, while taming directly or indirectly the NAE bearing a potential disaster, thus turning the destructive earthquake into constructive, sustainable geothermal energy for the common good of human society.

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