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Geothermal Energy and Earthquakes in Western Himalayas

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ABSTRACT

It is well corroborated that the earth is relentlessly bubbling inside since its birth and traversing continuously through a geological change. The source of this dynamism is the heat stored inside i.e. the geothermal energy, which is believed to be the product of mainly the decay of natural radio-isotopes in the crust and mantle, and in the core of earth. This heat exerts pressure towards the surface where it leads to earthquakes and geothermal events like spectacular volcanoes and fumaroles. The Himalayan Mountains are the youngest ranges amongst various developments in the crust of earth. As per the scientists and observed facts this region is the highest seismic prone zone. In our previous work we have shown, on the basis of substantial observed fact, that the intensity of earthquake can be abated by utilizing the geothermal power. In this work we focus on the state of Himachal, which falls in the base of the western Himalayas. Given the region of zone-V, the earthquake disaster management is one of the major challenges in the state. It is argued that by harnessing geothermal power from various geothermal sites in Himachal, the intensity and risk due to earthquake disaster can be made less detrimental.

Keywords: Geothermal Energy, Earthquake, Himalayas, Power Generation, California Geysers

I. INTRODUCTION

During the evolution of universe, scientists believe that after the formation of sun, the earth and other planets came into being. The entire atmosphere was extremely hot and fire-burning. The planets so formed were quite hot at the time of formation and have been continuously cooling since then. Apart from this the source of heat inside the earth could be the decay of radiogenic isotopes i.e. in particular uranium, thorium and potassium. In a recent study by the KamLAND Collaboration [1], the decay of Uranium-238 and Thorium-232 together contribute 20 Terawatts (TW) to earth's heat flux. The decay of Potassium-40 is known to contribute just 4 TW. However, the total power capacity is 44.2 TW.

On the basis of simulation studies using supercomputer, J. Marvin Herndon proposed earth's inner core as a nuclear reactor —the main source of earth's heat [2]. Earth's internal heat powers all geodynamic processes along with generation of geomagnetic field. Based on available scientific evidence, earth's crust and upper mantle are primarily composed of solid rocks. Geologists believe that the decay of radioactive elements in the solid rocks of the mantle and crust must heat up the rocks up to 750-1000 °C and melt the rocks to form the magma [3]. However, at the center of the planet, the temperature may be up to 6,000 °C and the pressure could reach 360 GPa [4].

The heat stored, bubbling and sputtering out of the interior of earth in the form of spectacular volcanoes, hot-rocks and hot-springs etc…, is known as geothermal energy. This energy is said to be clean and green, as it produce almost negligible amount of environmental pollutants as compared to the others. This is a domestic energy resource with cost reliability and environmental advantages over conventional energy sources. It contributes both to energy supply with electrical power generation and direct-heat uses.

There is large number of geothermal sites around the different parts of the globe and the energy is being harnessed as commercial and domestic uses in various countries. India has seven main identified geothermal provinces and harnessing the energy as electricity generation is not yet initiated significantly. Himalaya is the largest geothermal province and Himachal falls in the western part of it. The earthquake disaster is one of the major challenges in the state of Himachal. In the light of our recent work [5], we have shown that harnessing the power from the various geothermal sites in Himachal Pradesh like Manikaran, Tattapani, Manali etc… can supplement growing power needs and on top of that the state can become less risky for earthquake disaster.

In Section 2 various geothermal provinces in India and their thermal capacities are discussed. Section 3 gives details of the heat flow in the Himalayan geothermal province and earthquakes occurred in the region. However, the reduction of earthquake magnitude by installing the power generators is discussed in Section 4. Finally, the conclusions are presented in Section 5.

II. GEOTHERMAL SITES IN INDIA AND HARNESSING CAPACITIES

India is progressing ahead towards generating eco-friendly energy sources like wind power, hydropower, biomass, solar power and geothermal power. Large financial incentives and capital subsidy are given by the Govt. of India to harness energy from the non-conventional energy sources. India has a great potential of geothermal sources. There are several geothermal regions characterized by high heat flow (78-468 mW/m^2) and thermal gradients (47-100^o C/km). The total potential of generating power from the non-conventional energy sources in India is about 60,600 MW and the total installed capacity from renewable stands at 1313 MW which is < 2% of the total potential. At present, power generated through non-conventional sources is far less than the installed capacity of the power plants (Table I).

Several research groups have carried detailed geological, geophysical and tectonic studies. These investigations have identified several geothermal sites which are suitable for power generations as well as for direct use. The utilization of direct use technologies is normally practiced where water temperature less than 150^o C. At present, not much initiative has been taken to harness the heat for power generation. The geothermal regions in India are divided into seven provinces, as shown in Fig. 1, namely Himalayas, Sohana, Cambay, West Coast, SONATA, Godavari and Mahanadi. These seven geothermal provinces are characterized by high heat flow value (78-468 $milliW/m^2$) and thermal gradients (47-100 ^{0}C/Km) and discharge about 400 thermal springs within Indian jurisdiction.

After the oil crisis in 1970s, the Geological Survey of India conducted reconnoiters on the identified sites in collaboration with UN organization and reported the results in several of their records and special publications [7].

TABLE I
PRESENT STATUS OF NON-CONVENTIONAL ENERGY RESOURCES [6]

Renewable Power	Potential	Achieved
Wind Power	20,000 MW	1,000 MW (5%)
Small Hydro Power	10,000 MW	172 MW (<2%)
Biomass	20,000 MW	141 MW (0.7%)
Solar photo- voltic Power	20 MW/sq.km	810 KW/sq.km (4%)
Geothermal Power	10600 MW	--

The Tattapani geothermal field in Chhattisgarh is said to be the most promising geothermal resource. The state government has granted permission for the installation of a power plant at Tattapani area of the Balrampur district to the National Thermal Power Corporation (NTPC). The other promising sites are Puga and Chhumathang in J&K, Cambay Graben in Gujarat, Surajkund in Jharkhand, and Manikaran in Himachal Pradesh.

In fact, a pilot binary cycle power plant of 5 kW, using R113 as a secondary fluid was installed at Manikaran (located in Parbati valley, SW of Puga) in Himachal

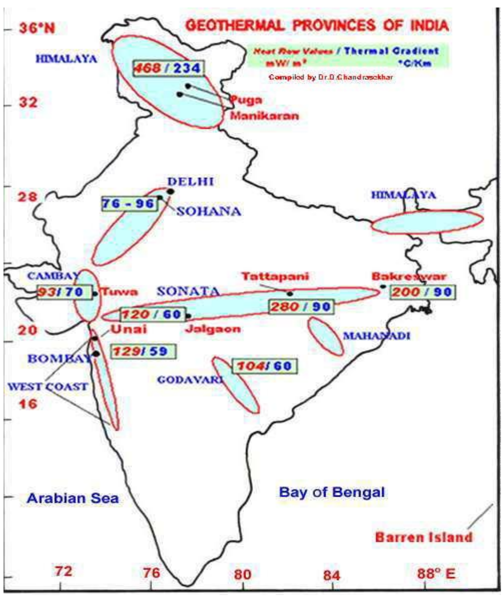

Figure 1 : Geothermal energy provinces in India

Pradesh, by the Geological Survey of India and National Aeronautical Laboratory in the eighties. Unfortunately this plant was later abandoned due to landslides, but proved the capability of geothermal sites of the Himalayan region to generating power [6]. In addition, the space heating experiments in the province were also conducted successfully using thermal discharge by the Geological Survey of India.

In the Table II, the temperatures and heat flows of the most promising five provinces i) The Himalaya, ii) Sohana, iii) Cambay, iv) Son-Narmada-Tapi (SONATA) and v) Godavari are shown.

Thus with the available technology all the above thermal provinces can be exploited for power generation as well for direct use. These provinces are capable of generating 10,600 MW of power [8]. With the escalating energy needs and existing open economic policies of the Govt., and large incentives given to non-conventional energy sectors, the future of geothermal energy sector in India appears to be bright.

TABLE III
LIST OF MAJOR EARTHQUAKES ASSOCIATED WITH THE HIMALAYAN GEOTHERMAL PROVINCE

Year	Region/ Epicenter	Magnitude	Toll
1885	Sopore, JK	7.0	2,000
1897	Shilong	8.7	1,542
1905	Kangra, HP	8.0	19,500
1918	Assam	7.6	NA
1930	Assam	7.1	NA
1934	Bihar – Nepal	8.3	10,700
1941	Andaman Island	8.1	NA
1943	Assam	7.2	NA
1950	Arunachal	8.5	1,526
1975	HP	6.5	-
1988	Bihar – Nepal	6.4	900
1991	Uttarkashi, UP	6.6	2,000
1999	Chamoli, UP	6.8	100
2004	Andaman Island	7.5	2,000
2005	Muzafarabad,JK	8.5	36,000
2009	Andeman Island	7.7	26
2011	Gangtok, SKm	6.9	118
2012	Andeman Island	6.2	0
2013	J &K	5.8	2
2014	Andeman Island	6.7	0

III. HIMALAYAN GEOTHERMAL PROVINCE AND EARTHQUAKES IN THE REGION

The collision of the Indian plate with the Eurasian plate resulted in the formation of the Himalayas about 45 million years ago and as one of the largest geothermal belt, over 150 Km wide extends 3000 Km through parts of India, Tibet, China, Myanmar and Thailand replete with more than 1,000 hot-spring areas. Over 150 of these areas are hot enough to generate electricity. The arc of volcanic islands incorporating the Coco Island (Burma), Nar-Condom Island (India), and Barren Island (India) is situated on the eastern tail end of Himalayan geothermal belt.

Himachal Pradesh is a part of the large Himalayan geothermal province, which covers an area of over 1500 sq km enclosing more than 150 thermal manifestations with surface temperatures varying between 57 and 97°C [6]. It has a high geothermal gradient (>260°C/km) and too high heat flow values (>180 mW/m^2). These thermal manifestations are at Manikaran, Tattapani, Manali etc… in the bank of Parvati, Satluj and Beas rivers, respectively.

Along with the wet geothermal systems, the region is endowed with hot dry rocks at surface and shallow depths. The high geothermal gradients and heat flow value in the state are well suited to commission geothermal based power projects and also to initiate feasibility study to tap hot dry rock resources. Himachal Pradesh has a great potential to produce electricity and supplement its various power needs in house heating and cold stores etc…

The closer view of the Himalayan province is shown in the picture (Fig. 2).

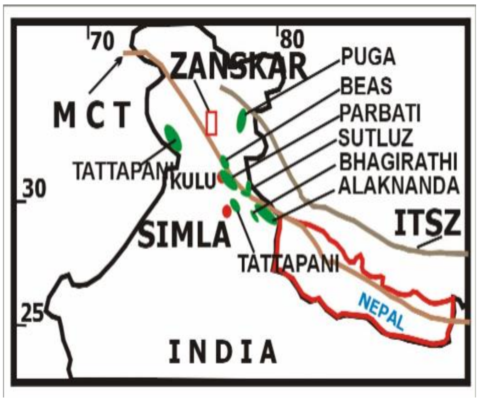

Figure 2: Geothermal energy sites in North-West Himalayan region [6].

From the table given in our previous work [5] it is quite evident that the epicenters of all the big damaging earthquakes of Indian region during last 200 years are strictly located in the jurisdiction of above mentioned seven geothermal provinces of India. This is a glaring fact in support of our hypothesis that earthquakes are the emission of surplus geothermal energy accumulated in the respective geothermal provinces during last two centuries.

There are data which show that the portion of the Gangetic Plains comprising of Kanpur, Allahabad and Varanasi situated in the vicinity of Himalayan plate boundary, but lying in non-geothermal province (a low heat flow region), has not witnessed any earthquake hazard in the last 3000 years. In addition, the earthquakes of very high magnitude reported in the Western and South Indian parts (Bhuj, Bhadrchalam and Latur), which are not lying on any of the tectonic fault lines, but situated on the geothermal provinces.

The year-wise data of the major earthquakes of Richter scale (>4) associated with the Himalayan geothermal province have been tabulated in the Table III.

From the above table it is quite evident that the epicenters of all the high magnitude and devastating earthquakes (>6 on Richter scale) of Himalayan region during the last 200 years are strictly located in the jurisdiction of the Himalayan geothermal province. One may easily connect these events with the tectonic fault activities; however the weight of geothermal origin is more.

IV. POWER GENERATION AND EFFECT ON THE MAGNITUDE OF EARTHQUAKE

The immense store of geothermal energy amounts to $\sim 10^{13}$ Joules, and would take over ten billion (10^9) years to exhaust. This source of energy is an extremely large, replenishing, self-sustained natural gift and that's why designated as the renewable source of energy. The power rates of this energy are more than double humanity's current energy consumption from all primary non-sustainable sources.

At present, only a little fraction of this energy is being harnessed worldwide. Thermal springs have been used for bathing, washing and cooking for thousands of years. At the beginning of the last century, experiments started for piping the hot water for house heating and production of electricity. As per the recent report of the International Geothermal Association (IGA) 10,715 Megawatts (MW) of geothermal power in 24 countries is online and out of which about 67,246 GWh of electricity is being generated [9].

The USA, Philippines, Italy, Argentina, Australia, Ethiopia, France, Greece, Portugal, Russia, Thailand, Mexico, Iceland Indonesia, Japan and New Zealand are the main users of geothermal energy resources. USA is the world's largest producer of geothermal electricity. The first geothermal plant, opened at 'The Big Geysers' in California in 1960 continues to operate successfully. The California Energy Commission (CEC) is running this largest geothermal energy plant of 1800 MW and fulfilling the electricity requirement of 10,00,000 house hold units of North California in an eco-friendly manner [10].

Heat source inside the earth exerts pressure towards the surface where it leads to geo-dynamism and geothermal events like spectacular volcanoes, hotspots, hot-springs, hot dry-rocks and fumaroles etc… The researchers of Utah University [11] have shown that the heat inside the planet accounts for half the reason land rises above the sea level or higher to form mountains. It is the pressure created by the heat that makes rock in the continental and ocean crust and upper mantle expand to become less dense and more buoyant. The internal heat is sustaining the crust and preventing to collapse. The heat is continuously being produced inside; however the release through surface is not in the same rate. Thus the excess pressure so created leads to tremor.

It is evident from the data that earthquakes occur in pockets, which means that it can't be an entire plate phenomenon. This shows that in the root the earthquakes are results of this excess heat pressure rather than plate tectonics, although the movements of plates are also the result of this excess pressure. Such that if we release this excess pressure locally by installing power generators and harness as electricity the magnitude of the tremor i.e. earthquake can be significantly reduced.

The encouraging results at page 19 and 20 (as shown in Fig. 3) of the California Energy Commission report [10] says that: "To date there has been no faults mapped in The Geysers which would generate a magnitude of 5.0 or greater. This is not an absolute guarantee that one would not happen, but does lower the likelihood". The largest earthquake ever detected in The Geysers area measured 4.6 on the Richter scale; while seismic activity elsewhere in the region can be much more dangerous.

It is true that at present about 11,000 MW is being harnessed and this is a tiny share of the total heat production rate inside the earth (44.2 TW), but the fraction of heat energy responsible for the earthquake is also too small i.e. ~0.01%[12].

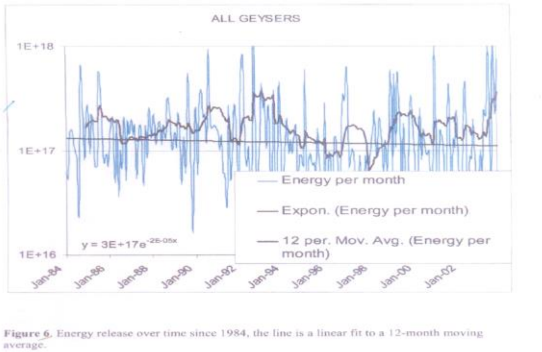

Figure3: Energy release from The Geysers': Figure 6 of the report [10].

As we argued above it is the surplus amount of internal heat pressure (excess pressure) that is released by funding the plate movements, point fracture/ rupture along the active fault and intra-plate regions. After penetrating, piercing, puncturing and punching through the surface of earth this energy emerges out and enters into open space. Therefore to reduce the intensity of earthquake significantly we need to play with this ~0.01% excess heat of earth.

However, it seems practically impossible to challenge the force of nature, and control its course, but in the light of the above results from 'The Big Geysers' of California (CEC Report figure 6) and relating it with our hypothesis [5] it looks viable to release this energy pressure as power production, and minimize the risk and hazard of the impending earthquakes. So, if we install electricity power plants in the geothermal sites of HP, like Manikaran, Tattapani and Manali etc... in addition to power production the magnitude of the potential earthquake in state can substantially be reduced.

V. CONCLUSIONS

Geothermal energy is the best domestic source of sustainable and renewable energy and an alternate to other energy sources, especially coal and fossil fuels. This is an environmentally clean source as it emits a negligible amount of greenhouse gases. Though not used fully due to factors such as location and high costs but in the years to come when these conventional fuels would start to diminish, it will turn out to be the cheapest source of power generation. Although initial investment is quite steep but for long run it is huge cost saving and efficient. It involves low running cost as it save 80% cost over fossil fuel as it require no fuel for power generation.

Earth is continuously shuddering by minor earthquakes in various parts of it and about 20% of these tremors can be felt. The major earthquakes occur less frequently, but in the identified pockets. The actual cause of the continental drift i.e. motion of the plates is not clear yet, it is however interesting that the tectonic activity —the volcanic eruptions— has also been discovered in some other planets and satellites. This shows a similar kind of processes going on in interior of those bodies [13]. It is the pressure created by the geothermal energy that makes the continental crust to be up high the sea level. The excess pressure leads to tremor and movements of the plate tectonics.

The correlation between geothermal energy and earthquakes leads us to conclude that if we somehow manage to release this excess energy (0.01%) the crust of the planet will be less quaking. The best possible management of the energy is to produce electricity. So, in order to cope with the escalating energy crisis and as the measure of Earthquake Disaster Management, there is dire need of harnessing the surplus pressure amount of geothermal power as direct use and electricity generation at least in selected pockets of natural geothermal provinces.

On the basis of our hypothesis [5] and in the light of CEC Report we put forward a potential proposal of harnessing the geothermal energy as house heating and electricity generation, which in turn can reduce the devastating impact of earthquakes, tsunamis and volcanoes. The region of Himachal is considered as the most sensitive to the earthquakes and falls under the zone-V, and situated in the western tail of the largest Himalayan geothermal province of Indian subcontinent.

In conclusion, it is strongly advocated that if we harness this energy from the various geothermal sites in Himachal as electricity, the magnitude and risk of the impending earthquakes in the state can be significantly reduced. So, it is beyond doubt that commissioning the geothermal project(s) in the state, or geothermal site situated anywhere on earth, is not shear wastage of public money, but can be proved as a boon to the state in earthquake disaster management. This can set an example and motivation to the other states and to rest of the world. In either case, the very purpose of electricity generation is not going to be futile.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

[1]. KamLAND Collaboration, 2011. Nature Geoscience 4, p647.

[2]. H. J. Marvin. 1993. Journal of Geomag. and Geoelectr. 45, p423; 2007. Current Science 93, no. 11, p1485.

[3]. J. T. Edward and K. L. Frederick, "Earth: An Introduction to Physical Geology", Prentice Hall Inc., New Jersey, 1996.

[4]. Alfè D. *et al.* 1795. Philosophical Transactions of the Royal Society 360, p1227.

[5]. S. P. Kapoor and B. C. Chauhan. 2014. Univ. Journal of GeoSc. Vol.2 (5), p141.

[6]. D. Chandrasekhram et al. 2000. IBC Conference, Manila, Philippines; Proceedings World Geothermal Congress, Kyushu -Tohoku, Japan, May 28 -June 10; 2003. International Geothermal Conference, Reykjavík, Sept. p15; 2005. Proceedings World Geothermal Congress, Antalya, Turkey, 24-29 April.

[7]. Geological Survey of India (GSI): Geothermal Atlas of India (GAI) 1987 & 1991.

[8]. S. Ravi. 1996. Geo. Surv. of India, Spec. Pub. 45, p1.

[9]. en.wikipedia.org/wiki/Geothermal_electricity.

[10]. California Energy Commission (CEC) Final Report, "Integrated High Resolution Micro-earthquake Analysis and Monitoring for Optimizing Steam Production at The Geysers Geothermal Field, California, 2004." http://quake geo.berkelev.edu

[11]. D. Hasterok and D. S. Chapman. 2007. J. Geophys. Res., 112, B06415.

[12]. W. Lowrie, "Fundamentals of Geophysics", p179, Cambridge University Press, 1997.

[13]. A. V. Byalko, Our Planet: The Earth; Mir Publishers, 1987.