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Enhanced Geothermal Resources: Indian Scenario

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Keywords

Granite batholith, leucogranites, Himalayas, Indian Geothermal

ABSTRACT

India needs additional electric power generation on the order of 100,000 MWe to bridge the gap between demand and supply by the year 2012. This will generate about 620 million metric tones of CO_2. Both mitigation of CO_2 emissions and meeting the future electricity demand can be accomplished by exploiting available enhanced geothermal sources across the Himalayas as well as in the central Indian continent.

Coal Energy Source and CO_2 Emission

India is one of the largest consumers of coal for generating electric power. Carbon emission from coal-based thermal power plants stands at 399 million metric tonnes as of 2004 and is projected to reach 620 million metric tones by the year 2012 by adding an additional 100,000 MWe to the present production of 124,000 MWe (Figure 1). Additional licenses to mine more than 20 billion tones of coal from the existing mines and licenses to open new mines are granted. Power generation during the year 2005-06 showed an increase of about 4.6 %. The situation has not changed in the following year and with this growth rate, even by increasing the coal production, it not possible for the country to bridge the demand and supply gap of electric power. At present the contribution to power by hydro, nuclear and renewables is only 26, 2.7, and 4.9 percent respectively. India has already entered into carbon trade with the European countries to reduce carbon emission to the limit prescribed by the United Nations Framework Convention for Climate Change (UNFCCC). This only gives the country the liberty either to maintain or increase the CO_2 emission level in the future. This situation may change if the geothermal sources, both wet and dry systems are, exploited. M/s GeoSyndicate has already acquired licenses to exploit the wet systems and is planning to exploit the huge enhanced geothermal resources available in the country.

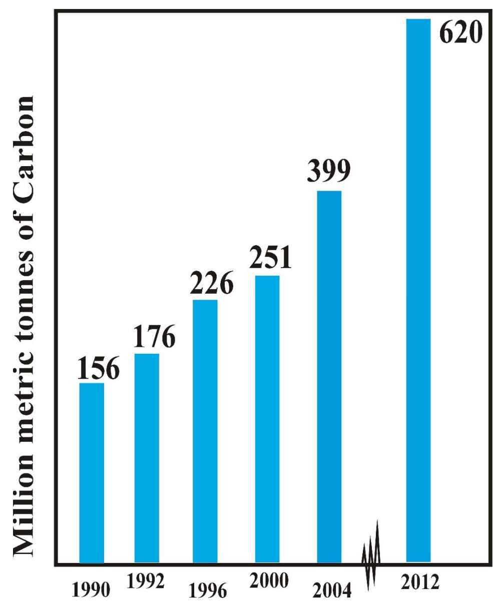

Figure 1. CO_2 emission since 1990.

Enhanced Geothermal Systems

With the advancement of drilling technology, heat mining from rocks appears to be the most cost effective method to produce electric power to meet the ever growing demand of electricity in developing countries like India. The current cost of electric power in India is the highest compared to other developed countries like US, China, France and UK. At present the cost of electricity for the consumer is about 15 US cents/kWhr which is the highest compared to China (7 US cents/kWh), France (14), UK (12) and US (10) (IEA, 2005). With increase in cost, to sustain a constant CO_2 emission level, and maintain low particulate content in the lower atmosphere, the unit cost of power will be higher in the near future. The current cost is higher than the present estimated cost of electric power from EGS. With the available advanced drilling technology, the cost of electricity from EGS for a stimulated volume of 7 billion cubic feet is about 5.5 US cents while this is expected to decrease by 2010 to below 5 US cents (Sanyal et al., 2007). The estimated shortage of about 100,000 MWe that India is facing can easily be plugged by tapping the huge enhanced geothermal resources available across the country. Considering the existing excellent power distribution network, the major expenditure involved in exploiting these sources would be the drilling cost.

High heat-generating granites, with heat producing capacity of 1.5 to 8.2 $\mu W/m^3$ are distributed throughout the Indian continent. Their high heat producing capacity resulted in high heat flow geothermal provinces with the recorded heat flow of 75 mW/m^2 to > 110 mW/m^2 (Rao et al, 1976, Menon et al., 2003, Roy and Rao, 2000). Resource base temperature estimate (Rowley, 1982) was carried out using the heat flow, thermal gradient, crustal density, specific heat, thermal conductivity and heat capacity of the granites at specific locations. The estimated temperature at 1.5 km depth is about 150 to 180°C and increases to > 210°C at 4 km depth. Besides their inherent capacity to generate heat due to high U (2-8 ppm), Th (16-88 ppm) and K content (Chandrasekharam et al., 2006), some of the younger granites like the leucogranites. located along the central and middle Himalayas, are generated at shallow depth due to anatectic melting (~ 5-7 km) above the subducting continental slab (Hochstein and Regenauer-Lieb, 1998, Makovsky and Klemperer, 1999). These leucogranites are the products of trans-Himalayan batholiths with mantle $^{87}Sr/^{86}Sr$ signature (Patterson and Windley 1995). These batholiths extend along the Himalayas, covering a length of about 2700 km with exposed width of about 60 km (Figure 2). The leucogranites of younger age (~5.3 Ma; Schneider et al., 1999 a,b, Searle, 1999 a,b, Le Fort and Rai, 1999, Harrison et al., 1998, 1999), also run parallel to the batholiths. The leucogranite exposures are found only at a few localities while a large part of it is buried, below a thick fore-arc basin sedimentary cover, in the form of lopoliths and sheets.

Thermal modeling suggests that cooling of leucogranite sheets of 2 km thickness will require about 200 ka (De Yoreo et al.,1989; Davidson et al., 1992, Harris et al., 2000). The melt, after generation, segregates in the magma chamber at about 5-7 km depth. These melts are generated due to intracrustal melting (Toksoz and Bird, 1977). A granite sheet of ~ 100m thickness, thus segregated, needs greater than 500 years to crystallize. The frequency of individual magmatic pulses, identified in the Manaslu region of the Himalayas, is on the order of 1 Ma. The melt segregation in the lower crust takes place due to dilatancy pumping initiated by subducting slab along the main central thrust system (Harris et al., 1995). The time scales required for melting, ascent and emplacement of granite magma is much shorter for orogenic granites, like the Himalayan leucogranites, compared to the same processes in non-orogenic regions. Shear-strain heat, dislocation creep, mantle convection and high radioactivity (U: 36 ppm; Th: 5 ppm; Schirer et al., 1986) are some of the processes responsible for high heat flow in this region(~70-180 mW/m^2 (Chandrasekharam, 2005) that are promoting generation of intracrustal melts.

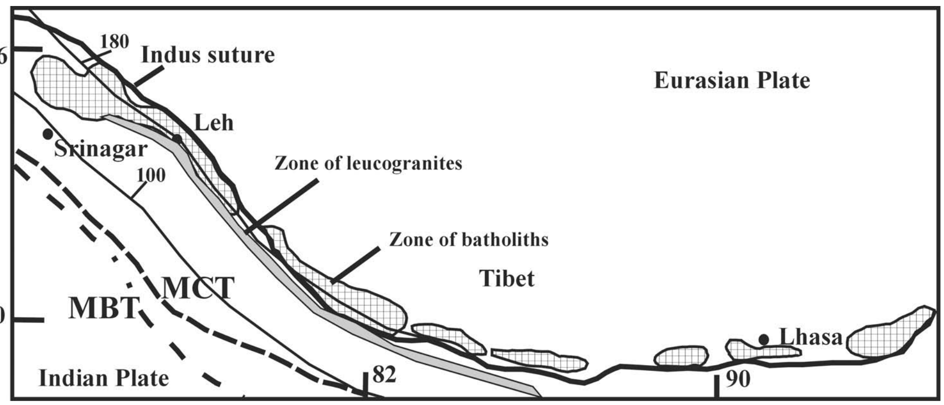

Figure. 2. Distribution of granite batholiths and leucogranites in the Himalayas. 100 and 180 represent heat flow contours (mW/m^2) (modified after Patterson and Windley, 1995). MBT: Main Boundary Thrust, MCT: Main Central Thrust.

Stress Distribution on the Granites

The granite masses in the central Indian and Himalayan regions are under the stress regime characterized by NNE-ENE oriented S_{Hmax} (Gowd and Srirama Rao, 1992). These stresses are induced on the granites due to the northward compression of the Indian plate together with the net resistive forces arising from the Himalayan collision zone. The tectonic forces acting on these granites are of the order of 7 x 10^{12}N/m. The S_{Hmax} in these provinces increases at the rate of 55 MPa/km while the global average is about 29 MPa/km (Gowd et al., 1996, Chandrasekharam et al., 2006). Such high horizontal stress regime on these high heat generating granites, with estimated resource base discussed above, appears to be excellent sites for initiating enhanced geothermal resource projects in the country. The Himalayan granite provinces alone should be able to generate power more than the demand projected for the next decade.

Conclusions

India has tremendous potential to offset carbon trade and reduce carbon dioxide emission by 2010 by exploiting its enhanced geothermal resources. While the central Indian EGS (Chandrasekharam et al., 2006) are ready for exploitation, future EGS technology should address the method of extracting such huge thermal resources from plate boundaries. Considering the future electric power demand and the past growth rate of electric power generation, coal-based thermal power plants alone may not be in a position to meet this demand. If the projected cost of electric power generated from enhanced geothermal systems is < 5 US cents (Sanyal, 2007), then with the huge human resources available in the country, India would be in a position to generate electric power half this cost by 2010 through EGS.

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