

Under the auspice of:  
Division of Earth Sciences

## Chapter 3.7

# HDR PROSPECTS OF HIMALAYA GEOTHERMAL PROVINCE

D.Chandrasekharam

Department of Earth Sciences, Indian Institute of Technology, Bombay, India.

### Abstract:

*A large data base on geological, geophysical and subsurface geological information on the wet hot rock geothermal provinces is now available to exploit this energy resource. Besides wet hot rocks, Himalaya Geothermal province has excellent hot dry rock sites for future exploration and exploitation. This province falls within the Indo-Tibet collision zone and sufficiently large plutons occur within this zone which can be exploited for future energy needs of the state. With participation of local government and investment from independent power producers, this energy source can developed to meet the energy demands of the hill rural population.*

### Introduction:

Nearly 70% of India's power production is based on thermal because of the availability of huge and inexpensive coal reserves. Excessive use of this source without the use of strategies to mitigate its effects will have deteriorating effect on the quality of human life in future. In another decade emission of CO<sub>2</sub>, SO<sub>2</sub> and Nx will exceed 1500 million tones, 1900 kilo tones and 1200 kilo tones respectively ( World Bank Report 1999). This means CO<sub>2</sub> emissions will be 775 million metric tones per year as

compared to 1000 million metric tones per year produced in the entire European Union! There is no doubt that the cost of electricity produced from coal is far less expensive compared with other fuels. The present day cost of one unit of power is less than US\$ 0.02 in the case of coal based power while liquid fuel based power costs about US\$ 0.04 per unit (Mehta, 1999) and hydro power costs about US\$ 0.03 (World Bank Report, 1999). But the expenditure spent to meet the consequences (like disposal of fly ash; treating the high ask coal etc) is high which automatically increases US\$ 0.02 a unit to little over 1 US\$. Now a time has come to look into those alternate energy sources which were not viable a decade ago due to non availabilities of technical know how. At present 1.5 percent of total power generation capacity comes from non-conventional energy sources like wind, solar and bio-mass (Table 1; Chandrasekharam, 2000a). In the next fifteen years, according to the world bank report (World Bank report, 1999), this energy supply could increase by seven times and above. India can not ignore its huge energy resource available from wet and hot dry rocks in future.

### Hot Dry Rock Province:

Out of the seven geothermal provinces, projects have been initiated to tap power from the wet hot rocks from one of the central geothermal provinces (Tattapani) and serious consideration is being given to tap this energy from other provinces. Besides wet rocks, Indian geothermal provinces have excellent sites to initiate hot dry rock projects.

The three important criteria a site should satisfy to be HDR prospect are a) a substantial mass of hot rock should be available at a reasonable depth, b) the region with such mass of hot rocks should be under compressional stresses and c) this hot rock should have a insulating cover above to sustain the heat generated by the radioactive decay of U and Th.. There is one such excellent province, the Himalaya geothermal province which satisfies all these conditions. This paper examines the geological, geophysical and tectonic aspects of this province.

Figure 1 shows all the sub-provinces in the Himalaya. These provinces lie parallel to the Indo-Asia collision zone (Main Central Thrust and Indo-Tibet Suture Zone). The entire geothermal province covers an area greater than 1500 sq.km. The heat flow value varies from 70 - >180 mW/m<sup>2</sup> (Fig. 2). The thermal waters issuing in this province record temperatures as high as 98 °C and some times are associated with high steam content (Chandraekharam, 2000 b). The geothermal gradient recorded from shallow bore-wells is greater than 100 °C/km. Such high heat flow and geothermal gradient are due to high radioactive elements present in the granites and also due to the presence of seismic bright spots (discussed below) in this region. The Himalaya geothermal province falls within the Asia-Indian plate collision zone and the main central thrust (MCT) passes through this geothermal province (Fig 1). Besides Precambrian and sedimentary formations related to the fore-arc basin, this provinces encloses a large number of granite intrusives (Fig. 3) which vary in age from 60 to 5.3 Ma (Schneider et al., 1999a,b; Searle, 1999a,b; Le Fort and Rai, 1999; Haris et al., 2000; Harrison et al.,

1998, 1999). These granites are exposed on the surface at several places and are covered by sedimentary formations at several places. These granites occur as lopoliths, sheets and dykes (leucogranites) which vary in thickness from a few meters to several kilometers. Permian Granites of 268 Ma also occur in the western Zanskar (Noble et al., 2001). International Deep Profiling of Tibet and the Himalayas (INDEPTH) project located seismic bright spots in Tibet region (east of the Indian Geothermal provinces) which are attributed to the presence of magmatic melts and or saline fluids within the crust (Makovsky and Klemperer, 1999). Highly saline fluids are also found in Ladakh granites (~60 Ma) as inclusions which are attributed to the high volatile content in the granitic melts (Sachan, 1996). Though INDEPTH investigation has not been carried out, considering the proximity of INDEPTH site in Tibet, probability of occurrence of such seismic bright spots within the Himalayan geothermal province is high. This inference gains strength from the 1 Ma anatexis process recognized in Nanga Parbat (Chichi granite massive) in Pakistan Himalayas (Schneider et al., 1999 c) and similar processes must be in operation on the eastern side of Nanga Parbat also. These evidences confirm that the present day observed high heat flow value (>100 mW/m<sup>2</sup>) and geothermal gradient is related to crustal melting process at shallow depth in this region.

Regional stress analysis based on earthquake focal mechanism, bore-hole blow-outs and hydrofracturing (Gowd et al.,1992) indicates that the entire Himalayan belt in general and the Himalayan geothermal province in particular, is under compressive stress regime due to the northward movement of the Indian plate and net resistive forces at the Himalayan collision zone. Thus the central and northern India including Nepal, the Great Himalayas and Pakistan fall under this stress province characterized by NNE-ENE oriented  $S_{Hmax}$  (Fig.4). Investigation carried out around Zanskar (north of Kulu, in the Himalayan Geothermal province) by Pierre Dèzes (1999) also shows compressive regime in this region (Fig.5). Com-

pressional stress regime is favourable to create several sub-horizontal reservoirs in granites by hydrofracturing, interconnected by boreholes ( Baria et al., 1999; Wyborn 2001).

The entire subduction tectonic regime along the Himalayan geothermal province appears to be similar to Hijiori and Kansai provinces in Japan where HDR prospect is being evaluated. International HDR feasibility study can be initiated in this region with Local Himachal Pradesh Govt. support and support from the independent power producers.

With the present trend of globalization, incentives given to non-conventional energy power producers, problems in establishing power grid in the hilly terrains of Himalayas and environmental problems associated with coal based power projects, the future of HDR prospects in this geothermal province is very promising.

#### **Reference:**

- Baria, R., Baumgartner, J., Rummel, F., Pine, R.J. and Sato, Y. 1999. HDR/HWR reservoirs: concepts, understanding and creation. *Geothermics*, 28, 533-552
- Chandrasekharam, D. 2000a. Geothermal energy resources of India- Opportunities for IPPs. *Proceed. Geothermal Power Asia 2000 Conference, Manila, Philippines. February, 2000.* 10p
- Chandrasekharam, D. 2000b. Geothermal energy resources of India- Country update. *Proceedings, World Geothermal Congress 2000, Japan.* (Edts) E. Iglesias, D. Blackwell, T.Hunt, J.Lund, S.Tamanyu and K. Kimbara. pp- 133-145.
- Gowd, T.N. and Srirama Rao, S.V. 1992. Tectonic Stress Field in the Indian Subcontinent. *J.Geophy.Res.*, 97, 11,879-11,888.
- Haris, N., Vance, D. and Ayres, M. 2000. From sediment to granite: timescales of anatexis in the upper crust. *Chem. Geol.*, 162. 155-167.
- Harrison, T.M., Groove, M., Lovera, O.M. and Catlos, E.J.1998. A model for the origin of Himalayan anatexis and inverted metamorphism. *J.Geophy. Res.*, 103, 27,017-27,032.
- Harrison, T.M., Grove, M., McKeegan, K.D., Coath, C.D., Lovera, O.M. and Le Fort, P. 1999. Origin and episodic emplacement of the Manaslu intrusive complex, Central Himalayas. *J.Petrol.*, 40, 3-19.
- Le Fort, P. and Rai, S.M. 1999. Pre-Tertiary felsic magmatism of the Nepal Himalaya: recycling of continental crust. *J. Asian Earth Sci.*, 17, 607-628.
- Makovsky, Y. and Klemperer, S.L. 1999. Measuring the seismic properties of Tibetan bright spots: Evidence of free aqueous fluids in the Tibetan middle crust. *J.Geophy. Res.*, 104, 10,795-10,825.
- Mehta, A.1999. Power Play, A study of the Enron Project. *Orient Longman Pub. Com.*, New Delhi. 226 p
- Noble, S.R., Searle, M.p. and Walker, C.B. 2001. Age and tectonic significance of Permian granites in Western Zaskar, High Himalaya. *J.Geology*, 109, 127-135.
- Pierre Dèzes.1999. Tectonic and metamorphic Evolution of the Central Himalayan Domain in Southeast Zaskar (Kashmir, India)". Ph.D. Thesis. Université de Lausanne, Switzerland.
- Sachan, H.K. 1996. Cooling history of subduction related granite from the Indus Suture zone, Ladakh, India: evidence from fluid inclusions. *Lithos*, 38, 81-92.
- Schneider, D.A., Edwards, M.A., Zeitler, P.K. and Coath, C.D. 1999a. Mazeno Pass pluton and Jutial pluton, Pakistan Himalaya: age and implications for entrapment mechanism of two granites in Himalayas. *Con. Min.Pet.*, 136, 273-284.
- Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Asif Khan, M., Seeber, L. and Zeitler, P.K. 1999 b. Tectonics of Nanga Parbat, western Himalaya: Synkinematic plutonism within the doubly vergent shear zones of a crustal - scale pop-up structure. *Geology*, 27, 999-1002.
- Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Zeitler, P.K. and Coath, C.D. 1999 c. Early Miocene anatexis identified in the western syntaxis, Pakistan Himalaya. *Earth. Planet. Sci. Lett.*, 167, 121-129.
- Searle, M.P. 1999a. Extensional and compressional faults in the Everest massif, Khumbu Himalayas. *J. Geol. Soc. London*, 156, 227-240.
- Searle, M.P. 1999 b. Emplacement of Himalayan leucogranites by magma injection along giant complexes: examples from the Cho Oyu, Gyachung Kang and Everest leucogranites (Nepal Himalaya). *J. Asian Earth Sci.*, 17, 773-783.

World Bank Report 1999. Meeting India's future power needs: Planning for environment-

tally sustainable development, The World Bank, Washington DC, USA. 28 p  
Wyborn, D. 2001. Personal communication.

Table 1. Power production status of non-conventional energy in India

Renewable Power	Potential	Achieved
Wind Power	20,000 MW	1,000 MW
Small Hydro Power	10,000 MW	172 MW
Biomass	20,000 MW	141 MW
Solar photo-voltic Power	20 MW/sq.km	810 KW

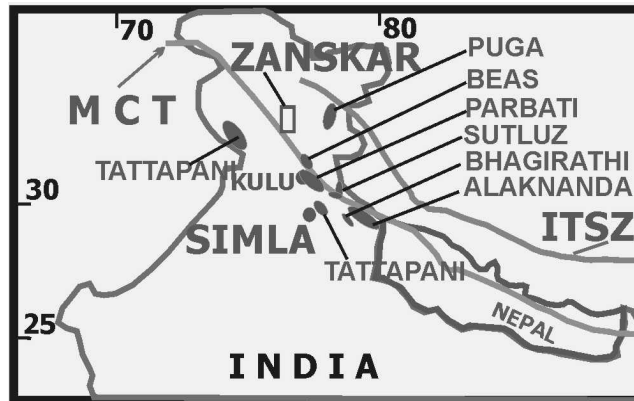


Figure 1. Geothermal Sub-provinces of Himalaya. MCT: Main Central Thrust; ITSZ: Indo-Tibet Suture Zone.

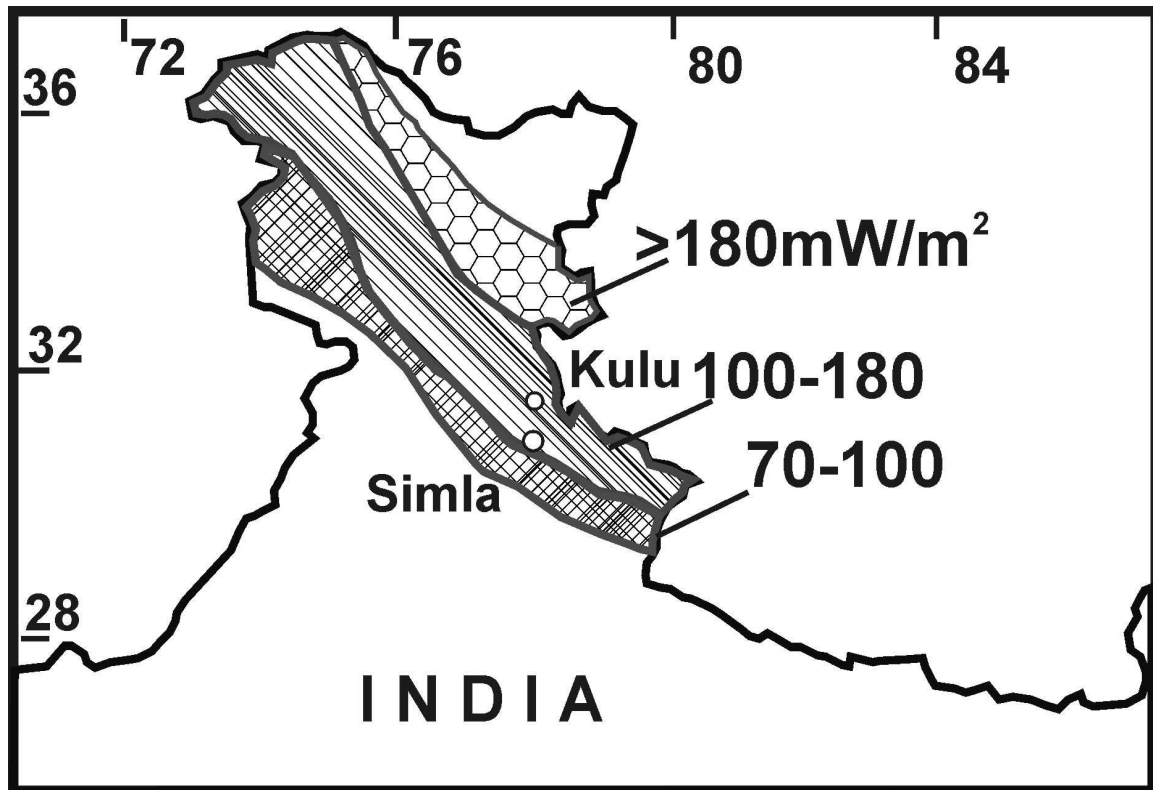


Figure 2. Heat Flow zones of Himalaya geothermal province.

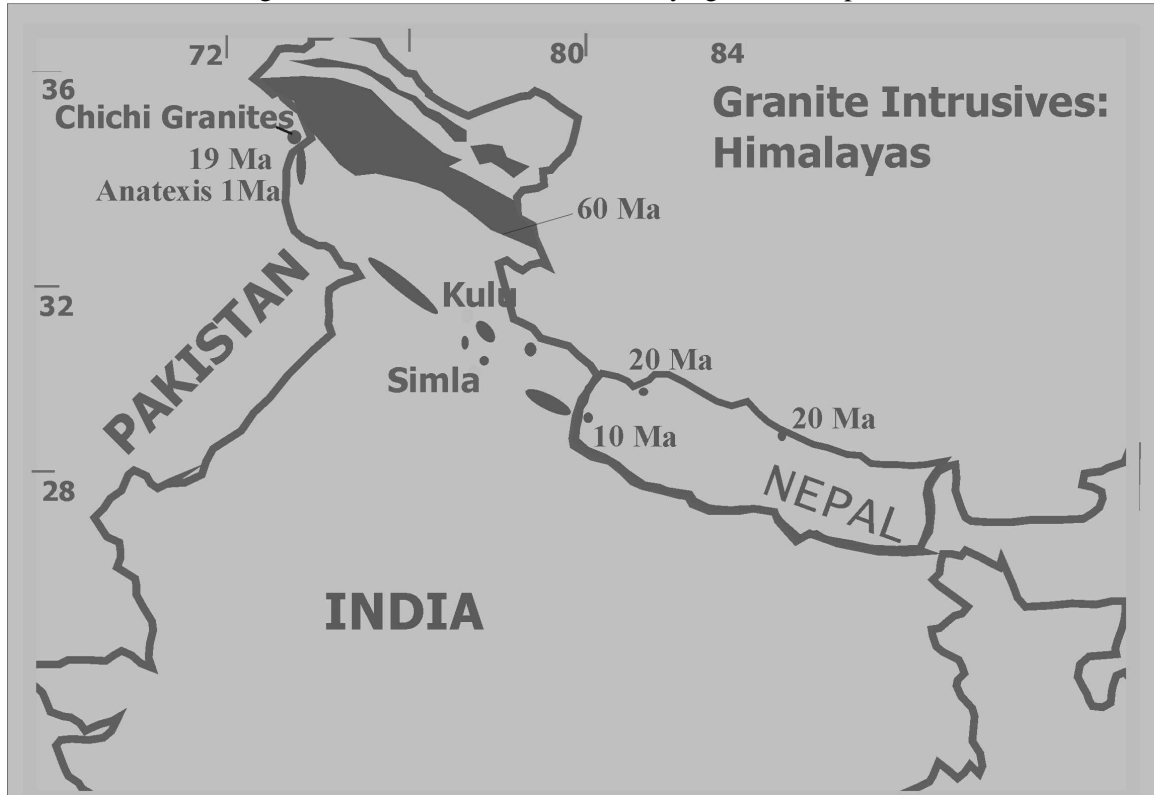


Figure 3. Granite intrusives (with ages) of Himalaya geothermal Province.

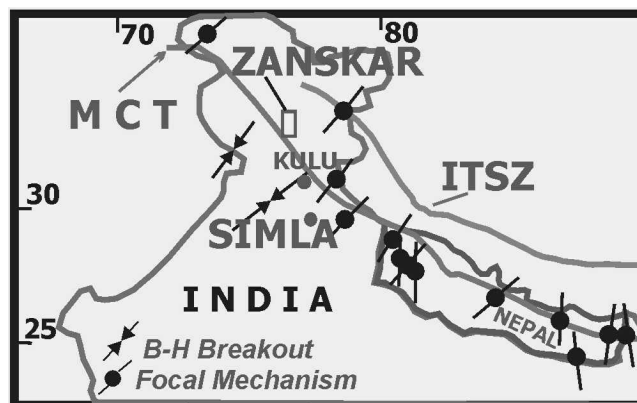


Figure 4. Stress field distribution in the Himalaya geothermal province.

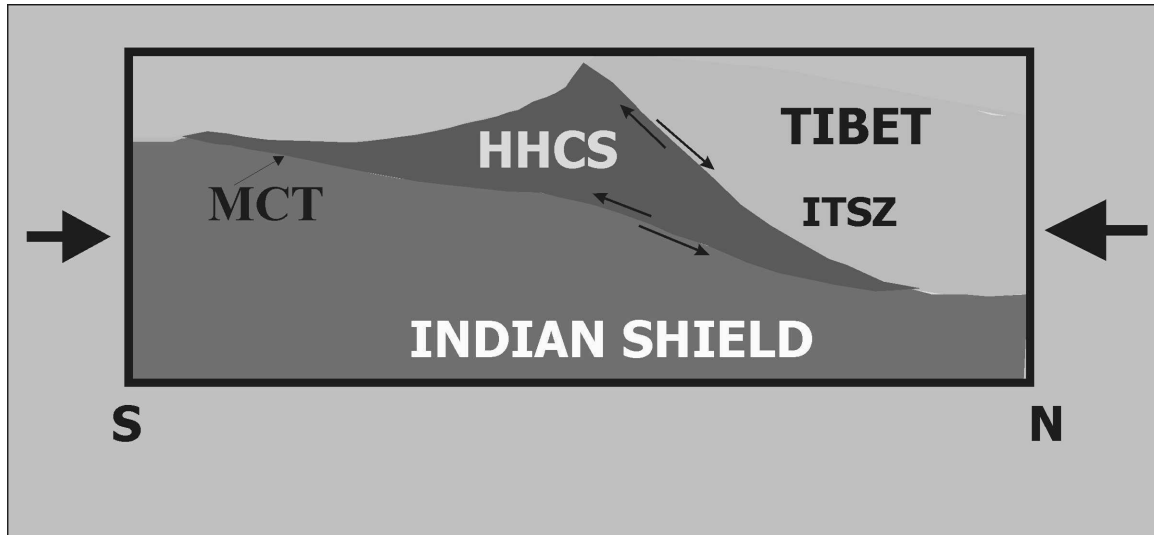


Figure 5. Cross section of Indo-Tibet Thrust Zone (at Zaskar). HHCS: High Himalaya Central Suture.

