Earths Heat as an Energy Source

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INTRODUCTION

Energy is an important component for development. Better health, clean water, transportation, production of fertilizers and food, creation of jobs and social development all depend on energy. In the case of Sri Lanka major sources of energy* are bio mass (70%), hydropotential (10%) and imported forsil fuel (20%). However note that sun in responsible for the production of both bio mass and hydropotential. Biomass is used mostly by the domestic sector and by industries such as tea, tile, brick and bakeries. Fossil fuel is consumed by the transport sector and is also used to generate electric power during prolonged droughts. It is expected that by the year 2000 Sri Lanka's major, reliable and indigenous energy source - hydropotential - would have been completely exploited. Other indigenous, environmentally accepted energy sources for exploitation are solar, geothermal, wave, wind, ocean thermal and biomass. Ocean thermal energy conversion (OTEC) in the deep waters (eg. Trincomalee harbour) are not favoured due to the still prevailing technological inadequacies and uncertainties of the life-time of an OTEC plant. A few experimental stations exist but there is no commercialization of this method. Small scale wave energy plants are considered to be suitable for isolated communities and again there are no commercialized wave energy plants. Based on present technology solar thermal for purposes other than power generation and scientifically managed dendro power can save on fossil fuel based energy for Sri Lanka. Presently uninterrupted solar thermal power production is difficult in the tropics due to frequent cloud-cover as compared to desert regions. Solar electricity by photo-voltaic panels are suitable for small scale applications, but the cost per kilowatt generated is prohibitively high for extensive use. Wind power generation is possible where there is sufficient wind. Wind energy farms are now available in many parts of the world and feed electrical energy to their national grid. Limitations similar to exploitation of solar energy apply to wind energy in Sri Lanka. Sri Lanka's total wind potential is not known. It should however be noted that small scale wind mills for mechanical and electric power are suitable for irrigation and village industries in Sri Lanka. In contrast, geothermal energy where available gives an uninterrupted supply. Presently the earth is still cooling form its initial molten state as well as heat is generated within by the decay of long lived radioacline material (Table 1). Where the outflow is the most volcanoes occur. Heat energy available in volcanic region are a large source of geothermal energy. In such areas bore holes drilled into few hundred meters can bring out steam that can be used for electricity generation and also provide heat energy for industrial and domestic use. In other regions thermal waters are available that can be used for electrical power generation in small quantities and for certain agro based industries and tourist hotels. Another method of utilizing geothermal energy is to use the heat of a hot dry rock (HDR) formed by a recently formed granite.

Heat flow from the earths interior

The high heat flow regions of the earth are now well known. They are also the locations of high earthquake and volcanic activity. Our present knowledge indicate that the earth's surface can be divided into a number of movable plates (FIgure1). Earthquake activity is predonminant along the margins of these plates.

Table 1

. Heat from Radioactive Decay (Adapted from Bullard, 1973)

Isotope	Heat Generated (cal/g/yr)	Half Life (10^9 yr)	Reaction
U^{238}	0.70	4.50	$U \rightarrow Pb^{206}$
Th^{232}	0.20	13.9	
K^{40}	0.21	1.31	$K \rightarrow$ or Ca^{40} / A^{40}
$K_{ordinary}$	27×10^{-6}	—	
U^{233}	4.3	—	
$U_{ordinary}$	0.73	—	
U^{235}	0.03	0.71	

. Heat Production in Common Rocks (Adapted from Bullard, 1973)

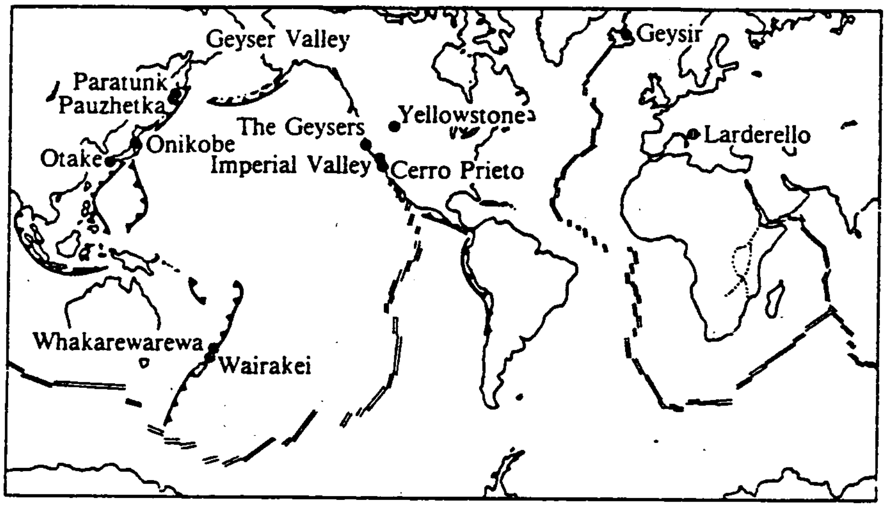
Rock Type	Concentration of Elements			Heat Production (μcal/g/yr)			
	U ppm	Th ppm	K %	U	Th	K	Total
Granite	4.7	20	3.4	3.4	4.0	0.9	8.3
Basalt	0.6	2.7	0.8	0.44	0.54	0.23	1.21
Peridotite	0.016	0.004	0.0012	0.0012	0.001	0.0003	0.013

. Heat Production in Different Layers of the Earth (From Stacey, 1969)

	Total Heat Production for Complete Spherical Shell (ergs/s × 10^{19})	Radioactive Production per Unit Volume	Mean Density (g/cm³)	Heat Production per Unit Mass (ergs/g/yr)
Continental				
Crust	20	200	2.7	104
Upper Mantle	8	8	3.35	3.34
Lower Mantle	3	1	5.15	0.27
Oceanic				
Upper Mantle	28	28	3.35	11.6
Lower Mantle	3	1	5.15	0.27

1 Calorie = 4.2 Joules

10^7 ergs = 1 Joule



Map showing features of tectonic plates and geothermal areas.

Fig. 1

The convection currents generated in the earth's mantle by the internal heat moves these plates like those on a conveyer belt. Where the convection current rise (mantle upwelling) are the places of high heat flow and where the convection currents go down, the plates collide and sometimes are sucked back (subducted) to the earth's interior (Figure 2a, 2b).

Where mantle upwelling occur the plates spread out creating fresh earth surface.

There are certain region of the earth where molten rock material (magma) from the mantle are intruded to the earths crust. Such intrusive rock that are geologically recent keep themselves hot by the heat generated from the radioactive decay of long living radio isotopes. Such rock are popularly known as hot dry rock (HDR) and is a source of geothermal energy.

Another source of geothermal energy is hot water in porous rock formations. The water is hot either because it is near a volcanic region or near a HDR or by heating under the normal temperature gradient of the earth (figure 3) which provide a outward heat flow rate of about 6 mw/m^2. Hot springs like those in Sri Lanka (eg. Kinniya at Trincomalie; Mahaoya, Mahapelessa at Sooriyawewa) are manifestations of the earths heat flow. Water entering the deep fracture zones in mountain regions transport water to great depths where it get heated. Water can come out again from another fracture path by artesian action to give rise to thermal springs. Hot water can exist in large quantities within fracture zones and in porous rock formations.

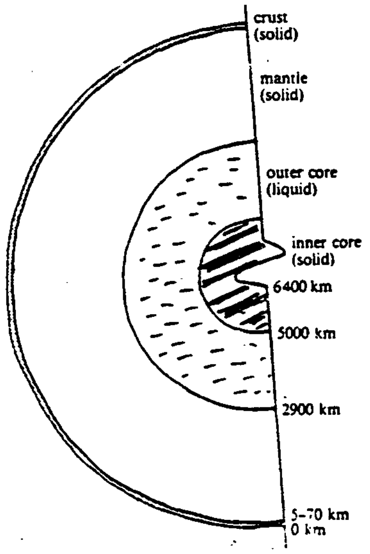
Important factors for an economic geothermal source

The economical value of a geothermal field varies according to the geothermal source. Magma associated sources are referred to as high heat sources. Their temperatures are greater than 600^{0}C. Medium and low heat and low temperature fields are associated in deep sedimentary or metamorphic rocks that are heated by normal (30^{0}C/Km world average) or slightly above normal temperature gradient of the earth.

A major component of a geothermal field is the fluids that bring the heat from the interior to the surface through a low thermally conducting intermediate region. For an economical field these fluids must be available in abundance. Therefore porosity and permeability of a reservoir are vital factors that decide the production potential of a heat reservoir. In the case of a H.D.R intrusive body, the rock may need artificial hydrofracturing unless natural fractures exist. Water is injected at an injection well and steam recovered at a production well further away. H.D.R geothermal system with depths greater than about 4 km can be uneconomical due to high cost of drilling and pumping.

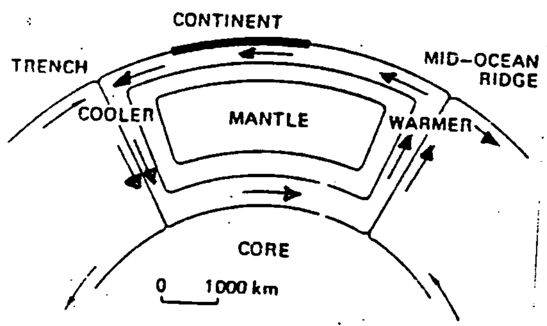
Geologic Features of the Earth

2a



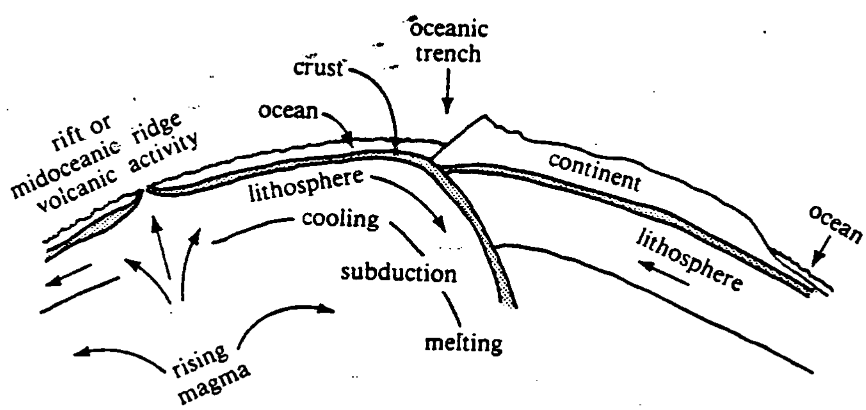
Cross section of the earth showing layering.

2b



Mantle-wide convection with resulting sea-floor spreading and continental drift as envisaged by Hess.

2c



A model of the crust and mantle of the earth showing movements of the plates and lithosphere, and thermal convection of the viscous mass beneath.

Fig 2.

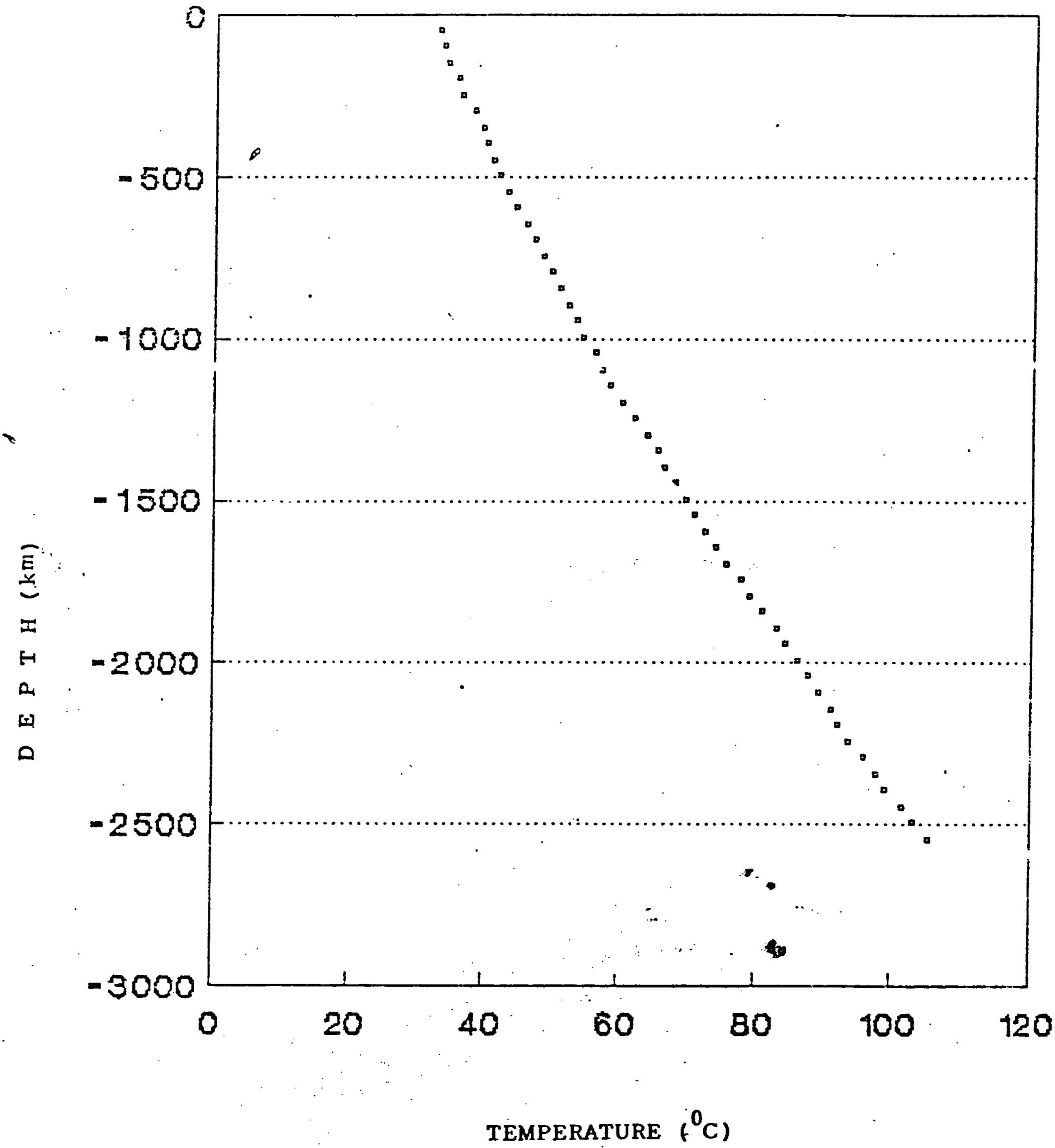


Figure 3 : DEPTH-TEMPERATURE PLOT IN MANNAR ISLAND, NOTHERN, SRI-LANKA (courtesy Ceylon Petrolium Corporation).

Another component of importance in a geothermal field is the cap-rock of sufficiently low thermal conductivity (table 2) to keep the interior heat of the reservoir with minimal dissipation to the surface. For this purpose the cap rock need to be impermeable preventing thermal fluids from escaping.

Table 2. Thermal Conductivity of Rocks

Rocks	K (cal/cm·s × 10^{-3})
Chalk	2.2
Schist	2 to 4
Limestone	5 to 7
Igneous rocks	6
Marble	7.5
Granite	8
Rhyolite	8
Dolomite	10
Dunite	12
Rock salt	13
Quartzite	16

Environmental factors

Just as environmental problems are associated with energy production from coal, oil, etc, geothermal energy exploitation has its own environmental problems. But they can be minimised or can be avoided in some cases.

Hot water brought to the surface in large quantities can bring out hamful gases H_2S, SO_2, and fluids (eg containing arsenic) etc. However it is found that in many occassions the fluids that are brought up can again be recirculated back into earth.

In the case of HDR we will have to inject water at the injection well and recovered at the production weel. The process can at time consume a large amount of water as some injected water is never recovered.

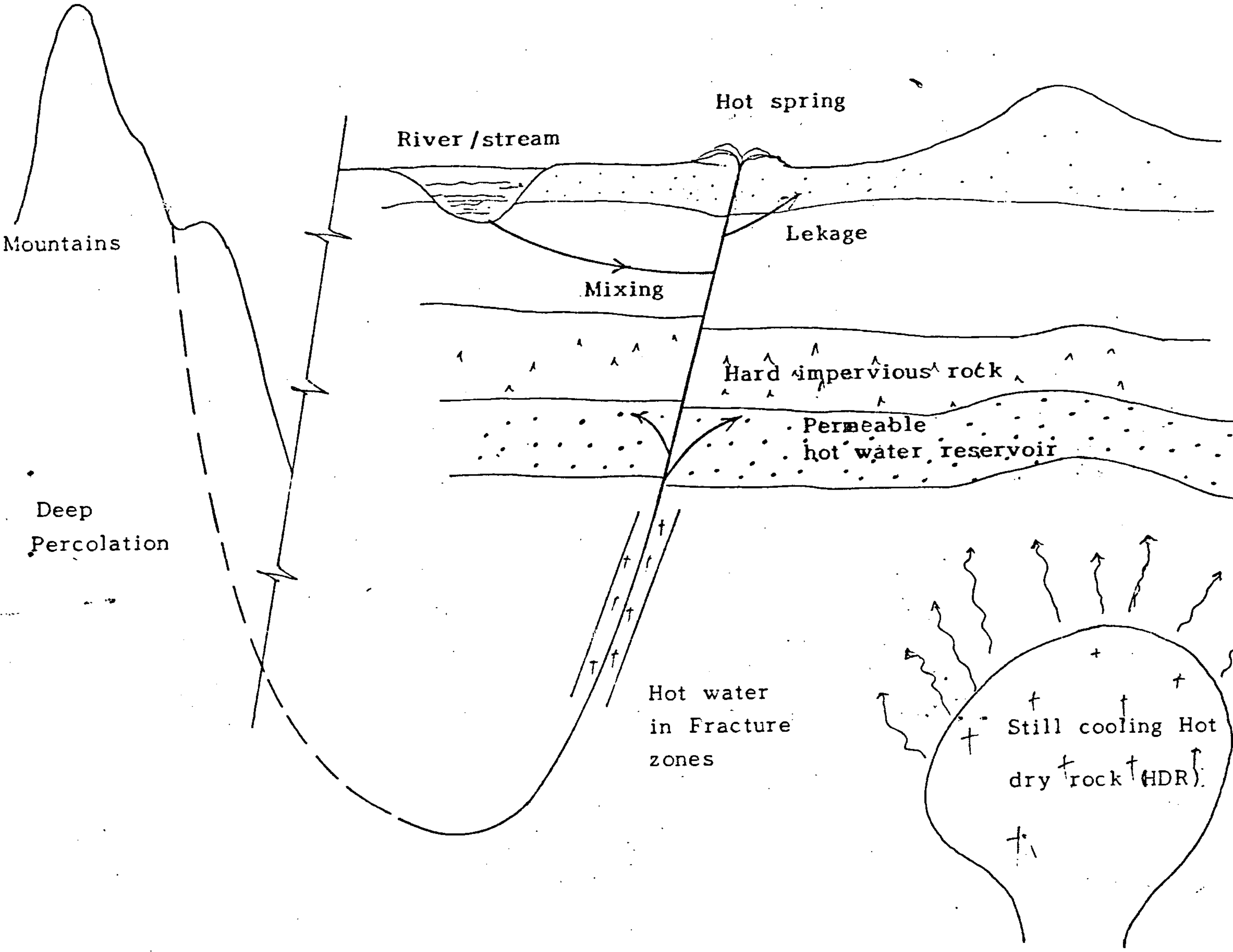


Figure 4

A MODEL FOR GEOTHERMAL SYSTEMS IN SRI LANKA

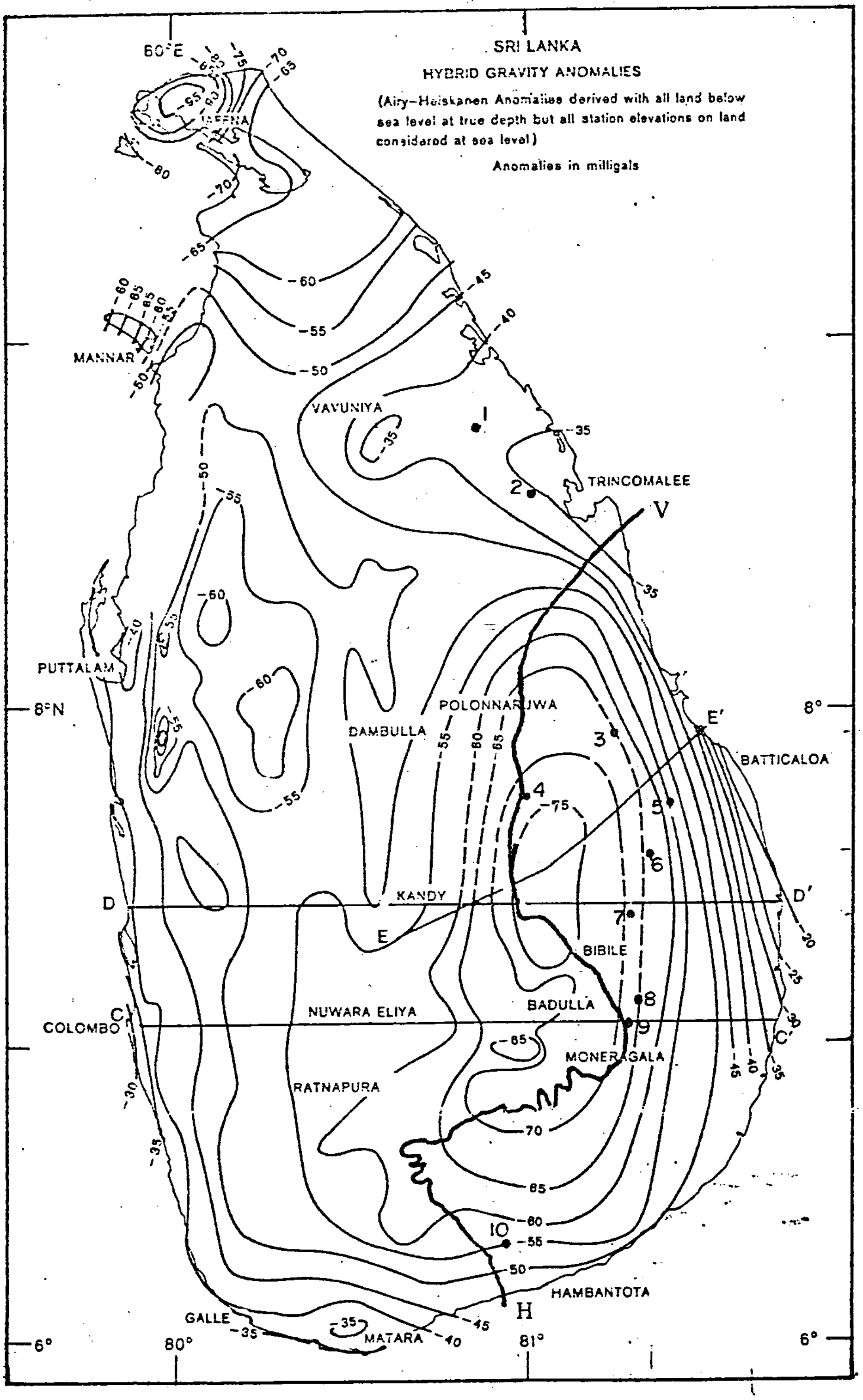


Figure 5 : The hybrid gravity anomalies* and the location of thermal springs. The heavy line (HV) indicates the Highland-Vijayan boundary. Hot Springs : 1. Rankiri Ulpota 2. Kanniyai, 3. Nelum wewa (former Madawewa) 4. Mutugalwela 5. Kapurella 6. Maha Oya 7. Marangalawahawa 8. Embilline 9. Jayanthi Wewa (Pallan Oya) 10. Mahapelessa.

(* Courtesy Geological Survey of Sri Lanka. Airy-Heiskaren anomalies derived with all land below sea level at true depth but all station elevations on land considered at sea level).