

HEAT FLOW AND HEAT GENERATION IN GREENSTONE BELTS; Malcolm J. Drury, Earth Physics Branch, Energy, Mines and Resources Canada, 1 Observatory Crescent, Ottawa, Ontario, K1A 0Y3 Canada

Heat flow has been measured in Precambrian shields in both greenstone belts and crystalline terrains. Values are generally low, reflecting the great age and tectonic stability of the shields; they range typically between 30 and 50 mW/m², although extreme values of 18 and 79 mW/m² have been reported (1,2). For large areas of the earth's surface that are presumed to have been subjected to a common thermotectonic event, plots of heat flow against heat generation appear to be linear (3,4), although there may be considerable scatter in the data. The relationship is expressed as:

$$Q = Q_0 + D A_0 \quad [1]$$

in which Q is the observed heat flow, A_0 is the measured heat generation at the surface, Q_0 is the "reduced" heat flow from the lower crust and mantle, and D , which has the dimension of length, represents a scale depth for the distribution of radiogenic elements. Most authors have not used data from greenstone belts in attempting to define the relationship within shields, considering them unrepresentative and preferring to use data from relatively homogeneous crystalline rocks, e.g. (5).

The heat generated by radioactive decay is expected to be less in basic than in acidic rocks because of their different chemistry. Hence we would expect heat flow in greenstone belts to be lower than that in adjoining crystalline areas if the greenstones are thick, but to be similar if the belts are merely superficial. Table 1 is a compilation of data from seven Precambrian shields. Only those data specifically identified as being from greenstone belts, or those for which geological descriptions are unambiguous, are used in column 2. There is the possibility that some of the data identified as being from crystalline areas are in fact from greenstone belts.

Table 1. Compilation of heat flow data for Precambrian shields, listed according to geological setting. The ratio in column 4 is that of the mean heat flow in the greenstone belts to that in crystalline areas of the shield.

Shield	Mean and 1 s.d. heat flow (mW/m ²)			Ratio
	All sites	Greenstones	Crystalline	
Canadian ^a	42±8 (22)	39±5 (8)	43±10 (14)	0.91
Canadian ^b	43±10 (10)	40±9 (6)	48±11 (4)	0.83
Baltic ^c	40±6 (26)	41±6 (4)	40±6 (22)	1.03
W. African ^d	36±12 (19)	35 (1)	38±11 (18)	0.92
Indian ^e	64±15 (6)	44 (1)	68±12 (5)	0.65
Australian ^f	40±8 (16)	38±8 (8)	42±8 (8)	0.90
Brazilian ^g	52±11 (12)	51±18 (2)	52±10 (10)	0.98

^a Superior province, reference 6 with additional data not yet published;

^b Churchill province, 1; ^c 5,7,8,9,10,11; ^d 12; ^e 2; ^f 13, 14, 15; ^g 16. * - heat flow values adjusted for glaciation effects.

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Although it appears from column 4 of Table 1 that mean heat flow in greenstone belts is indeed lower than that in crystalline areas of the shields, there is, in all shields except one, considerable overlap of the two values. The exception is the Indian Shield, but there is only one value from a greenstone belt for that. Further, in most cases no statistical significance can be inferred as there are fewer data for greenstone belts than for crystalline areas. Taking the mean values, the heat flow from crystalline areas is apparently approximately 10% higher than that from greenstone belts.

Not all heat flow data used for compiling Table 1 had associated heat generation data. The most complete set is for the Canadian shield (Superior and Churchill provinces). Linear least squares regression for those data yields:

	Q_0 (mW/m ²)	D km	r	Q^* (mW/m ²)	A^* (μ W/m ³)	n
Greenstone belts	33±4	7±6	0.45	37±7	0.51±0.46	7
Crystalline areas	26±6	12±4	0.67	40±9	1.16±0.51	11

where n is the number of data pairs, r is the correlation coefficient, Q^* is the mean heat flow and A^* is the mean heat generation of borehole samples. The correlations are low and statistically the differences between the parameters for the two crustal types are insignificant. However, assuming that radiogenic elements are distributed uniformly with depth to D, the value of D for the greenstones suggests that they are approximately 7 km thick, a value compatible with those cited by Condie (17). The data also suggest that the heat flow - heat generation relationship for the greenstones could be written as

$$Q = Q_0 = (D_c - D_g)A_c + D_g A_g \quad [2]$$

in which subscripts g and c refer to greenstone and crystalline crust and Q_0 is the reduced heat flow for the crystalline crust. This can be seen by inserting appropriate values for greenstones and crystalline terrain into equation [2]. It implies that the greenstones are underlain by normal crystalline crust, including 5 km of upper crust, but that they are not allochthonous, replacing 7 km of that crust rather than simply overlying it.

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