approximation, and exact determination will require further analysis. Interestingly, when treated with acridine orange, the Nl_{10} strain lost all the three covalently closed circular DNA bands. Acridine orange-mediated curing of plasmids is evident from the loss of plasmid bands of treated strain (Figure 1, lane 2) but the loss of UV resistance character raises the question whether this trait is plasmid-borne. Although extant information on cyanobacterial plasmids indicates that they are cryptic, the change observed by us seems to indicate that plasmids may possibly have a role to play in UV resistance in *N. linckia*.

Acridines have been employed to cure or disinfect bacterial cells carrying sex factor or other episomes in an autonomous state in the cytoplasm and also to distinguish between their autonomous state, in which they are susceptible to curing by acridines, and the integrated state, in which they are not affected by acridines[12]. The loss of UV resistance seems to be due to loss of a particular class of plasmid, harbouring genes for UV resistance.

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RESEARCH COMMUNICATIONS

Magnetic properties in granulites of South India: implications for crustal magnetization

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The magnetic properties of 220 metamorphic rocks from South Indian granulite terrain, and representing the now exposed deeper levels of the Archaean crust show that multidomain magnetite is the dominant magnetic phase responsible for regional magnetic anomalies from deep crustal sources. The low Koegnisberger ratios (Q), with a mean value of 0.37 in rocks with higher order susceptibilities, indicate that the contribution of natural remanent magnetization for regional magnetic anomalies is not very significant. The total magnetization (induced + remanence) obtained in the most magnetic rocks varied between 1800 and 4130×10^{-6} emu/cc, suggesting an initial estimate of 3000×10^{-6} emu/cc for the total magnetization of the deeper crustal levels of South Indian granulite terrain.

THE most straightforward method to infer about deep crustal magnetization is to study the magnetic properties of the now exposed deeper crustal sections. Some of the recent investigations on the crustal evolution of South Indian granulite terrain[1-5] suggest that it can be considered to represent the exposed deeper levels of the Archaean crust. P/T studies indicate burial depths of 25–30 km at the time of granulite facies metamorphism for the northern parts of Noyil–Cauvery shear zone[6,7]. The medium to low pressure granulites south of Noyil–Cauvery shear zone represent higher crustal levels characterized by significantly higher geothermal gradients demonstrating large scale variations of P/T conditions[8]. The magnetic properties for 220 rocks of deeper crustal origin obtained in the present study would be very important in the interpretation of regional magnetic anomalies. A regional aeromagnetic anomaly map of South India between 12°N and 8°N latitudes was prepared by Reddy *et al.*[9] as part of the National Aeromagnetic Survey.

The sample locations and the generalized geology of South Indian granulite terrain are given in Figure 1. The samples comprise mostly of charnockites, gneisses, khondalites and amphibolites. From each sample, one core of 2.6 cm diameter and 2.1 cm length is cut for low field susceptibility and natural remanent magnetization (NRM) measurements, and one core of 2.6 diameter and 0.5 thickness was cut for highfield hysteresis and saturation magnetization studies. The initial susceptibility was measured in a field of 1 Oe at room temperature, at liquid nitrogen temperature (−196°C) and at about −150°C, and the saturation magnetization and hysteresis loops were studied at room temperature in a peak field of 3000 Oe using the equipment described earlier[10,11]. The NRM was measured using a

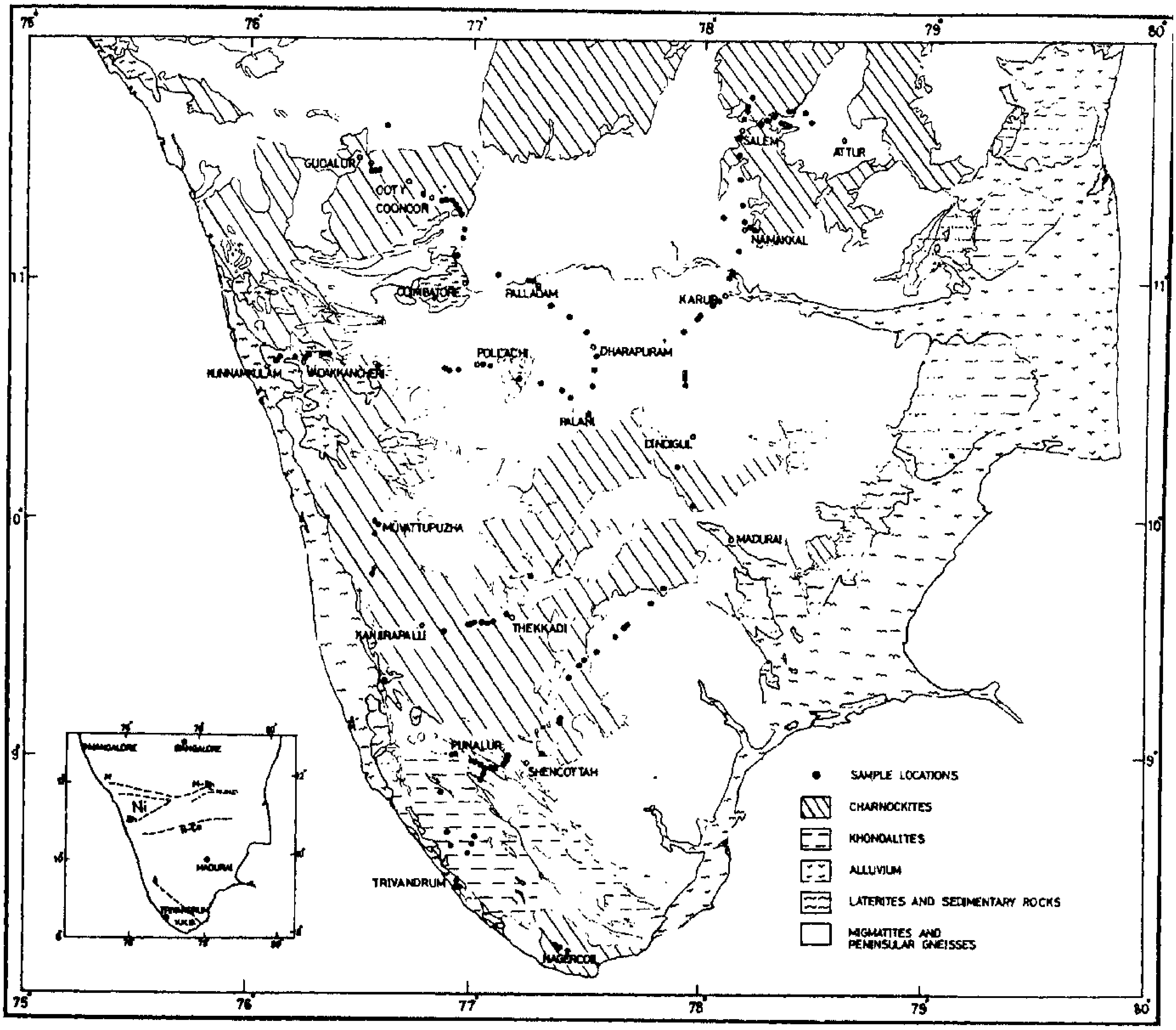

Figure 1. Sample locations and generalized geology of South Indian granulite terrain. N–Ca in inset is Noyil–Cauvery shear zone. Geology taken from a map compiled by Vasundhara Project group of AMSE, Geological Survey of India, Bangalore.

Molespin slow speed spinner magnetometer.

The results of the magnetic properties measured in 220 metamorphic rocks are summarized in Table 1. The rocks are divided into two groups based on distinct magnetic properties and petrography.

Figure 2 shows the susceptibility variations at room and low temperatures for group I and group II rocks. Figure 3 shows the hysteresis loops at room temperature in some typical group II samples with high susceptibilities. The susceptibility peak at $-150°C$; low Jrs/Js values (<0.05), low coercive force (Hc <50 Oe) and low Koegnisberger ratio (mean $Q=0.5$) and petrography show that multidomain magnetite is the dominant magnetic phase in group II rocks with medium to high susceptibilities. Though Haggerty[12] and Haggerty and Toft[13] considered a source mineral other than magnetite to account for origins of deep crustal magnetic anomalies, the observed multidomain magnetite phase in rocks with high susceptibilities show that multidomain magnetite could only be the dominant magnetic phase in the deeper crustal levels of the granulite terrain. Similar results are obtained in other study areas by Schlinger[14] and Shive and Fountain[15].

For the interpretation of long wavelength anomalies from deep crustal sources, reasonable estimates of lower crustal magnetization should range from 3000 to 6000 $\times 10^{-6}$ emu/cc and among the few investigations reported to date on the magnetic properties of exposed lower crustal sections[15,16], only Schlinger[14] obtained such high magnetizations. Williams *et al.*[16] considered a strong viscous remanent magnetization (VRM) directed parallel to the present field as a possible source to

Table 1. Magnetic properties of 220 metamorphic rocks from South Indian granulite terrain.

Physical property	Group I	Group II
Rock type	Mostly charnockites, gneisses, khondalites and amphibolites	Mostly charnockites and gneisses
Number of samples	99	124
Magnetic mineralogy (30 samples)	Predominantly among ilmenite or haematite with minor sulphides	Predominantly magnetite with varying proportions of ilmenite and minor sulphides
Metamorphic conditions	Many of the rocks suffered retrograde metamorphism during which magnetite is consumed	Different degrees of prograde metamorphism to granulite facies. Some rocks could have suffered retrograde metamorphism resulting in partial loss of magnetite
Initial susceptibility in field of 1 Oe (k)	Low. Varied between 6 and 200×10^{-6} emu/cc Oe	Medium to high. Varied between 200 and 4420×10^{-6} emu/cc Oe
Susceptibility variations at low temperatures in a field of 1 Oe	The susceptibility monotonously increased from room temperature down to liquid nitrogen temperature. $k(-196)/k(25)$ varied from 1.6 to 4.0 in most of the samples	The susceptibility decreased at −196°C and then showed a peak at −150°C, which is the isotropic point of magnetite. $k(-196)/k(25)$ generally varied between 0.2 and 0.6, while $k(-150)/k(25)$ varied from 1.1 to 1.35
High field (3000 Oe) characteristics at room temperature	Thin hysteresis loops with low saturation magnetization (Js) values generally varying between 0.06 and 0.6 emu/cc	Thin hysteresis loops with high saturation magnetization values, generally varying between 1 and 16 emu/cc
Domain state	Susceptibility increase at low temperatures could be due to the formation of very fine particles during alteration, which exhibit superparamagnetism even at or below liquid nitrogen temperatures. In such case, the presence of SD and multidomain states cannot be inferred	The susceptibility peak at −150°C, thin hysteresis loops with low coercive force and Jrs/Js ratio (<0.05), low Q ratios (mean 0.5), and petrography indicate that multidomain magnetite is the dominant magnetic phase
Natural remanent magnetization (Jn)	Low Jn values, generally varying between 3 and 200×10^{-6} emu/cc	High Jn values, generally varying between 100 and 2000×10^{-6} emu/cc
Koegnisberger ratio ($Q = Jn/kH$)	High. Generally varied between 1 and 30. NRM could be a significant contributor to net magnetization depending on stability and consistency in directions.	Low. Generally varied between 0.2 and 1.0 with an average of 0.5 if a few extreme values in 6 samples, which could be due to thunderbolt effects, are disregarded. NRM is not a major contributor to net magnetization.

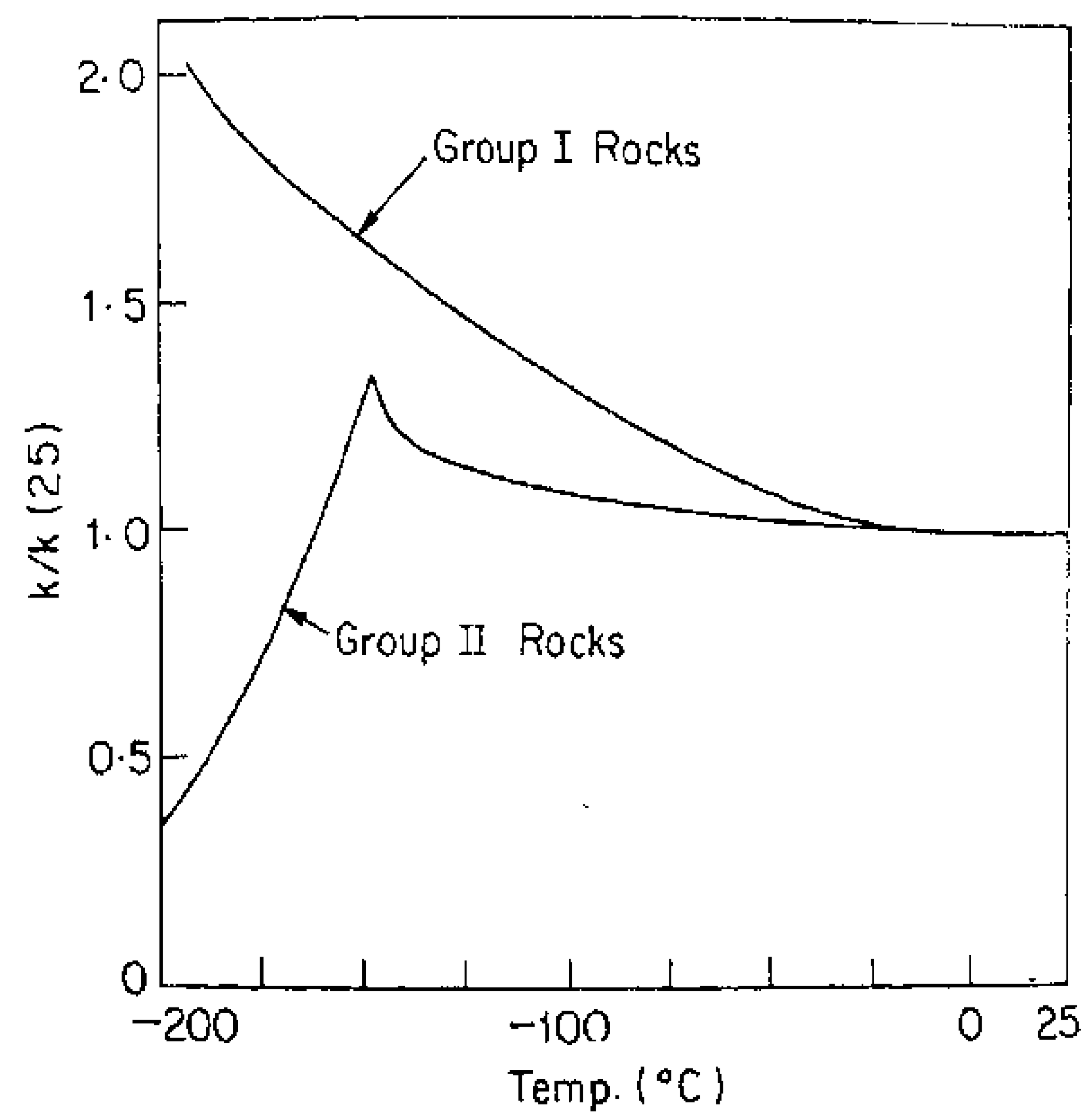

Figure 2. Schematic representation of susceptibility variations at room and low temperatures for group I and group II rocks. $k/k(25)$ is the normalized susceptibility.

account for the high total magnetizations. In the present study, the low mean Q ratio of 0.37 in rocks with susceptibilities above 1000×10^{-6} emu/cc Oe shows that whether the observed initial NRM is stable TRM, CRM or VRM, it would not be a major contributor for regional magnetic anomalies from deep crustal sources.

Retrograde metamorphism is widespread in the granulite terrain and many of the samples of the present study are effected by retrograde metamorphism resulting in partial to complete loss of magnetite and thereby exhibited reduced susceptibilities[17]. Hence the rocks with low to intermediate susceptibilities would not throw any light on the magnetization of the deeper crustal levels. Because of the later retrogression no clear relation is evident between the depth of formation, indicated from limited palaeopressure data, and the magnetic susceptibilities. The high pressure granulites from the northern foothills of Nilgiris, which represent the deepest section, exhibited only intermediate susceptibilities which could be due to the partial replacement of Fe–Ti oxides by garnet during late stage cooling from granulite facies at high pressures[14].

In most of the rocks, the induced magnetization (Ji) in a field of 0.5 Oe would be less than 1200×10^{-6} emu/cc. The induced magnetization of the most magnetic metamorphic rocks of the present study varied between 1500 and 2210×10^{-6} emu/cc. The total magnetization

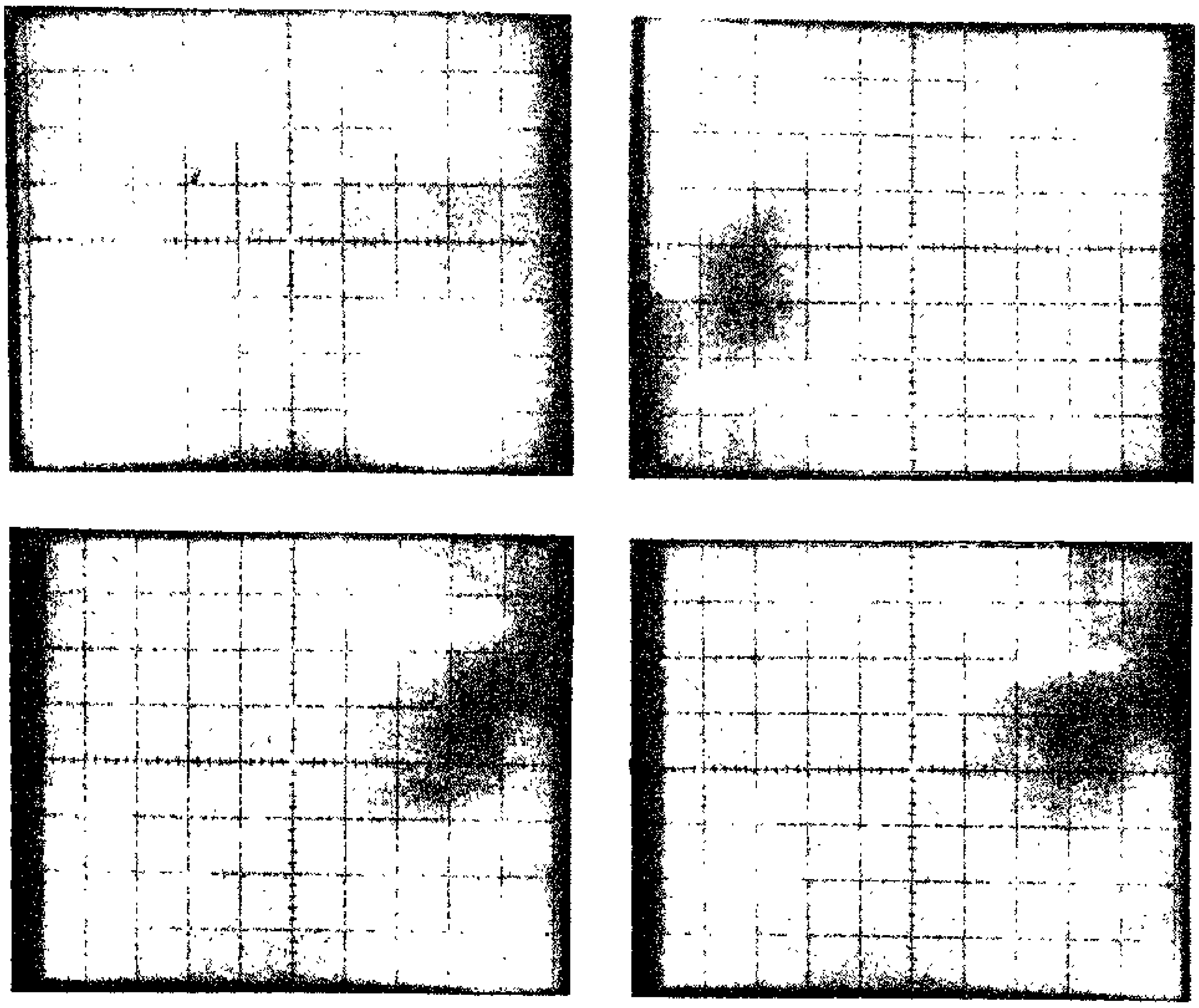

Figure 3. Hysteresis loops for some typical group II rocks with high susceptibilities. Hysteresis loops are studied in a peak field of 3000 Oe and at room temperature.

(induced + remanence) in these rocks would vary between 1800 and 4130×10^{-6} emu/cc. At temperatures of 300–600°C, an increase in total magnetization can be visualized from the findings of Pulliah *et al.*[18] Although the samples were collected from a total traverse length of about 2500 km, it is possible that other crustal sections of the granulite terrain may contain significant volumes of rocks with high total magnetizations. However, from the high total magnetizations in a few samples, an initial estimate of 3000×10^{-6} emu/cc can be made for the total magnetization of the deeper crustal levels in the granulite terrain.

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