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Structural Constraints on Reworking in the Western Ghats Granulite Belt, India and the Antarctic Analogue

S. Bhattacharya and Rajib Kar

Geological Studies Unit, Indian Statistical Institute, 203 B T Road, Calcutta - 700 035, India.

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Abstract

The Granulite Belt along the West Coast of India in Kerala-Tamil Nadu is particularly important for the study of Proterozoic events in the pre-drift East Gondwana super-continent. In Antarctica, structural, petrological and geochronological lines of evidence points to a Proterozoic reworking of Archaean granulites. In the Western Ghats Granulite Belt the Late Proterozoic (Pan African) event is overwhelmingly dominant, though some Late Archaean to Early Proterozoic granulites have been reported. Structural evidence presented here points to a Late Proterozoic reworking resulting in a break or discontinuity in the tectonic evolution of this granulite belt. Thus relicts or vestiges of probable Late Archaean to Early Proterozoic granulites are recognised in the largely Pan-African granulite belt of the Western Ghats.

Key words : Structural reworking, Pan-African, Western Ghats, Pre-drift, Gondwanaland.

Introduction

The granulite belt in South Kerala, parallel to the West Coast of India, is called the Western Ghats Granulite Belt. Based on the dominant lithology, it is commonly referred to as the Kerala Khondalite Belt. Recent work focuses on the mechanisms and age of arrested charnockite formation. Although Late Archaean to Early Proterozoic dates by Rb-Sr whole rock systematics (Crawford, 1969) and Late Proterozoic Pan African dates by Sm - Nd systematics (Choudhury et al., 1992) have been recorded from the Kerala Khondalite Belt, many workers believe in a continuous P-T cycle (Chacko et al., 1987). Some early workers (Sinha Roy, 1983, Sinha Roy et al., 1984) have described a sequence of deformation - repeated folding and development of fault-shear-fracture systems. But they did not address the question of distinct orogenic cycles. However, Yoshida and Santosh (1987) proposed "repeated tectono-metamorphic episodes". In this communication we present structural and tectonic evidence of discontinuity attesting to Early Proterozoic orogeny and Late Proterozoic reworking.

Geological Setting

The study area in South Kerala and adjoining parts of Tamil Nadu (Fig.1, inset: location map) exposes metapelites, orthopyroxene granulites and garnetiferous granite gneisses. The metapelites are dominantly khondalites (garnet-sillimanite-K-feldspar gneisses) with minor calc-granulites and garnetiferous quartzites. Orthopyroxene granulites, occurring as banded rocks, include two - pyroxene granulites, intermediate charnockites (enderbite) and acid charnockites. The pegmatitic orthopyroxene granulites (commonly referred to as "incipient" or "arrested" charnockites) are acid charnockites. The garnetiferous granite gneisses are commonly migmatitic and include several types of garnet-biotite gneisses (grey gneiss of Ravindra Kumar et al.,1985), cordierite - garnet gneiss and leptynites (Sen and Bhattacharya, 1993). In terms of the lithologic make up the study area is quite distinct from the Southern Granulite Belt of Karnataka and Tamil Nadu and is more akin to the Eastern Ghats Granulite Belt.

Signature of polyphase deformation has been recognised by several workers and a regional tectonic framework was described by Drury et al. (1984). Sinha Roy (1983) and Sinha Roy et al. (1984) described polyphase deformation structures and geometry of superposition. The Achankovil Shear Zone of Drury et al. (1984) forms the north-eastern boundary of the Kerala Khondalite Belt or the Western Ghats Granulite Belt.

Deformation Structures

Three episodes of folding and a shear system are recognised in the present study (Fig.1). Banded orthopyroxene granulites (Fig.2a,b) and khondalites (Fig.2c) preserve early intrafolial folds (F_1) with axial planar fine gneissic foliation, designated as S_1. The rootless, isoclinal F_1 folds are defined by quartzite bands (So) in the khondalites and by quartzofeldspathic and/

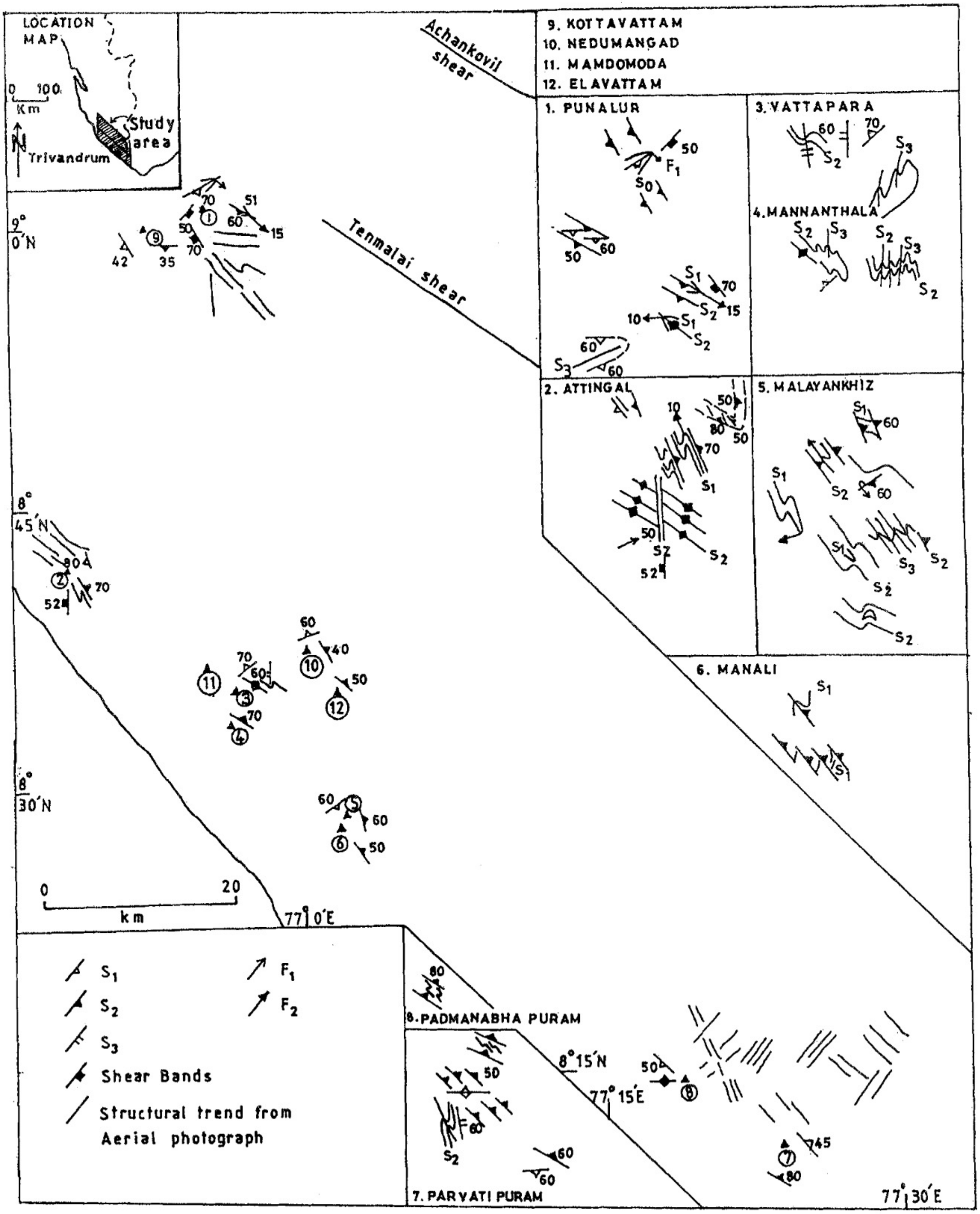

Fig.1. Structural map of the Western Ghats Granulite Belt, South of Achankovil Shear Zone ; regional structural trends from aerial photograph shown. Insets (schematic) show interrelationships of different planar fabrics. Also a location map at the top left.

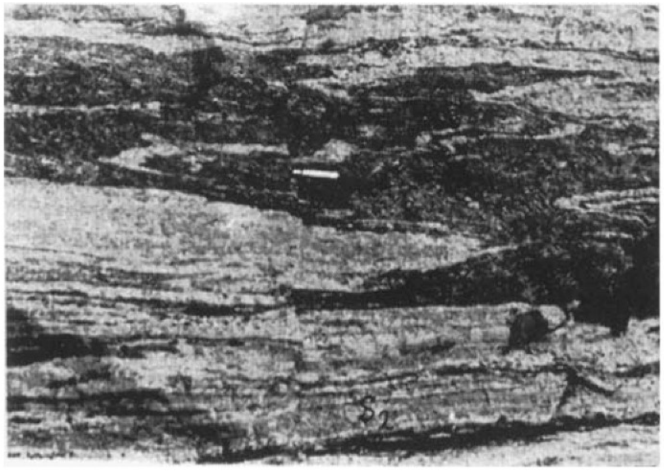

Fig. 2a. Early intrafolial folds in layered pyroxene granulite and granite gneiss at Attingal; gneissic foliation in granite gneiss S_2 unaffected and parallel to axial planes of early folds.

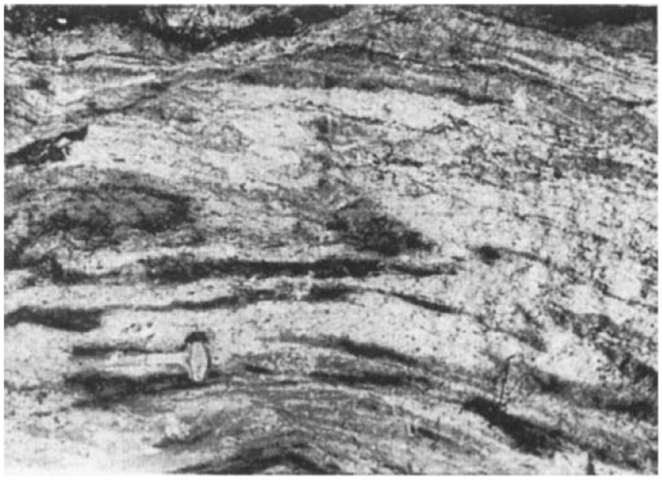

Fig. 2b. Early folds in banded charnockite in the middle; granite gneiss on both sides with prominent gneissosity S_2 and devoid of intrafolial folds, at Attingal.

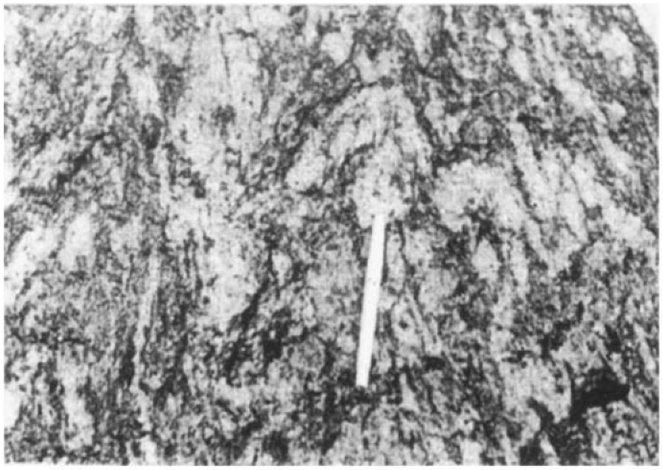

Fig. 2c. Hook-shaped folds (F_1-F_2) in migmatitic metapelites at Punalur ; pen parallel to pervasive gneissic foliation S_2.

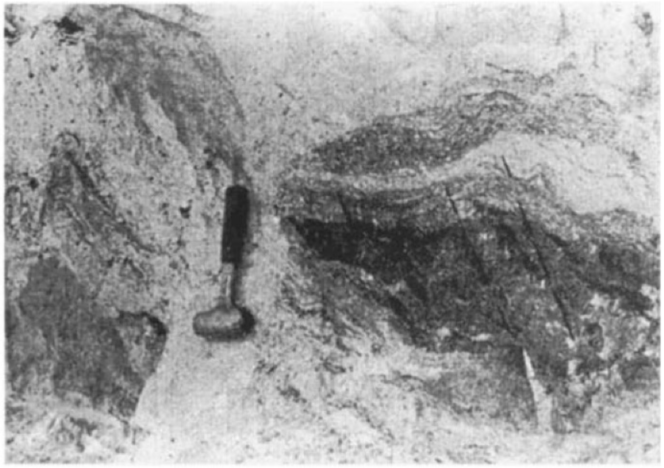

Fig. 2d. Blocks of charnockite discordant to S_2 in host leptynite; brittle fracture (dashed) in folded gneiss and charnockite boudins, at Vattapara.

or mafic bands in the orthopyroxene granulites. F_1 axes have steep but variable plunges (Fig.1, insets 1,2). F_2 folds are upright, open to close with gentle plunge towards SE or NW. A secondary coarse gneissic foliation developed parallel to the axial planes of mapable F_2 folds in both orthopyroxene granulites and migmatitic granite gneisses (Fig.1, insets 1,2,6). This secondary gneissic foliation (S_2) is the most pervasive planar structure and defines the regional NNW-SSE tectonic trend (Fig.1). S_2, gneissic foliation, describes open warps (F_3) on various scales and an axial planar cleavage (S_3) is developed only locally (Fig.2d). S_3 is sub vertical with nearly N-S axial trend (Fig.1, insets 3,4). However, two different trends NNW-SSE (Fig.1, insets 2,5,7) and ENE-WSW (Fig.1, inset 1), form a conjugate pattern (Fig.4c). In fact, conjugate fracture cleavage (S_3) is also observed on exposure scales.

Strike-slip shear bands are common and, like S_3 cleavage, have two different orientations NW-SE and NE-SW (Fig.1,insets1,2). Although, the two sets of shear bands are

Fig. 3a. Sinistral shear affecting S_2 in banded charnockite-leptynite sequence, at Attingal.

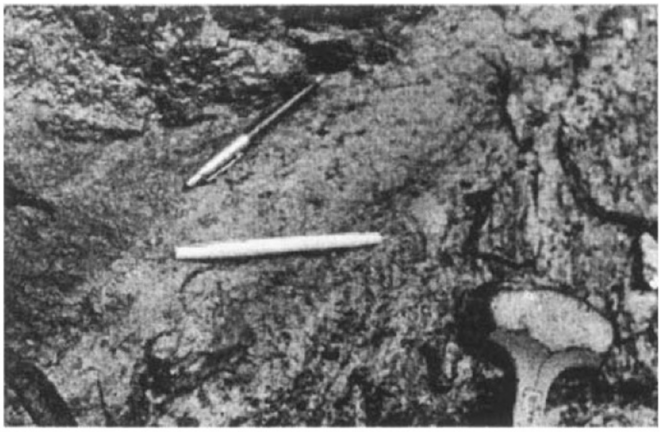

Fig. 3b. Dextral shear affecting S_2 in charnockite, at Mannanthala.

Fig. 3c. Transposition of early fine gneissic foliation S_1 parallel to coarse gneissic banding S_2 in migmatitic gneiss, at Punalur.

Fig. 3d. Charnockite band depicting early reclined fold ; gneissic foliation S_2 in the host granite gneiss (leptynite) disrupts (arrow) the folded charnockite band, at Malayankhiz.

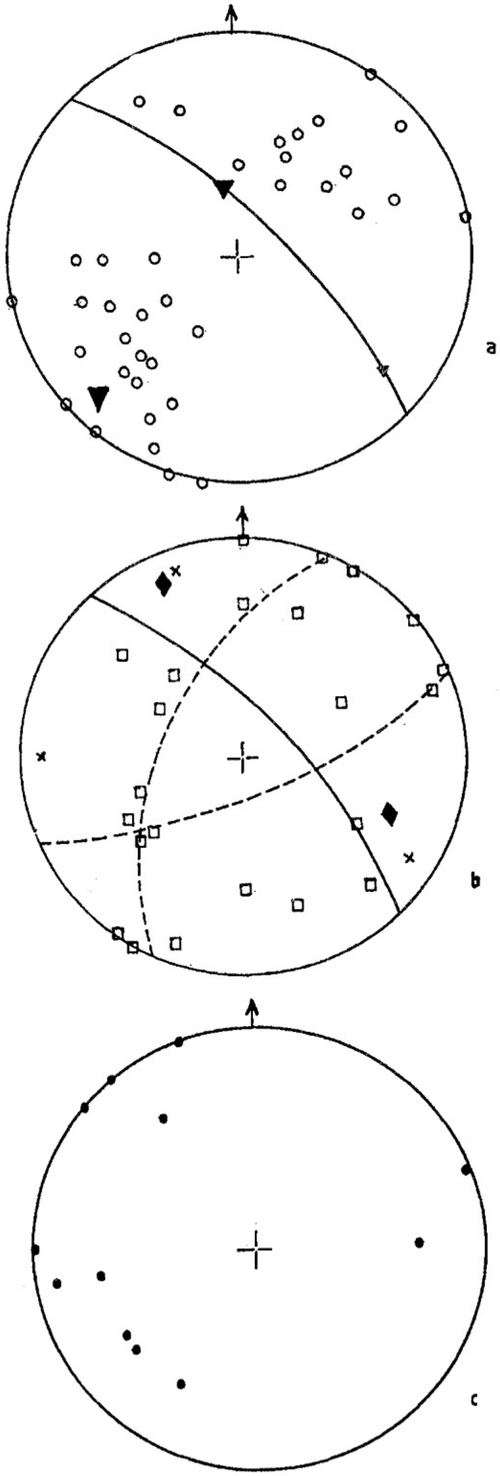

Fig.4. Stereographic plots of the planar structures.

a. Synoptic plot of poles to S_2 (open circle, n=37); great circle represents average S_2 ; three eigen vectors (filled triangles) of S_2 distribution are also shown.

b. Synoptic plot of poles to S_1 (open square, n=23) show cross girdle distribution; mesoscopic F_2 axes (cross), β - poles (filled diamonds) and average S_2 plane (from Fig. 4a) are also shown.

c. Synoptic plot of poles to S_3 (filled circle, n=12); a conjugate pattern of NE-SW and NW-SE is discernible.

not observed together, the sense of movement is consistent with a conjugate system. Sinistral movement is observed on the NE-SW system (Fig. 3a) while dextral movement is observed on the NW-SE system (Fig. 3b). Thus orientation-wise as well as from the associated sense of movement shear bands can be correlated with the S_3 fracture cleavage.

S_2 has contrasting geometrical relations with pre existing gneissic foliation. Three types of geometrical relations are observed. The most common relation is the one in which S_2 is axial planar to folds defined by streaky gneissic foliation (Fig.1,insets1,2,6). Another relation is transposition of earlier fine gneissic foliation parallel to S_2 (Fig.1,insets2,5,6; Fig.3c). The third type is one in which the S_2 truncates the variably oriented fine foliation (Fig1, insets1,7,8; Fig.3d).

The orientation of S_1 is highly variable (Fig.4b). S_1 is obviously folded by F_2. In spite of F_3 folds, S_2 orientation before F_3 can be reconstructed from S_2 pole distribution. The average orientation of S_2 plane is represented by the great circle whose pole is given by the eigen vector 1 (Fig.4a). With respect to the average orientation of S_2 plane the S_1 pole distribution can be described by a cross-girdle whose poles are consistent with mesoscopic F_2 fold axes (Fig. 4b). However, some of the S_1 poles plot outside the cross girdles. This, together with the fact that S_2 foliation often truncates S_1 foliation in irregularly disposed enclaves, implies a structural break or discontinuity leaving earlier structures as relicts or vestiges in a largely reworked granulite belt.

Discussion

The polyphase deformation signatures in the Kerala Khondalite Belt (Western Ghats Granulite Belt) can hardly be explained in terms of a single orogenic cycle. Sinha Roy (1983) correlated the late phase deformation (F_3 of the present study?) with the Eastern Ghats orogeny on the basis of NE-SW to NNE-SSW trends of this late foliation. However, he did not explain the earlier episodes of deformation in terms of a different or older orogeny. Chacko et al. (1987) considered "the granulite facies metasediments of probable Early Proterozoic age" as "related to a continuous P-T cycle", from petrological investigations. However, these authors did not consider the polyphase deformation history in terms of single or multiple orogeny. Yoshida and Santosh (1987) described "breaking" and "making" of charnockites in terms of repeated tectonic-metamorphic episodes. Moreover, two widely separated age clusters, namely ca.2100 to 3070 Ma (Crawford, 1969) and ca.550 Ma (Choudhury et al.,1992) from the Kerala Khondalite Belt would imply at least two tectonic-metamorphic episodes, or two orogenic cycles or a Late Proterozoic reworking of an Early Proterozoic granulite belt. The structural evidence presented here strongly suggests reworking of pre- existing metamorphic fabric in an incongruous fashion, leaving some vestiges or relicts of the previous tectonic-metamorphic episode.

The aforesaid discussion on the evidence of structural reworking in the Kerala Khondalite Belt has important bearing on Proterozoic events in the pre-drift East Gondwana. In the granulite terrain of Antarctica there is ample evidence of Proterozoic reworking (Sheraton et al.,1980). Structural studies in certain key localities like Forefinger Point (Harley et al., 1991), Kemp Land (Clarke, 1988) both in the Rayner Complex (Proterozoic) and Fyfe Hills (Black et al., 1983) in the Napier Complex (Archaean) provide structural evidence of Proterozoic reworking.

The main structural trend of the Archaean Napier Complex, represented by D_1 deformation, is ENE-WSW, while in the Proterozoic Rayner Complex the main structural trend, representing D_1 deformation, is NE-SW to NNE-SSW. The latest deformation in the Napier Complex is represented by an E-W shear zone with a westerly- converging tectonic transport (Sandiford, 1985 ; Clarke,1988). The aforesaid sense of movement is consistent with the reorientation of Archaean ENE-WSW trend to NNE-SSW trend (Fig.5). Moreover, petrological and geochronological studies from several localities - Forefinger Point (Harley et al.,1990), Sostrene Island (Thost et al.,1991), Raur Group (Harley et al., 1991) and Fyfe Hills (Sandiford, 1986) indicate a widespread Proterozoic (ca.1000 Ma) decompression reaction and relict high P-T granulites of Archaean age (ca. 3100 - 2500 Ma, Black et al., 1983).

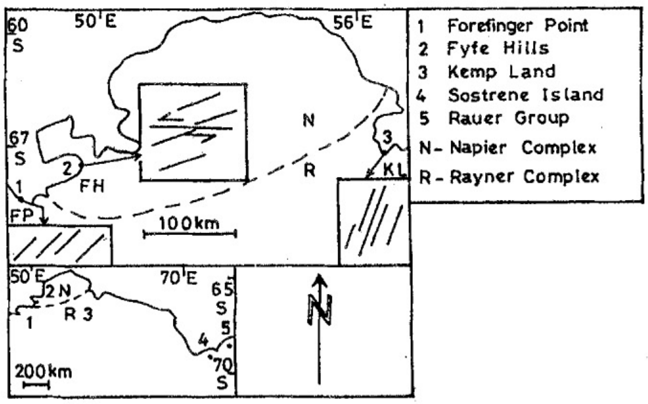

Fig.5. Structural trends (inset box) in the Napier Complex and Rayner Complex in Antarctica depicting the Proterozoic reworking of Archaean granulites.

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