CHAPTER 4

CHAPTER 4

Structure and deformation pattern

Detailed study of the structural features from all the lithological zones mentioned in the previous chapter reveals a complex structural history. Based on the disposition of rocks with broadly uniform metamorphic characters, the area can be subdivided into several WNW-ESE trending elongated zones. These zones are characterized by distinct deformational patterns in rocks showing contrasting grades of metamorphism. Significantly, these zones or belts were separated by regional-scale faults or shear zones. These are

(1) Kerajang Fault Zone (KFZ)

(2) Northern Supracrustal Belt (NSB)

(3) Central Gneissic Belt (CGB)

(4) Southern Supracrustal Belt (SSB)

(5) Barkot Shear Zone (BSZ)

(6) Riamol Shear Zone (RSZ), and

(7) Akul Fault Zone (AFZ)

The Southern Supracrustal Belt (SSB) is bounded by the regional-scale Barkot Shear Zone (BSZ) in the north and the Kerajang Fault Zone (KFZ) in the south. Two other important transverse shear zones, the Riamol Shear Zone (RSZ) in the west and the Akul Fault Zone (AFZ) in the east controlled the deformational pattern of these longitudinal belts. The RSZ is further branched into the North Riamol Splay, which separates the CGB from the NSB and the South Riamol Splay, which separates the CGB from the southerly lying SSB.

4.1 Kerajang Fault Zone

This regional scale shear zone trends in a WNW-ESE direction. The overall foliation within the fault zone varies from sub-vertical to steeply southerly dipping (average orientation being 104°/79° S; Fig. 4.1a) with foliation strikes sub-parallel or at a low angle to zone boundaries indicating a dextral kinematics. Prominent mineral lineation, defined by elongated quartz and mica crystals shows a girdle distribution with mean orientation plunging due east at a low angle (02°→093°) in an equal area stereoplot (Fig. 4.1a). Development of asymmetric Z-shaped minor folds (Fig 4.2), boudins, porphyroclasts, shear band, fish structures (Fig. 4.3) and S-C fabrics indicate an essentially dextral kinematics, with mean orientation of shear plane; 149°/87° W (Fig 4.1a). Though some local asymmetric, southerly verging folds and asymmetric boudins on sub-vertical planes are observed, which indicate a reverse slip kinematics (with top-to-the-south movement sense), dextral strike-slip features of KFZ far outweigh in intensity the thrust-related structures suggesting an overall dominance of strike-slip faulting over thrusting in KFZ.

A later deformation is characterized by development of fault parallel breccia, cataclasite and gouge zones (Fig. 4.4) and intense fracturing (Fig. 4.5). It is confined in a longitudinal band subparallel to the highly sheared rocks within the fault zone. Development of similar fault zone-parallel breccia ridges within the Gondwana rocks and the migmatitic gneisses of the EGB can be identified and constraints the timing of brittle reactivation of the KFZ to be post-Jurassic.

4.2 Southern Supracrustal Belt

This longitudinal belt also trends in a WNW-ESE direction and essentially composed of alternate bands of quartzite-mica schist (Fig 4.6). Asymmetric fold development can be observed both in macroscopic (Fig. 4.7) and microscopic scale in the alternate quartzite-mica schist layers of this zone. These folds are southerly verging and inclined in nature, with the major fold axis having an attitude of 08°→282°. Minor fold axes plunge towards east or west. Dominant foliation is sub-vertical to northerly dipping, with mean attitude 286/83°N (Fig. 4.1b). Mylonitic, as well as S-L tectonite fabrics, are present in outcrop scale, with downdip mineral lineations (mean attitude 76°→329°), defined by elongated mica crystals observed (Fig. 4.8). The boundary between SSB and CGB is marked by a major boundary fault termed South Riamol Splay and rocks of SSB near this thrust zone are highly mylonitized in nature. From asymmetric southerly verging folds (Fig. 4.9) which get overturned at places as well as mylonitic zones with reverse dip-slip movements and S-C fabric on sub-vertical planes, a top-to-south reverse sense slip is determined as the prevalent kinematics in SSB. The major boundary fault – the South Riamol Splay is also reverse slip in nature. Here, along the major thrust surface of South Riamol Splay, a section of the mid-crustal basement rock, represented by the amphibolite-grade gneisses of CGB, was thrusted over the low-grade rocks of SSB. The basement gneiss outcrops present within SSB occur at the core of large-scale asymmetric southerly verging antiformal folds. Locally, Type-2 to Type-3 interference folds are preserved within the gneisses exposed on horizontal planes (Fig. 4.10) with later axial traces subparallel to folds in overlying supracrustals rocks. Superposed folds within the basement gneisses are present as a testament to an earlier phase of deformation, in contrast to the overlying supracrustal rocks.

4.3 Central Gneissic Belt (CGB)

This belt has been subdivided into three longitudinal subdomains, on the basis of distinct deformational fabric and pattern from south to north. 1) Hanging wall of South Riamol Splay, is considered as a sub-domain 1 of CGB is characterized by a steep northerly dipping foliation with a down-dip mineral lineation (Fig. 4.11) and average attitude of foliation and lineation is 281°/79° N and 72°→234° respectively (Fig. 4.1c), with foliation strike sub-parallel to zone boundaries. Minor folds on gneissic layers are asymmetric in nature (Fig. 4.12), southerly verging and are syn-kinematic with top-to-south thrust sense slip on South Riamol Splay. Minor fold axes show a girdle distribution with concentrations at low-to-moderate angles towards WNW or ESE (Fig. 4.1c). Fabrics in these gneissic rocks are represented by S-L tectonites, which grades to mylonite towards the margin with the southerly lying SSB. Grain size reduction and development of S-C fabric is also recorded. The overall kinematics in this sub-domain can be inferred in terms of southerly verging regional scale thrusting, which juxtaposes the high-grade rocks of CGB over the southerly lying low-grade rocks of SSB.

The second subdomain (2) is characterized by sub-vertical foliations with prominent mineral lineations, that varies from sub-horizontal, lowly plunging pointing due east or west to steeply plunging subparallel to foliation dip (mean orientation 103°/85°S; Fig. 4.1d). Intensely deformed gneissic layering alternate with foliated layers and also subparallel to these adjacent foliations. These intensely folded zones can be traced along the entire length of this subdomain from east to west and indicate distinctiveness compared to other subdomains. Mesoscopic folds are asymmetric Z-shaped in nature (Fig 4.13), with fold axis sub-vertical (Fig. 4.14) and average foliation is axial planar to the mesoscopic folds. Gneissic foliations from the fold zone show great circle distribution, with regional-scale fold axis having an attitude 78°→207° (Fig 4.1d). Type 2 or Type-3 interference pattern can be observed in these folds on sub-horizontal plane, with later axial trace trending WNW-ESE (Fig 4.15). Several structural features like fold asymmetry on sub-horizontal planes, sub-vertical orientation of foliation parallel to zone boundary and outcrop-scale occurrence of WNW-ESE trending dextral shear planes displacing fold trains (Fig. 4.16) suggests an overall dextral strike-slip kinematics to be dominant in this subdomain. The interference pattern points to the presence of an early phase of deformation in the gneisses.

A linear ridge, of charnockite gneiss is present along the northern boundary of CGB with NSB. This boundary is also marked by North Riamol Splay constituted of highly sheared granites and supracrustal rocks and it is considered as the third sub-domain (3). In this subdomain of CGB, foliation is steep southerly dipping and characterized by a prominent down-dip mineral lineation with average orientation of 103°/71°S and 71°→159° respectively (Fig 4.1e). Development of minor folds on gneissic layering with axes plunging lowly to steeply due east or west with dominant foliation being axial planar to the folds and indicates reorientation of axes subparallel to mineral lineation during progressive northward shearing. Poles to gneissic layering show a great circle distribution with major fold axis plunging 41°→108°. Near the Northern Riamol Splay, development of mylonitic fabric in the rocks along with S-C structures, asymmetric recrystallized tails on porphyroclasts (Fig. 4.17) and asymmetric northerly verging folds (Fig. 4.18) on subvertical planes points to a strong component of thrust sense top-to-north shear. The effect of shearing is maximum near the North Riamol Splay, which is a northerly verging regional scale thrust plane. The latter pushed the amphibolite grade gneissic rocks of CGB over the low-grade supracrustals of NSB. In this subdomain, sub-vertical shear planes having average orientation 145°/81°W and 027°/89°E appear as conjugate planes (Fig. 4.19) and displaced as well as crenulated gneissic layering (Fig. 4.20) and subparallel foliation, producing shear bands or extensional crenulation cleavage structures on sub-horizontal planes. Also development of local WNW-ESE trending outcrop-scale dextral shears (Fig. 4.21) with attitude 119°/81°S is observed in this subdomain. Pegmatite veins (Fig. 4.22) were emplaced and co-deformed with this dextral shear. Although these dextral shears displace the basic dyke (Fig. 4.23), a gross mutual overprinting relationship with transverse shear planes can be observed in the detail map (Fig 4.24) and it indicates a contemporaneous nature of these shear planes.

4.4 Northern Supracrustal Belt (NSB)

In this belt, essentially composed of low-grade supracrustals, bedding within the rock define macroscopic to mesoscopic folds which are asymmetric and northerly verging with steeply inclined axial surfaces due south. Near North Riamol Splay, development of higher temperature quartz-muscovite-sillimanite-fibrolite assemblage is observed, which also shows mylonitic fabric. Bedding poles are distributed along a great circle in stereographic lower hemispheric projections with major fold axis plunging 13°→276° (Fig. 4.1f). Minor fold axes plunge either towards east or west at low to moderate angles. The dominant foliation is parallel to the axial plane of the folds and is sub-parallel to the zone boundaries and is characterized by a steep southerly plunging down-dip mineral lineation (Fig. 4.25). The mean orientations of foliation and lineation are 103°/79°S and 62° →177° respectively (Fig. 4.1f). Fabric within the deformed supracrustals varies from S-L tectonite to mylonite at or near NRS footwall. Here S-C fabric can be identified with stretched quartz grains showing ribbons that alternate with smaller recrystallized grains at an angle to the ribbons. The shear sense is consistently top-to-north. Thus dominant kinematics in the subdomain3 is top-to-north shearing as evident from asymmetric folds and S-C structures (Fig. 4.26) on sub-vertical planes (orthogonal to foliation and parallel to lineation). This thrust movement towards the north is not restricted to NRS only, but a common feature of the entire NSB. The high-grade gneissic rocks exposed in the middle part of the belt are characterized by a steep southerly dipping foliation (having average orientation 111°/78°S) with down-dip mineral lineation. Mesoscopic fold development is also frequent within the gneissic rocks with the folds having plunging, inclined to reclined geometry (Fig. 4.27) and axes plunging moderately due east or west or steeply due south. Locally occurring hook-shaped folds are also observed. Intrusive quartzofeldspathic veins display an early isoclinal folding which gets modified by northerly verging later folds (Fig 4.28).

4.5 Barkot Shear Zone (BSZ)

This shear zone marks the northern boundary of the Rengali Province with the Singhbhum Craton. A narrow zone (~500 m width) of strongly deformed rocks which include quartzite, conglomerate and pelitic rocks, as well as some exposed basement gneisses, define the E-W trending BSZ. The cratonic rocks transform to quartzite mylonites and foliated conglomerates with steep, southerly dipping foliation and a down-dip mineral lineation within the shear zone.The average orientation of foliation in this zone is 115°/59°S (Fig. 4.1g) and it is sub-parallel to the shear zone boundaries. Elongated quartz and mica grains in mylonites define the stretching lineation with average orientation 57° →218°, while in conglomerates it is defined by pebble elongation lineation (Fig 4.29). Mesoscopic folds with southerly inclined axial plane show asymmetric northerly verging geometry on sub-vertical planes (orthogonal to foliation and parallel to stretching lineation). The shorter forelimbs of the asymmetric folds get overturned with development of reverse shears sub-parallel to back limbs. In some cases locally fold attain reclined geometry (Fig. 4.31) where axes reorient sub-parallel to the down-dip stretching lineation. These asymmetric folds and reverse shears indicate a top-to-north shearing in BSZ. Also, local development of asymmetric Z-shaped folds (Fig 4.30) is observed on sub-horizontal planes (orthogonal to both foliation and down-dip lineation) with fold axes plunging steeply due S-SE and development of a sub-horizontal to low plunging lineation.

4.6 Riamol Shear Zone (RSZ)

The dominant foliation within high-grade rocks of CGB, which shows steep north or southerly dip, in proximity to RSZ, developed crenulation with pucker axis plunging NNE or SSW (mean attitude 78°→031°; Fig 4.1h). Outcrop-scale shear planes displace gneissic banding in quartzofeldspathic and migmatitic gneisses (Fig. 4.32) in a sinistral sense. The average orientation of these shear planes is 212°/90° and within RSZ, anticlockwise rotation and warping of the gneissic layering from its original E-W to WNW-ESE orientation with axis plunging 68°→246° (Fig 4.1h). Deformation and strong overprinting by a sub-vertical NNE trending crenulation cleavage is also observed within the low-grade rocks of NSB along RSZ. Overall kinematics of this belt is essentially sinistral. The WNW-ESE trending thrust-sense North Riamol Splay and South Riamol Splay get reoriented and merge with this major transverse structure near the western boundary of the study area.

4.7 Akul Fault Zone (AFZ)

In outcrop-scale, the mesoscopic folds are steeply NNE or SSW plunging (mean orientation 85°→148°; Fig 4.1i) with the development of a sub-vertical axial planar crenulation cleavage and a sub-horizontal mineral lineation (average orientation 23°→144°). Mesoscopic NNE trending shear planes show prominent dextral offset of gneissic layering (Fig. 4.33) and chert bands developing in single or parallel sets with average orientation 330°/89°E. Pole plotting of gneissic rock foliation in the Central Gneissic Belt adjacent to Akul Fault Zone shows a pronounced warping with the warp axis plunging 63 °→138° (Fig. 4.1i) from which it can be inferred that reorientation through shearing took place in this region. Moreover, in outcrop-scale, this shearing also results in development of N-NNE directed fold closures and hook-shaped interference patterns (Fig. 4.34) on horizontal faces in the gneisses.

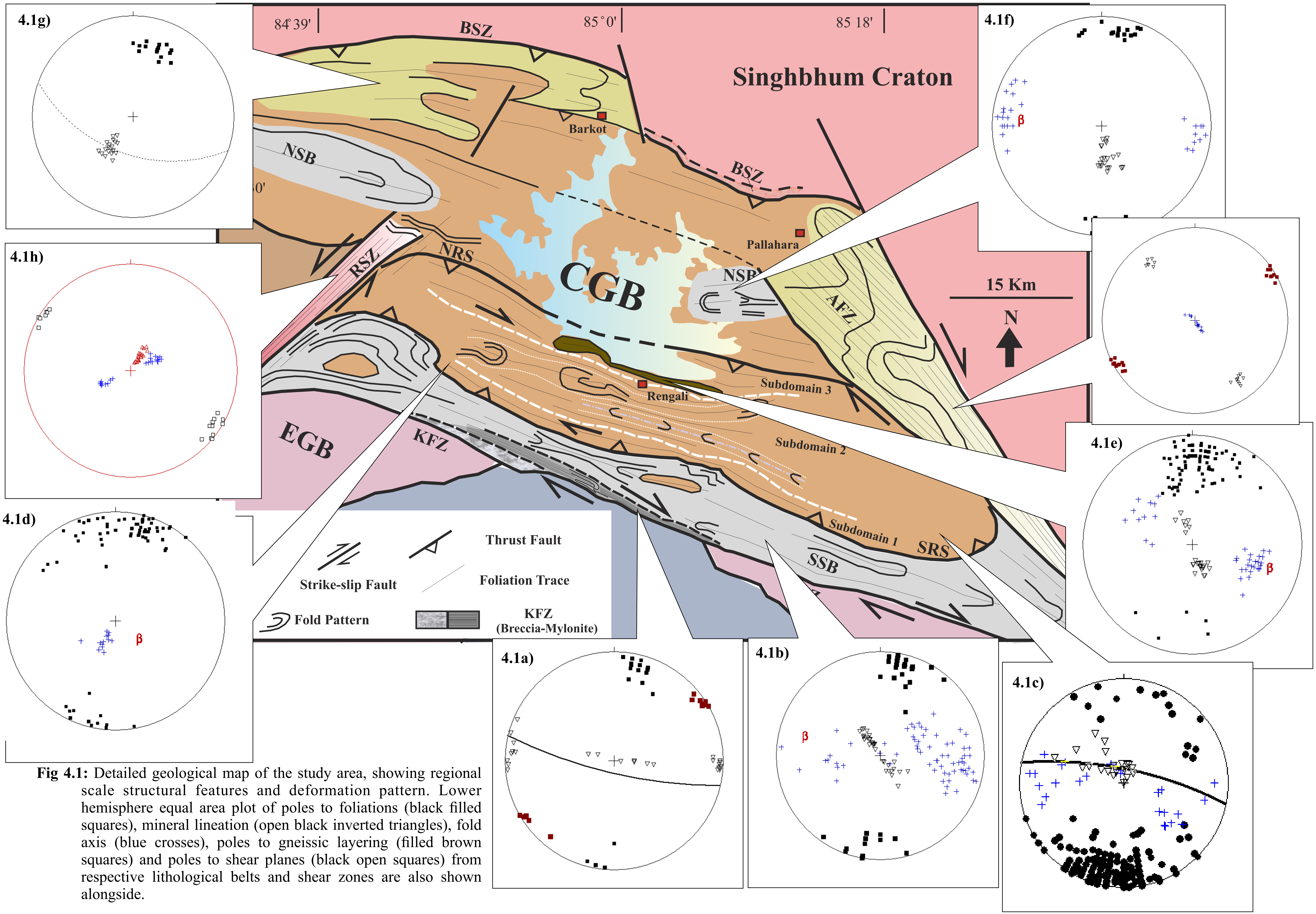
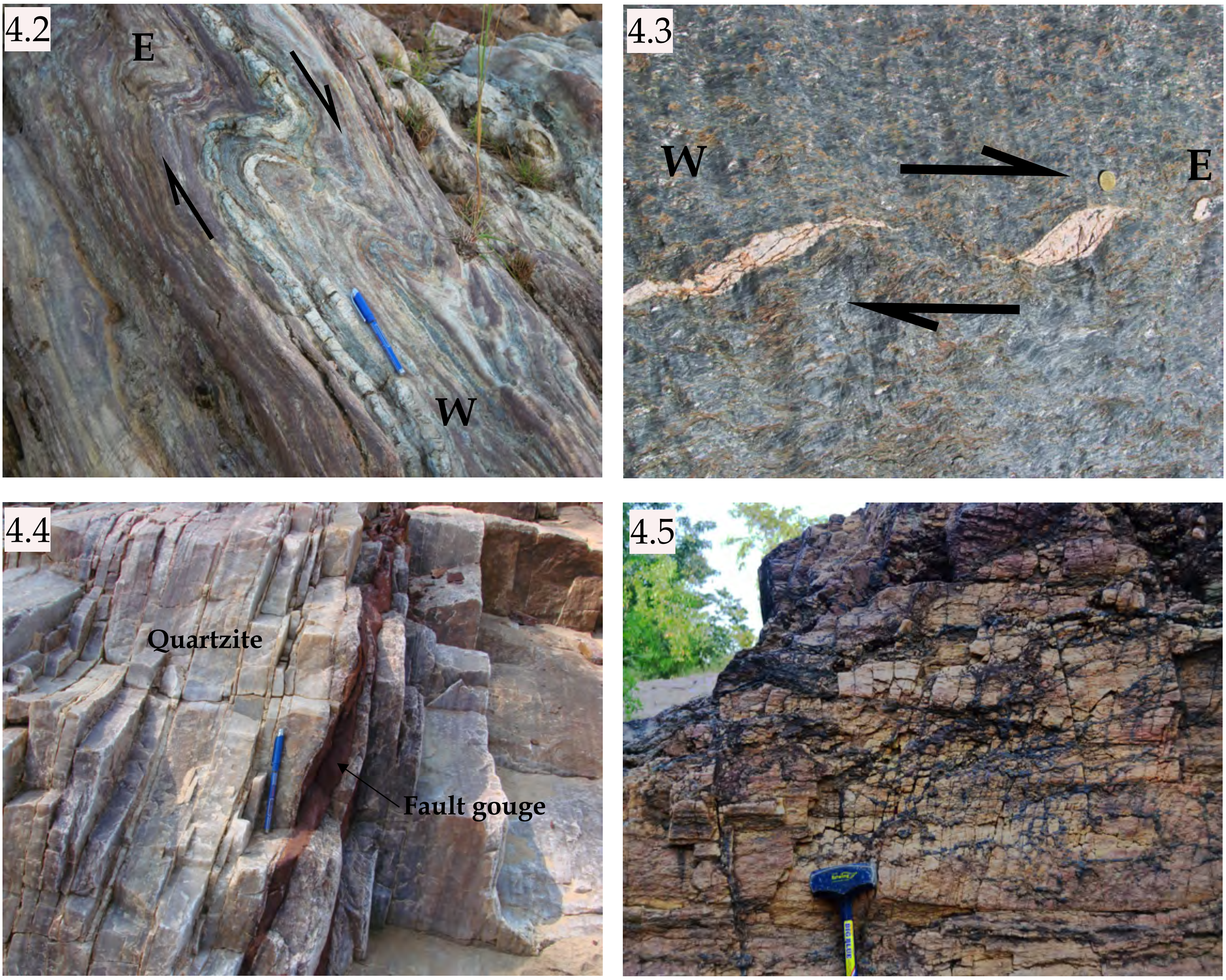


Fig 4.1: Detailed geological map of the study area, showing regional scale structural features and deformation pattern. Lower hemisphere equal area plot of poles to foliations (black filled squares), mineral lineation (open black inverted triangles), fold axis (blue crosses), poles to gneissic layering (filled brown squares) and poles to shear planes (black open squares) from respective lithological belts and shear zones are also shown alongside.



Kerajang Fault Zone
Field photographs of Fig. (4.2) Asymmetric Z-shaped minor folds in calc-silicate schsit. (4.3) Fish structure of leucogranite within mica-schist. (4.4) Gouge zone within quartzite bed. (4.5) Intense fracturing within quartzite, indicating a late brittle phase of deformation.

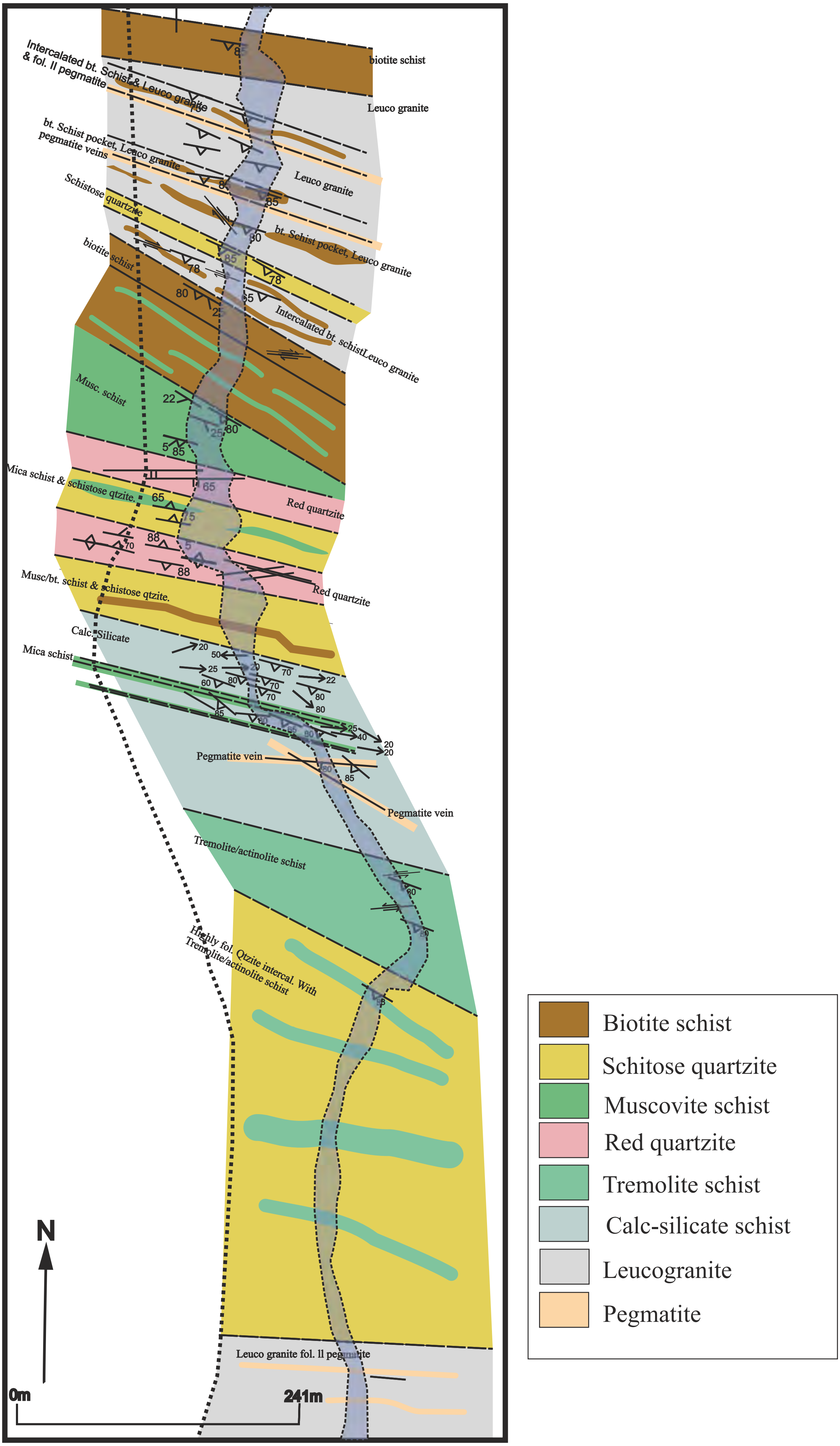
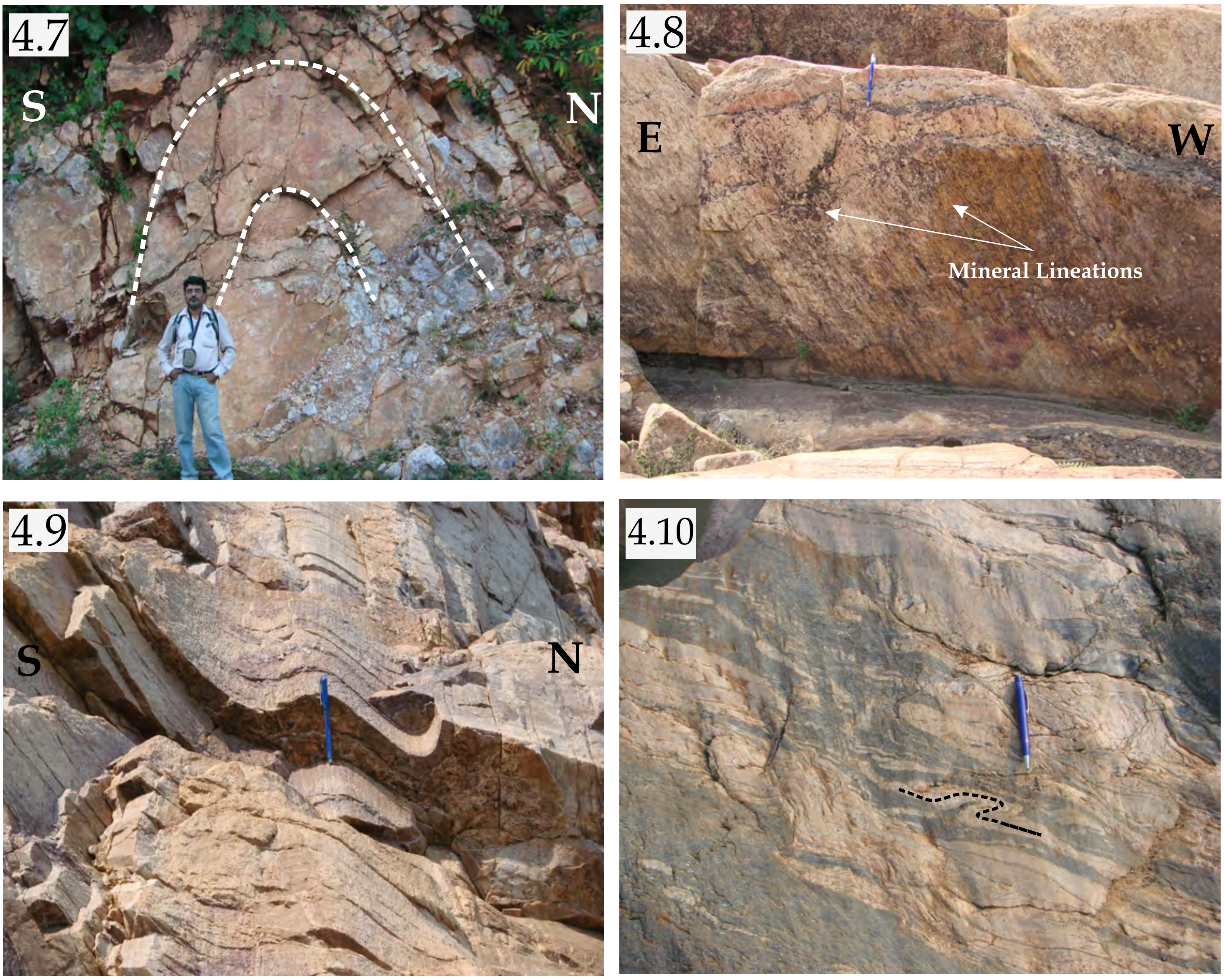
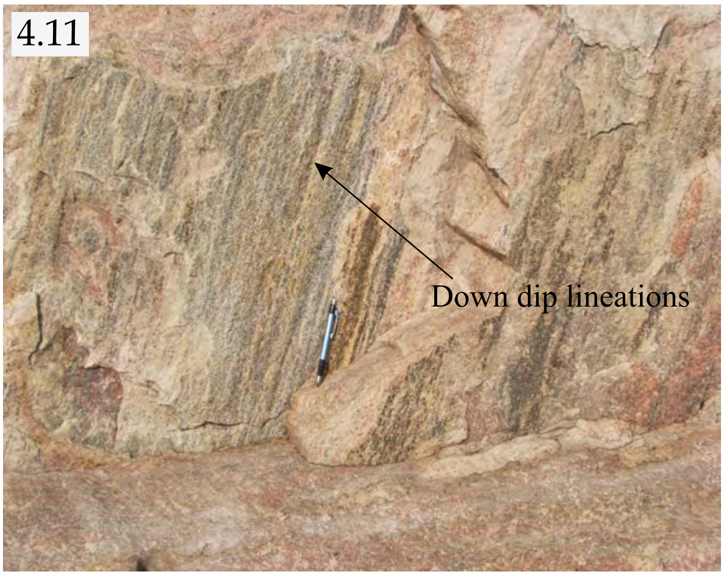
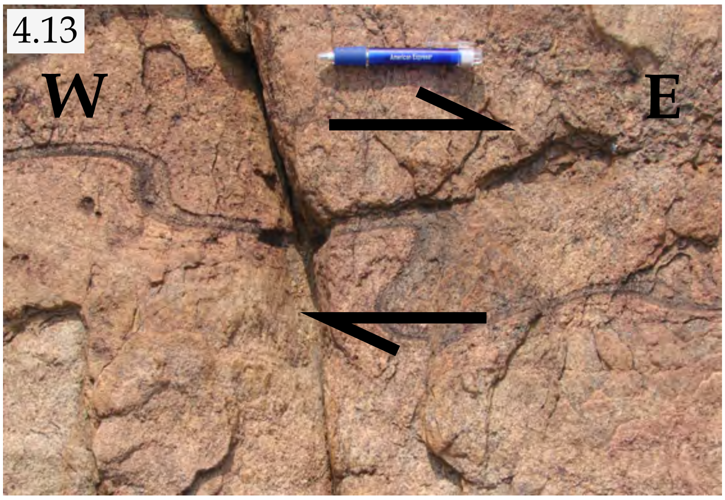


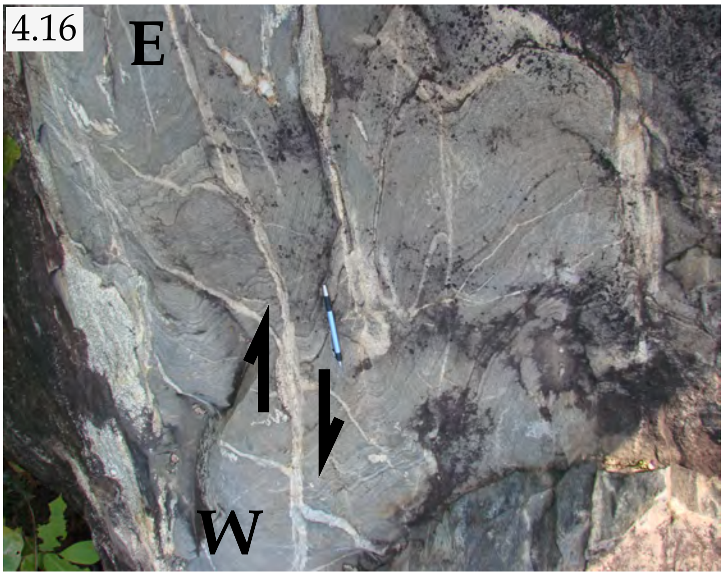
Fig. 4.6: Detailed map of Tikra nullah section, showing alternate layers of quartzite-mica schist with their foliation trend.



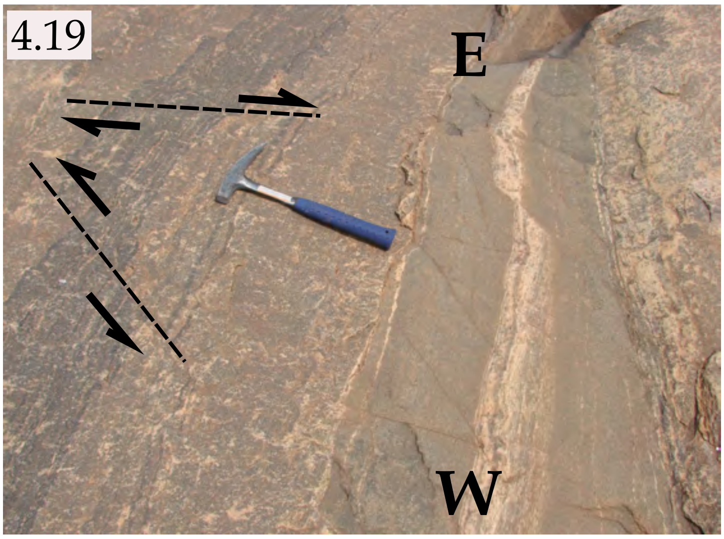
Southern Supracrustal Belt
Field photographs of the Fig. (4.7) Development of macroscopic inclined folding of the bedding plane of the quartzite. (4.8) Downdip mineral lineations defined by elongated mica crystals. (4.9) Asymmetric, southerly verging fold developed in quartzite layer, N-S section view. (4.10) Fold preserved within gneissic basement exposed within Southern Supracrustal Belt.

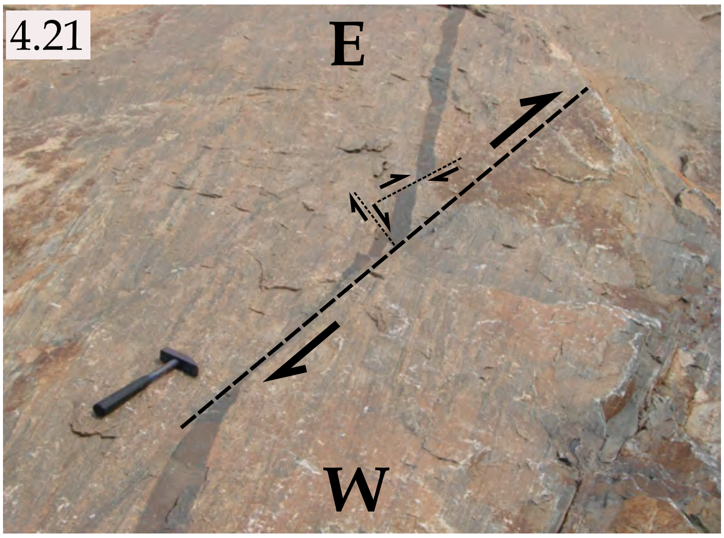


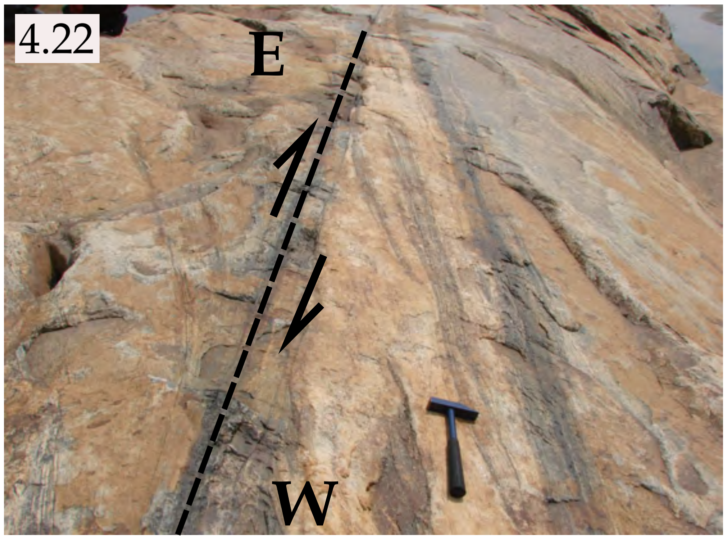




Central Gneissic Belt
Field photographs of the Fig. (4.11) Downdip mineral lineation on the foliation plane of the basement gneiss. (4.12) Asymmteric southerly verging minor folds developed within gneissic layers. (4.13) Develoment of mesoscopic Z-shaped folding with sub-vertical fold axis. (Fig. 4.14) Type 2 or Type-3 interference pattern on sub-horizontal plane. (Fig. 4.15) Type-3 fold interference pattern shown by gneissic layers. (4.16) Steep shear planes displace fold trains and quartz veins in gneiss in a dextral sense.







Field photographs of the Central Gneissic Belt Fig. (4.17) Asymmetric recrystallized tail developed against feldspar clast in gneiss showing top-to-the-north shear sense. (4.18) Asymmteric northerly verging fold in charnockite gneiss. (4.19) Conjugate shear planes displacing foliation in charnockite gneiss. (4.20) Development of crenulation (arrow) in gneissic layering. (4.21) WNW-ESE trending dextral shear plane displacing mafic banding in charnockite gneiss. (4.22) WNW-ESE trending dextral shear plane along shear parallel pegmatite emplacement. (4.23) Dextral displacement of N-S trending dolerite dyke body.

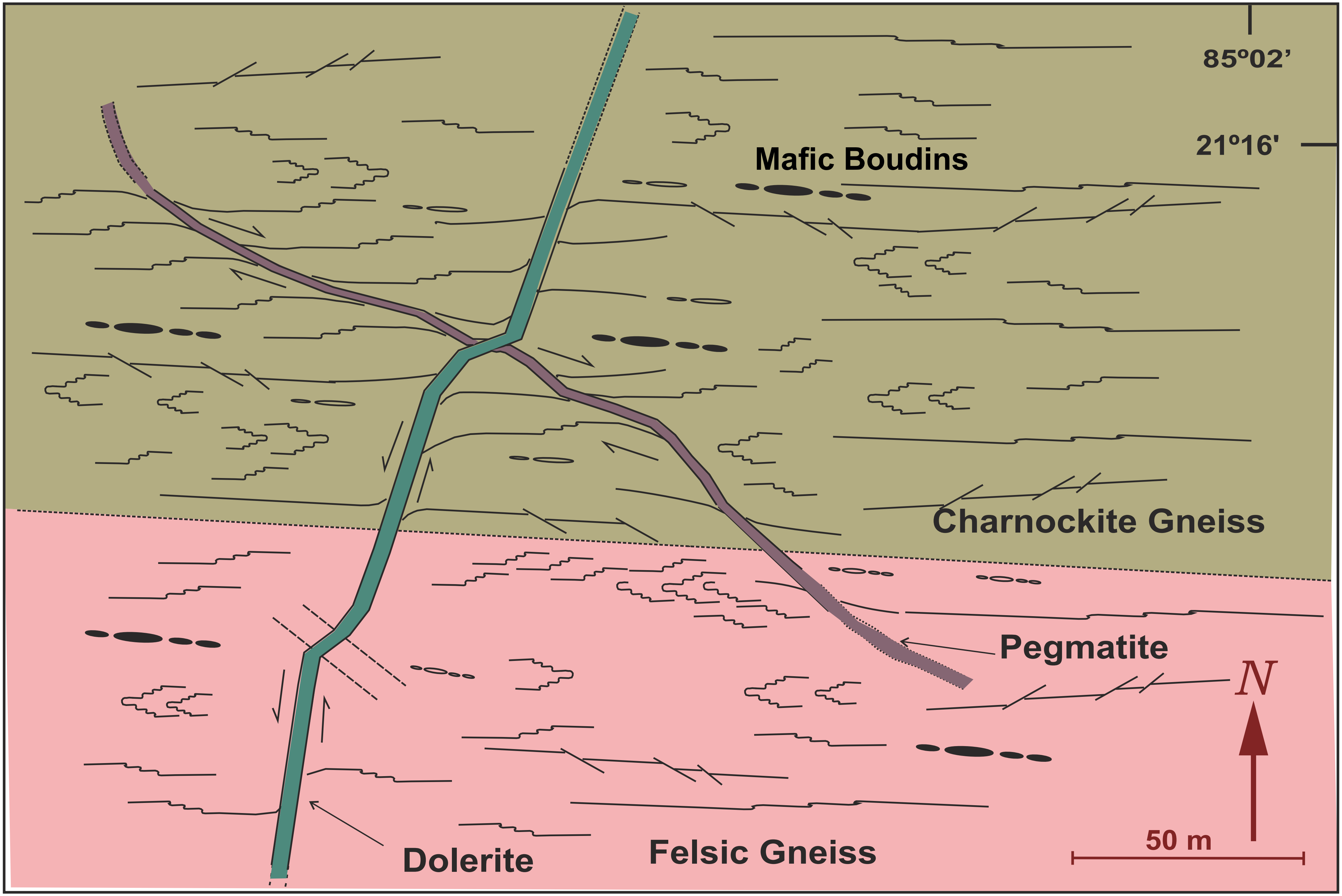
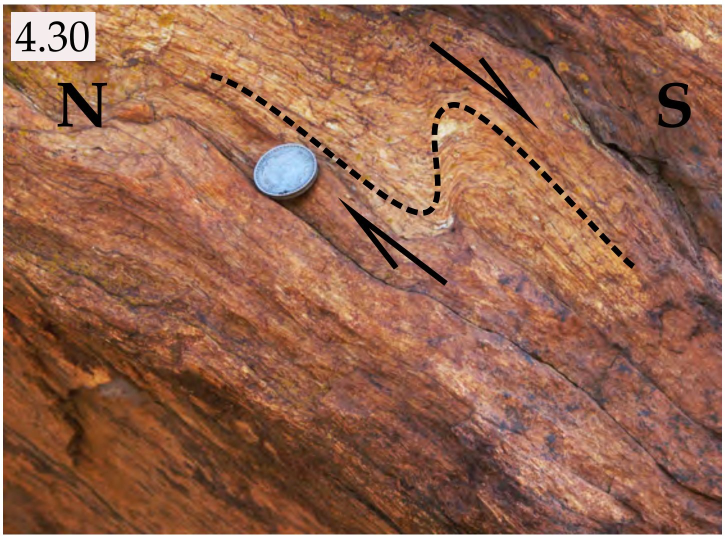
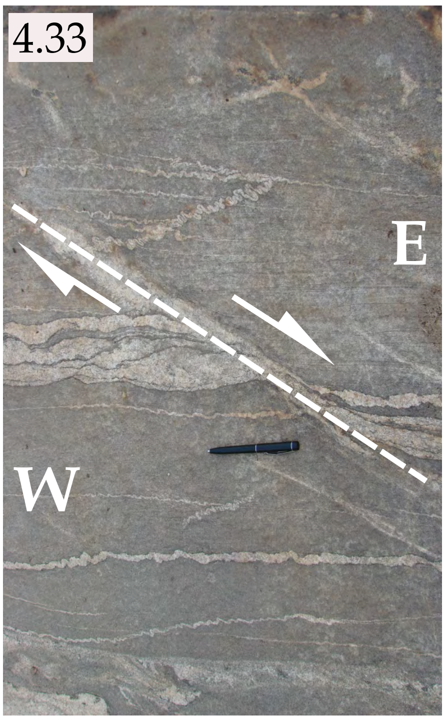
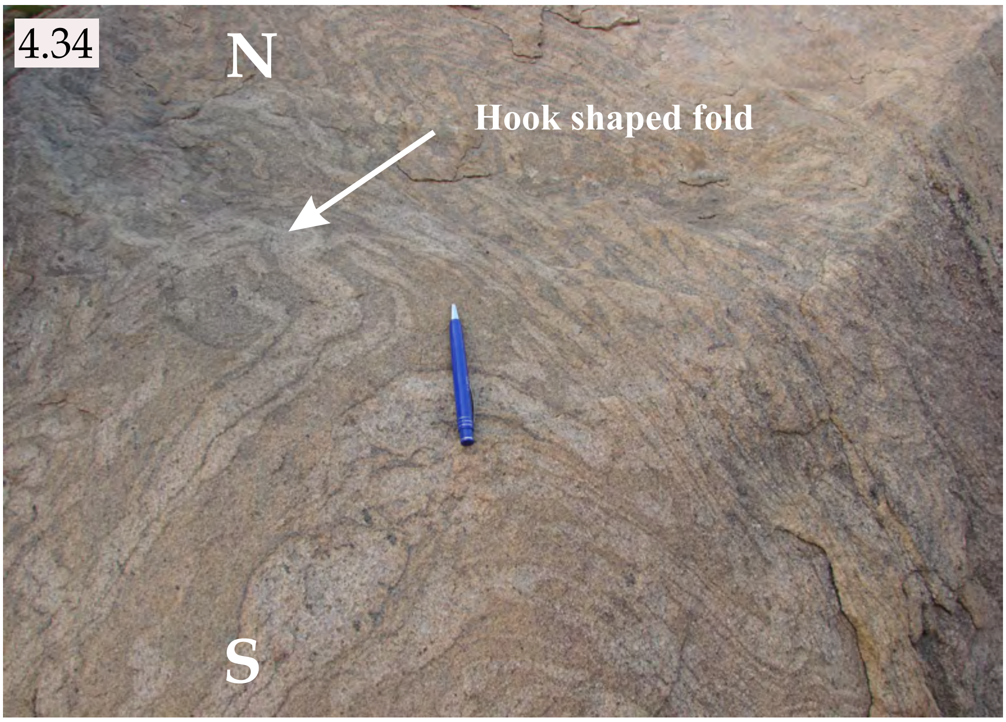


Fig. 4.24: Detailed map of the river bed south of Rengali dam showing detailed structural features in the form of folds and foliation development in Subdomain 3 of the Central Gneissic Belt. The dolerite dyke emplaced along the NNE trending sinistral shear plane shows mutual overprinting relationship with respect to the pegmatite dyke emplaced parallel to the WNW trending dextral shear. Also note development of conjugate shear planes displacing mafic layers in gneiss and boudin development indicating E-W extension.

Northern Supracrustal Belt
Field photographs of the Fig. (4.25) Steep southerly dipping foliation developed at high angle to bedding and development of down-dip mineral lineation. (4.26) S-C fabric developed in quartzite mylonite indicating top-to-the-north slip sense. (4.27) Exposed gneissic basement showing steeply plunging reclined fold pattern. (4.28) Leucosomal layer showing two generation of folding.







Field photographs of Fig. (4.29) Pebble elongation lineation in a sheared conglomerate plunging steeply due south west. (4.30) Asymmetric, northerly verging minor folds developed in quartzite mylonite showing top-to-the-north shear sense. (4.31) Steep northerly plunging reclined fold developed in sheared quartzite of the Barkot Shear Zone. (4.32) Sinistral shearing and offset in migmatitic gneiss within Riamol Shear Zone. (4.33) NW-SE trending dextral shear plane displace layering in migmatitic hornblende gneiss. (4.34) Development of hook shaped fold in migmatitc gneiss due to fold interference.