3.1. Introduction

The present study area forms a small corridor in the southern margin of the CSZ occurring between Namakkal in the north and Mohanur in the south and would hereafter be described as NMC (Fig. 3.1). It was a great opportunity to examine and study fresh outcrops of recently exposed rail cutting section along this corridor. Interestingly, the section trends north-south nearly orthogonal to regional trend of the rocks exposing a natural geological cross section over a length of ~6 km between Namakkal and Mohanur, around Anniyapuram, north of Cauvery river course in the south central part of the CSZ. The main focus of the present study is along the newly dug Rail cutting section. The Rail cutting section presents a variety of lithological assemblages dominantly of mafic-ultramafic complexes and the intrusives of younger granitoids. The important rock units in the region comprise mafic-ultramafic rocks, charnockitic rocks, hornblende gneisses, Banded iron formations, cherty bands and plagiogranites/trondhjemites. The mafic-ultramafic rocks include two–pyroxene granulites, metagabbros, amphibolites, peridotites, hornblendites, pyroxenites, serpentinites and minor amounts of feldspathoidal gneisses. These rocks are intruded by a chain of E-W aligned, Neoproterozoic granitoid plutonic rocks in the southern margin of the section (Nathan, 2001). The entire section forms the eastern extension of Palghat–Cauvery shear zone (PCSZ). All the lithological contact zones are, in general, highly sheared rocks with intense mylonitization. All the rocks trend WNW-ENE and dip predominantly northwards with gentle to moderate angles. However, the lithological contacts show often steep angles (60°-70°). These rocks show regional isoclinal to tight fold structures with gentle plunges both to east and west, but dominantly to east. At several places, the foliations preserve gentle
(10°-20°) dips suggesting the early fold structures to be of recumbent nature. Intensely folded and deformed chert bands are also recorded. Banded magnetite quartzites occur in the form of thin horizons co-folded with other mafic granulites. Pyroxenites and hornblendites occur mostly in the form of small lenses within the mafic granulites. Regionally, the two-pyroxene granulites represent marker horizons reflecting the isoclinal fold pattern in the region. The folds show varying thickness in the hinge regions and are highly stretched and extended in the high strain zone. However, fold plunges remain same in the orientation but the plunge values vary.

The chromiferous, layered Sittampudi anorthosite (2.91Ga, Bhaskar Rao et al., 1996; 2.45Ga, Rammohan et al., 2012) occurs about 40km west and the recently reported Devanur and Manamedu ophiolitic complexes occur to the east of Namakkal (outside the mapped area). Drury et al. (1984) noted Proterozoic dextral oblique slip movement along the CSZ and connected this to the post Cuddapah shear and thrust system along the eastern margin of Cuddapah basin and the Eastern Ghats Granulite Terrane. Based on regional structural mapping and the behaviour of stretching lineations, all the rock units of the region are interpreted to have been subjected to dextral transpressional tectonic regime, akin to modern collisional orogens (Chetty and Bhaskar Rao, 1998; Chetty and Bhaskar Rao, 2006a, 2006b).

3.2. Regional geological setting

The regional structure and the finite geometry of the eastern part of the CSZ are inferred from 1:250,000 scale Landsat TM imagery. Many large-scale structural features such as shear zones, fold patterns, elliptical closed structural forms and the regional orientations of structural trends are interpreted. The shear zones are delineated from the zones of closely spaced lineaments. The structural trends mapped from satellite images, in general, correspond to the gneissic foliations (S1), in the field presumably parallel to bedding and/or compositional layering. The interpretation from satellite data, therefore, led to a regional
tectonic map (Fig. 3.1). The map pattern suggests that the entire region preserves ‘high and low strain areas’. However, strain partitioning is conspicuous and results in a network of relatively higher strain belts (Chetty and Bhaskar Rao, 2006). The shear zones are characterized by mylonites, phyllonites, augen gneisses, and high asymmetric folds and associated well developed mineral stretching lineations. The shear zones envelop large fold dominated domains of relatively low strain. The prominent shear zones include: the boundary shear zones of Salem–Attur (SASZ), and Cauvery–Tiruchirapalle (CTSZ) and a set of sigmoidal shear belts connecting the boundary shear zones. The SASZ is an east–west trending 2–3 km wide zone along the Vasishta river valley between Salem and Attur and extends further east. It is characterized by steep southerly dipping mylonite and ultramylonites. Although gentle to moderate stretching lineations are common, steep plunging lineations are noted locally. Chetty and Bhaskar Rao (1998) described an excellent example of an outcrop at Belur, where both shallow and steep lineations are recorded in the same outcrop. The curvature of axial planar foliations swerving in to the SASZ in the region suggests dextral strike-slip shearing. Along the SASZ, extremely high aspect ratios (typically 1:20) indicate steep strain gradients. The CTSZ represents a near east west trending, 8–10 km wide zone where foliations dominantly dip moderately to the north. The CTSZ consists of a number of sub parallel shear zones characterized by highly deformed mafic-ultramafic rocks, which represent the present study area ‘NMC’. Profuse stretching lineations with consistent sub horizontal eastward plunges occur all along the CTSZ implying a dominant strike slip movement. Deformed younger granitoids (700–500 Ma) occur along this zone. Kinematic analysis is rendered difficult due to the complexity of mesoscopic scale markers owing to extensive melting, migmatisation, granite emplacement, retrogression and alteration. However, considering regional fold styles, direction of foliation fabrics and the nature of stretching lineations, it has been inferred that the rocks have been subjected to dextral trans-
pressional tectonics (Chetty and Bhaskar Rao, 2006). The sigmoidal shear belts connecting the marginal shear zones are relatively narrow (typically! 0.5 km wide) and show sub-vertical planar fabrics.

Two events of major deformation were identified in the area. The D1 structures consist of at least two events of progressive deformation that produced near coaxial refolded isoclinal folds (F1-F1a). The regional pattern of D1 finite strain is quite heterogeneous with
most strain concentrated along the boundary and sigmoidal shear zones. The Palghat-Cauvery Shear Zone (PCSZ), at the northeastern margin of the Madurai Block, is occupied mostly by supracrustal assemblages that occur as swaths.

Mylonitic rocks and mineral assemblages in the MBSZ have yielded Rb/Sr biotite, Sm/Nd garnet and U/Pb monazite ages between 0.7 and 0.5 Ga (Bhaskar Rao et al., 1996; Meissner et al., 2002; Ghosh et al., 2004). However, around Salem, domains of finite strain the biotites in basement gneisses yield 2.3–2.2 Ga ages. These are interpreted as the time of stabilization of late Archaean crust following a D1–M1 event. Younger, syn-to late kinematic granite, alkali syenite and ultra-mafic plutons in the region give whole-rock Rb–Sr isochron ages between 800–500 Ma (Nathan et al., 2001), which is also supported by U–Pb zircon age data on granitoids (Ghosh et al., 2004). Wickham et al. (1994) have described the effects of retrogression related to mantle derived CO2 and rich hydrothermal fluids along the Salem–Attur shear zone.

3.3. Geology and Structure of NMC

Fig. 3.2 shows structural interpretation of the Namakkal- Mohanur corridor from the Landsat images on 1:50,000 scale. These interpretations have been checked in the field and structural measurements like foliations, fold plunges and minereal stretching lineations are measured. The important rock types in the region are variably retrogressed charnockitic gneisses, mafic-ultramafic associations, banded iron ore formations and Neoproterozoic granitoids. Regional fold patterns show isoclinal nature with the exposures of rootless hinge regions between Namakkal and Mohanur. The fold plunges show gentle to moderate values both to the east and west. The foliations vary in their dip, mostly northward, with moderate to steep values. The foliations are steeply dipping towards north in a wide shear
zone at the contact with the granitoids. The foliations in granitoids represent plutonic fabrics in different orientation, with lineations predominantly plunging northwards. The study area of rail cutting section cuts across the shear zone orthogonal to the structural fabrics as shown in the Fig. 3.2. The fold structures within the shear zone show tight-isoclinal folds, often exposing the fold hinges parallel to the shear zone boundaries. The regional folds to the east of Namakkal show broad synformal structures plunging eastwards.
3.4. Deformational history

The complex deformational history in the region can be explained in terms of superposition of essentially two finite strain patterns referred to here as D1 and D2. The regional map pattern with reference to foliation trajectories (Fig. 3.2) reflects predominantly D2-strain that shows considerable partitioning. The zones of steep strain gradients constitute the shear zones described above. Regions of E-W elongated fold forms represent regional antiforms and synforms. A general observation is that the shear zones in the region are related to D2 strain. The following summarizes the characteristics of the D1 and D2 deformational events and associated structures.

The D1 structures consist of at least two events of progressive deformation that produced near coaxially refolded isoclinal folds (F1–F1a) that trend WNW-ESE. The resultant axial planar foliation is referred to here as S1, which corresponds to the particularly east of Namakkal. Regional E-W trending refolded isoclinal fold structures (F1–F1a) are well defined by two-pyroxene granulites and banded magnetite quartzites. Shallow dipping S1-fabrics and down-dip lineations are often recorded in the hinge regions of F2 metamorphic gneissic foliation. On a regional scale, the S1-foliation trends are near parallel to the WNW-ESE trending shear zones in the region. The D1 fabrics described here are well preserved, based on our field observations, at several places showing low D2 strain, folds. Numerous isoclinal intrafolial folds occur, at the outcrop scale, with hinges parallel to the L1 lineations and sub horizontal axial planes. Mineral lineations (L1) as well as other concomitant structures such as boudinages along the competent layers such as pyroxenites, hornblendites, websterites, peridotites which could be related to a phase of D1 extension, are also recognisable on mesoscopic scale outcrops. The boudinage structures seem to have been developed in the limbs of the F1 isoclinal folds. The L1 fabrics have no consistent regional orientation, but show a progressive reorientation to become parallel to L2 lineations in D2
shear zones where a distinction between L1 and L2 is often rendered difficult. It is interpreted that the D1 event included a dominant north-south shortening with a possible component of vertical shortening.

The regional pattern of finite strain is quite heterogeneous with most strain concentrated along the shear zones. Within these high strain zones, the S1 plane is reworked and/or transposed into new penetrative, steep mylonitic foliation (S2). The L1 stretching lineations are progressively reoriented and replaced by the pronounced L2 shallow plunging lineations consistent with the development of S–L tectonites (Flinn, 1965). The L2 lineations are mostly north or north-east plunging. Away from high strain zones, the D2 event is manifest in refolding of F1 isoclinal folds leading to kilometer scale elliptical (F2) folds. The F2 folds are mostly non-cylindrical with gentle to moderate easterly plunges. While in high strain zones, rigid body rotation fabrics, shear band structures and intense local folding associated with pinch and swell structures are common. All the evidence described above suggests that D2 deformation is a combination of (i) pure shear associated with north-south shortening and (ii) simple shear together with dextral strike slip shearing. The field observations are consistent dominant dextral shearing. In general, finite strain pattern involves both N–S shortening and dextral shearing together reflecting a dextral transpressive tectonic regime.

3.5. Google image of NMC

Google earth image (Fig 3.3) shows three prominent features, N-S trending rail cutting section of the Namakkal-Mohanur Corridor, WNW-ENE trending bands of mafic-ultramafic complexes around Anniyapuram and the Cauvery river course in the south western part of the image. In general, the structural fabrics in the region seem to be trending NW-SE with a few well preserved and isolated rootless fold hinges south of Namakkal. The mafic-ultramafic bands show closely spaced lineaments suggesting that the rocks are highly
sheared, coinciding with the major PCSZ, the southern boundary of the CSZ. On either side of these bands the general foliation of the rocks seems to be conformable with the mafic-ultramafic rocks.

Fig. 3.3: Google image showing the N-M corridor displaying WNW-ESE trending mafic-ultramafic bands. Note the location of N-S trending rail cutting section which is orthogonal to the structural trends providing ideal geological cross section.

3.6. Rail Cutting Section

The rail cutting section forms a crucial part of the NMC and exposes a variety of lithologies and structural patterns. The Rail cutting section has been geologically and structurally mapped on 1:10000 scale (Fig.3.4). Several large scale sketches have been drawn wherever key structural features are exposed. The mapping has been mostly based on geological sectional views on either side of the section facing either west or east.

The important rock units are: mafic-ultramafic assemblages, amphibolites, hornblende gneisses, charnockites, granitoids and pegmatites. Mafic-ultramafic assemblages include Pyroxenites, gabbros, peridotites, hornblendites, serpentinites and occur in the form of bands,
lenses and pods. These are intercalated with minor thin bands of folded magnetite-chert (Fig 3.5) and plagiogranite/trondhjemite. All these rocks trend WNW-ESE and are isoclinally folded with gentle to moderate dipping axial planes to north. It is also interesting to note the presence of near horizontal or gently dipping foliations to north (10°-20°) at many places indicating that the rocks witnessed south verging recumbent folding in the early stages of deformation. The metamorphic gneissic foliation is mostly superimposed by subsequent mylonitic fabrics obscuring the early metamorphic gneissosity. Presence of tectonic melanges is a striking feature in the area. Based on our field observations, a series of north dipping thrust/shear zones, associated with imbricate thrusting are interpreted from the section (see Fig. 3.4).

Fig. 3.5: Field photograph showing folded magnetite-chert bands
Fig 3.4: Detailed geological and structural map of N-M corridor
Fig. 3.6: Geological and structural map of N-M Corridor. Notice WNW-ENE trending structural fabrics marked by north dipping thrust planes.
For the sake of convenience and brevity, the entire rail cutting section has been divided into 6 zones based on distinct lithological assemblages and the presence of important shear zones (Fig. 3.6). Each zone displays characteristic predominance of distinct lithological units and the zones are described below: Hornblende gneiss-Pegmatite association (Zone I), Charnockite-Pegmatite association (Zone II), Charnockite-Pyroxenite association (Zone III), Granulite (Felsic & Mafic)-Amphibolite-Pyroxenite association (Zone IV) and Metagabbro-Amphibolite-Pegmatite association (Zone V). The lithological and structural details of each zone are described separately below.

3.7. Zones

3.7.1. Zone I

The Zone I represent the northern most segment of the rail cutting section. It has got a width of about 1km striking WNW-ENE. The major rock types in the zone include hornblende gneisses, amphibolites, hornblendites and a variety of mafic and felsic granulites (Fig.3.7a). The mafic and felsic granulites occur as pods and lenses surrounded by amphibolites and hornblende gneisses. Mafic-ultramic rocks are intensely folded and are intruded by plagiogranite/trondhjemite at several mostly along the foliation planes (Fig. 3.8a). These are cut across by younger pegmatite intrusives. The pegmatites occur both along and across foliation fabrics. The poles to the foliation in the stereo plot (Fig 3.7c) show dips on either side with moderate values suggesting that the rocks strike nearly east-west and are isoclinally folded. The lineations show gentle to moderate plunges either to east or west. The rocks often show recumbent fold structures with in highly weathered gneissic rock in association with pyroxenites, which are later intruded by 30-50 cm wide horizontal pegmatite veins (Fig 3.8b). Some of the thin pegmatite veins are seen cutting across intensely folded mafic-ultramafic rocks (Fig 3.8c). Mafic granulites are often intensely foliated and are intruded flat lying
Fig. 3.7: (a) Geological Map, (b) Structural cross section (c) Stereo plots
pegmatite veins (Fig 3.8d). These observations suggest that the majority of the pegmatites have possibly intruded along the thrust planes. Pegmatites vary in their thickness and often show enechelon folding (Fig 3.8e). At some places the pegmatites show displacements suggesting post emplacement brittle shearing (Fig 3.8f).

With a view to demonstrate the clear relationship of lithological assemblages and the mesoscopic structural features, some of the field photographs have been traced to show pencil sketches for understanding their mutual relationships. Fig. 3.9a shows a sectional view of isoclinal refolded folds in banded gneissic rocks along with the dark bands of pyroxenites. Structurally, these may be interpreted that they are genetically thrust related imbricate structures. The pegmatite observed in the section occurs as a lensoid body intruding the host mafic gneisses. Often, pegmatites are seen cutting across the structural fabrics of folded mafic gneisses (Fig 3.9b). In the upper part of the photograph thin pegmatite veins are seen as folded structures along with the host rocks. A broad recumbent fold structure defined by highly sheared alternate bands of mafic-ultramafic rocks is well displayed in a west looking sectional view (Fig. 3.9c). A conformable pegmatite vein with the foliation plane in the bottom part of the photograph and a thin pegmatite vein cutting across the banded structures in the upper part of the photograph are well preserved. Fig. 3.9d represents northern continuation of the previous field photograph exhibiting the continuity of the structural fabrics. Further continuity of structural pattern towards north but with diverging branches of pegmatite veins cutting across the foliation fabrics can be seen (Fig. 3.9e). Continuation of recumbent fold structure and the different forms of intrusive pegmatite veins are well in displayed (Fig. 3.9f).

All the above field observations have been considered for constructing the structural cross section across the Zone I (Fig. 3.7b). South verging thrust planes associated with northerly dipping refolded folds can be interpreted from the section. Large recumbent
structures with near horizontal planes are inferred. A few southerly dips are also recorded which may represent part of hinge zones of broader recumbent folds emerging from north.

Fig. 3.8: Zone-I field photographs: (a) West looking sectional view of folded mafic-ultramafic rocks. Notice the intrusion of plagiogranite along the foliation plane. (b) Recumbent folded structures in highly weathered gneissic rock intruded by pyroxenites, which are further intruded by 30-50 cm wide horizontal pegmatite veins. (c) Folded mafic-ultramafic rocks showing southerly dipping shear zones, later intrusions of thin pegmatite veins across folded rocks. The total width of photograph is about 4 meters. (d) Sectional view of southerly steeply dipping intensely foliated mafic granulites, which are further intruded by flat lying pegmatite veins. Notice the thickening of the hinge zone as well as horizontal shear zones cutting across the rocks. (e) Irregular shaped en echelon pattern and pinch and swell structures are seen in some of the pegmatites intruding the mafic gneissic rocks. Note the sharp contacts between pegmatite and the host rocks. (f) Pegmatite veins are some times displaced within the mafic granulites by brittle shearing.
Fig. 3.9a: A Field photograph and the sketch showing west looking sectional view of folded mafic-ultramafic rocks. Notice the intrusion of plagiogranite along and across the foliation plane.
Fig. 3.9b: Field photograph and the sketch showing recumbent folded structures in highly weathered gneissic rock intruded by pyroxenites along with 30-50 cm wide horizontal pegmatite intrusions.
Fig. 3.9c: Field photograph and the sketch showing folded mafic-ultramafic rocks with southerly dipping shear zones, later intrusions of thin pegmatite veins across folded rocks. The total width of photograph is about 5 meters.
Fig. 3.9d: Field photograph and the sketch showing sectional view of southerly and steeply dipping intensely foliated mafic granulites, which are further intruded by flat lying pegmatite veins. Notice the thickening of the hinge zone.
Fig. 3.9e: Field photograph and the sketch showing irregular shaped en echelon pattern and pinch and swell structures in some of pegmatites intruding the mafic gneissic rocks.
Fig. 3.9f: Field photograph and the sketch showing the sectional view of folded mafic gneissic rocks intruded by thin as well as wide pegmatite intrusions.
3.7.2. Zone-II

Fig 3.10a shows the geological and structural map of Zone II with major rock units such as mafic and felsic granulites, pyroxenites, serpentinites, hornblendites and charnockites, which are intruded by plagiogranites/trondhjemites and pegmatites. The rocks trend WNW-ENE with dominant southerly dips. The pyroxenites occur both as bands and lensoid bodies. The foliations in this zone, dip predominantly to south with values ranging between $40^0-70^0$. A few south plunging lineations are also recorded. Fig. 3.10c shows stereo plots of poles to foliation planes and lineations. All the foliation poles are plotted in the north eastern sector of the stereo plot suggesting that the dips are mostly to south west with moderate to steep values. All the lineations are clustered showing moderate plunges to south.

The intrusive plagiogranites/trondhjemites are well exposed in some of the sections (Fig. 3.11a). Serpentinites are mostly recorded in the proximity of thrust planes (Fig. 3.11b). Fig. 3.11c shows sheeted jointing in charnockites with gentle dip to south. A thin pegmatite vein is also observed steeply dipping; cutting across these rocks (Fig. 3.11d). A southerly dipping thrust contact between serpentinite and the mafic granulite and associated tectonic mélange within the serpentinite body is well exposed in this section (Fig. 3.11e).

The charnockites are highly deformed exhibiting sheeted and closely spaced joint planes (Fig. 3.11f). Mélange like structures are common in Rail cutting section. For instance mixed fragments of coarse grained charnockites, pyroxenites and websterite are seen as a typical mélange structure (Fig. 3.11g). The contact between these fragments is intensely sheared. At many places, steeply dipping shear zones are also well exposed in contact with relatively undeformed rock units (Fig. 3.11h).

The structural cross section (Fig. 3.10b) shows refolded folds often resembling sheath fold geometries. It is interpreted here that these structures may form a part of regional hinge
Fig. 3.10: (a) Geological Map, (b) Structural cross section (c) Stereo plots
Fig. 3.11 field photographs: (a) Highly deformed plagiogranite/trondhjemite in mafic-ultra mafic rocks. Notice the intense fracturing within the plagiogranites/trondhjemite. (b) A wide zone of possible serpentinite with thin pegmatite vein. (c) Sheeted jointing in charnockites with gentle dip to south. A thin pegmatite vein dips northerly and cut across these rocks. (d) Sectional view of steeply dipping shear zones within the high grade gneiss (feldspathoidal synetic rock). (e) A southerly dipping thrust contact between serpentinite and the mafic granulite. Notice the presence of tectonic mélange within the serpentinite body. A closer view of steeply and southerly dipping thrust zone. (f) Sheeted and closely spaced jointing in charnockite.
zone, perhaps extending into recumbent fold geometry. Thrust planes dipping to north are also inferred which are associated with serpentinite outcrops.

3.7.3. Zone-III

Fig. 3.12a shows the geological and structural map of Zone III with major rock units including mafic and felsic granulites, pyroxenites, hornblendites, charnockites and metagabbros. The rocks trend WNW-ENE with a dominant northrely dips. All the lineations are also plunging north and north east. Poles to foliations and lineations are plotted stereo plots (Fig. 3.12c). The foliation poles show their maxima in the southern sector suggesting the predominant moderate to steep dips of foliations to north. The lineations show moderate to steep plunges to north and north east.

Many complex structures associated with different lithologies have been mapped in this zone. Many of the rock formations are garnetiferous. The garnet varies in their size from few millimetres to centimetres. A large garnet boudin structure of segregated garnet grains within metagabbro is well exposed (Fig. 3.13a). Some of the garnetiferous rocks are highly foliated (Fig. 3.13b). At several places, intensely deformed chert bands are also seen cutting across the metagabbros (Fig. 3.13c). Some of the hinge portions of isoclinal folds are well preserved
at a few places in garnetiferous rocks showing hinge migration (Fig. 3.13d). Foliation wrapping around the well developed euhedral crystals of garnet is a common feature in feldspathic gneissic rocks (Fig. 3.13e). Fig. 3.13f shows profusely developed mylonitic fabrics in high grade gneissic rocks suggesting they may represent the sites of shearing. Some of the refolded fold structures and parasitic folds of mafic bands are well preserved in foliated charnockitic gneisses. They also show near horizontal plunges which are well exposed at several places (Fig. 3.13g, h & j). Mafic lenses comprising mostly websterite and pyroxenites are recorded at several places in association with shear zones. Often, they are highly deformed showing circular, highly elongated lensoid bodies which are enveloped by shear zone fabrics (Fig. 3.13i). At some places, the presence of mafic lenses indicate top to the south kinematic displacement in a sectional view (Fig. 3.13k). A well developed mesoscopic shear zone cutting across mafic bands within the charnockite is also recorded (Fig. 3.13l).

The structural cross section interpreted for Zone III (Fig. 3.12b) shows broad thrust related refolded fold structures indicating its emergence from north. This fold occurs between two inferred south verging thrust planes. The lensoid bodies of hornblendite and pyroxenites occur in the core of the broad aniformal fold. All these field observations imply that these structures are developed in association with south verging thrust planes.
Fig. 3.12: (a) Geological Map, (b) Structural cross section (c) Stereo plots
Fig. 3.13: Field photographs: (a) A large boudin structure of aggregate of garnet grains within the high grade gneissic rocks. (b) Foliated garnetiferous two pyroxene granulites. (c) High grade garnetiferous felsic gneissic rock showing the intrusions of chert bands. (d) A fold hinge zone showing the deformed fabrics within the garnetiferous charnockite. The plunges are into the wall and away from the viewer. (e) Note the horizontal mylonitic foliation in the host rock and also seen rotated enclaves showing south verging kinematic displacement. Flat lying gneissic charnockitic rocks with mafic as well felsic enclaves. (f) Banded gneissic rock showing annealed mylonites.
Fig. 3.13: Field photographs: (g) Parasitic folds of mafic bands within the foliated charnockite. (h) Well developed isoclinal folds with thickened hinges and horizontal fold axis. (i) Mafic boudins and euhedral shaped garnet phenocryst within the highly foliated garnetiferous charnockite. (j) Complex folds associated with shearing within the high grade gneissic rock. (k) Websterite enclave showing the kinematic sense within the charnockites. (l) Shear zones and deformed folds of mafic bands within the charnockites.
3.7.4. Zone-IV

Major rock units in Zone IV include mafic and felsic granulites, metagabros, pyroxenites, hornblendites, hornblende gneisses, amphibolites and plagiogranite/trondhjemite (Fig. 3.14a). The rocks trend WNW-ENE with a dominant northerly dips. The lineations are plunge towards north and north east with gentle to moderate values. Fig. 3.14c shows stereo plots of poles to foliations and lineations. The foliation poles show their maxima in the southern sector suggesting the predominant moderate to steep dips to north. The lineations also show moderate to steep plunges to north and north east.

Field observations show that the development of degree of intensity of foliations within the mafic-ultramafic rocks implies the intensity of deformation. At several places, steeply dipping foliated mafic-ultramafic rocks are recorded. They are also intruded by thin veins of plagiogranite/trondhjemite (both horizontal and vertical). The presence of mélangé structure in the south eastern segment is conspicuous (Fig. 3.14a). Refolded isoclinal fold structures with near horizontal fold axis within garnetiferous gneissic rocks are common. The hinge zones are exaggerated with varying plunge from horizontal to gentle nature suggesting that it could be a possible sheath fold structure (Fig. 3.14b). Some suspected obsidian fragments within the mafic granulites are also recorded (Fig. 3.14c). Pyroxenites occur in the form of steeply dipping dykes (Fig. 3.14d) as well as lensiod bodies (Fig. 3.14f) in association with other mafic rocks. At some places, folded mafic bands within the weathered garnetiferous gneissic rocks are seen (Fig. 3.14e). The structural cross section interpreted for the Zone IV (Fig. 3.14b) shows isoclinal folds dipping mostly to north preserving synformal fold hinges. Two important south verging thrust planes are inferred and are associated with mostly hornblendite and hornblende gneisses.
Fig. 3.14: (a) Geological Map, (b) Structural cross section (c) Stereo plots
Fig. 3.15: Field photographs: (a) Steeply dipping foliated and sheared mafic ultramafic rocks. Notice the presence of thin veins of plagiogranite/trondhjemite. (b) Refolded isoclinal fold structures with near horizontal fold axis with in garnetiferous gneissic rocks. The hinge zones are transformed with varying plunge from flat to gentle nature suggesting that it could be a possible sheath fold structure. (c) Suspected obsidian fragments within the mafic granulites. (d) Steeply dipping Pyroxenite dykes. (e) Folded mafic bands within the weathered garnetiferous gneissic rocks. Notice the presence of thin feldspathic veins. (f) Lensoidal bodies of pyroxenites within the mafic rock association.
3.7.5. Zone-V

This zone is an important segment representing the southern most part of the rail cutting section. The lithological associations and the structural features are very complex compared to other zones. This zone is unique with the presence of a major shear zone at the southern contact with a chain of small plutons of Neoproterozoic granitoids. The other important rock units are amphibolites, mafic and felsic granulites, metagabbros, pyroxenites, hornblendites, hornblende gneisses, peridotites and plagiogranite/trondhjemite (Fig. 3.16a). The rocks trend WNW-ENE with a dominant northrely dips. There are a few north-south trending foliations with westward dips indicating the presence of antiformal fold hinges. The stereo plots show (Fig. 3.16c) all the lineations are plunging either east or west and a few are southerly plunging. The mappable folds show the fold closures facing the east or west. The foliation poles show their maxima in the southern sector suggesting the predominantly moderate to steep dips to north. The stretching lineations also show moderate to steep plunges to north and north east. A variety of structural features are also well preserved in this segment. Fig.3.16b shows complex fold styles associated with north verging thrust and imbricate structures. Several important large scale sketches have been drawn to highlight the mutual relationships of distinct rock types and different structural styles. They include (i) A thin vein of plagiogranite/trondhjemite cutting across amphibolites (Fig. 3.17a), (ii) Distribution of veins of pyroxenite and peridotite within the hornblende matrix (Fig. 3.17b), Sheath fold structures and the pegmatite veins (Fig. 3.17c), Plagiogranite/trondhjemite in the form of lenses and banded structures within the amphibolites (Fig. 3.17d), Isoclinally folded sequence of amphibolite, pyroxenite and hornblende gneisses with gentle plunges to south east (Fig. 3.17e), Isoclinally folded sequence of mafic and felsic granulites, amphibolites and hornblende gneisses’ (Fig. 3.17f).
Two critical photographs of sectional views that represent complex structural styles are selected for a detailed structural analysis from this part of the rail cutting section. A west looking structural section shows interpreted structures and kinematic displacements (Fig. 3.18a). Isoclinally folded sequence of metamorphic gneisses with hinge line migration (left part) and imbricate-duplex structures and complex styles of folding (right part) are well displayed. The presence of sheath fold structures of different dimensions and geometries can also be observed. Fig. 3.18b is another west looking sectional view showing the development of complex structural styles within the matrix of the amphibolite. The presence of the extensional shear zones (left margin), recumbent fold structures (lower margin), folding and hinge migration (right margin), complexly deformed fold structures often representing sheath fold geometries are associated with near vertical extensional shear zones. The presence of sheath folds of different sizes is well exposed in this section. Well preserved and exposed possible sheath fold structures associated with gently and southerly dipping thrust zones are recorded in the section (Fig. 3.19f). At some places, some of the sheath folds are criss-crossed by feldspathic veins (Fig. 3.19a). The younger intrusive of plagiogranite/trondhjemite in the form of veins cut across highly sheared mafic-ultramafic rocks (Fig. 3.19b). As described earlier, gently dipping and north verging thrust planes are preserved in pyroxenites and amphibolites at a few places (Fig. 3.19c). These are further intruded by thin veins of plagiogranite/trondhjemite along the foliation planes. These are associated with the presence of parasitic folds which are helpful in kinematic interpretations. It has been observed that thin plagiogranite/trondhjemite veins within the mafic-ultramafic rocks have been folded together (Fig. 3.19d). Thin veins of plagiogranite/trondhjemite are often intensely folded in association with mafic bands exhibiting ‘Z’ style of folding suggesting antiformal closures.
Fig. 3.16: (a) Geological map, (b) Structural cross section (c) Stereo plots
indicating north verging thrust (Fig. 3.19e). Phlogophite bearing mafic rocks occur as enclaves within the mafic rocks and are recorded at some places (Fig. 3.19g). Highly deformed amphibolites associated with feldspathic veins are clustered at some places. Well defined north dipping shear zones preserving relict horizontal foliations and deformed sheath fold structures are well preserved in these amphibolites (Fig. 3.19h). In the proximity of north dipping shear zones, mafic granulites show feldspathic veins displaying steep foliations (Fig. 3.19i). Antiformal fold hinges defined by plagiogranite/trondhjemite veins are well preserved in some of the mafic-ultramafic rocks (Fig. 3.19j). At some places, high grade gneissic rocks are highly weathered preserving the banded and competent folded pyroxenites in the form of
Fig. 3.18 (a): Field photograph and the sketch showing west looking structural section showing isoclinally folded sequence of metamorphic gneisses displaying hinge line migration (left part), imbricate-duplex structures and complex styles of folding (right part). Notice the presence of sheath fold structures of different dimensions and geometries.
Fig. 3.18b: Field photograph and the sketch showing view showing the development of complex structural styles within the matrix of the amphibolite. Notice the presence of the extensional shear zones (left margin), recumbent fold structures (lower margin), folding and hinge migration (right margin), complexly deformed fold structures often representing sheath fold geometries associated with near vertical shear zones.
Fig. 3.19 Field photographs: (a) Folds of possible sheath geometries criss-crossed by feldspathic veins in the host synetic rocks. (b) Highly sheared mafic- ultramafic rocks traversed by plagiogranite veins. (c) Gently dipping and north verging thrust planes occupied by thin veins plagiogranites. Note the presence of parasitic folds showing top to north. The rock types are dominated by pyroxenites and amphibolites. (d) Thin folded plagiogranite veins within the mafic ultramafic rocks. (e) Sectional view showing south dipping foliations. Veins of plagiogranite associated with mafic bands exhibit ‘Z’ style of folding suggesting antiformal closure to west and synformal to east and indicating north verging thrust. (f) Tight isoclinal folds with possible sheath geometry associated with gently and southerly dipping thrusts.
assymetrical folds associated with sub vertical shear zones (Fig. 3.19k). It is common to come across the association of mafic rocks with some of the south verging shear zones in this part of the section (Fig. 3.19l). The presence of tectonic mélanges is striking feature displaying the chaotic assemblage of fragments of pyroxenites, websterites, amphibolites and syenitic gneisses (Fig. 3.19m). Complex fold structures including sheath fold geometries are well preserved within the mafic granulite (Fig. 3.19n). Thin veins of plagiogranite/trondhjemite have been intensely folded at a few places, often associated with south verging thrust planes (Fig. 3.19o). Tight isoclinal folds are well displayed within the amphibolites in association with south verging thrust (Fig. 3.19p). These field observations described above suggest that the south verging thrust planes are marked by intense deformation.
Fig. 3.19 Field photographs: (k) Highly weathered high grade gneissic rocks preserving the banded and folded pyroxenites. Notice the presence of sub vertical shear zones and highly asymmetrical folds. (l) South verging shear zones comprising mafic rocks. The host rock represents highly weathered TTG gneiss criss-crossed by thin feldspathic veins. (m) Tectonic mélange showing the fragments of pyroxenites, websterites, amphibolites and synetic gneisses. Complexly criss crossed by feldspathic veins. (n) Complex fold structures including sheath fold structure within the mafic granulite. (o) Intensely folded plagiogranite veins associated with south verging thrust. (p) North dipping tight isoclinal folds within the amphibolites showing south verging thrust.

3.8. Structure

Detailed structural mapping of the rail cutting section on scale 1:10,000 reveals the preservation of early metamorphic gneissic foliation at several places. These are
superimposed by secondary mylonitic fabrics well exposed mostly restricted to shear zones. The rocks in general trend WNW-ENE with dips prominently to north, varying from $20^\circ$ to $70^\circ$. These rocks are isoclinal refolded folds with plunges varying from $10^\circ$ to $30^\circ$ dominantly to east. Mylonitic fabrics are distinctly observed along the shear zones that separate distinct lithological assemblages. Stretching lineations are mostly plunging northward with values ranging between $30^\circ$ to $65^\circ$. Form line trajectories are interpolated based on the structural measurements made from the rail cutting section and the surrounding isolated outcrops in the region. The width of the shear zone at the contact between the mafic ultramafic associations and granitoids is about 200 meters while the other shear zones are relatively narrow around 50 meters. All shear zones invariably dip towards north.

3.9. Regional cross section NMC

A regional structural cross section has been attempted based on the field observations from the entire rail cutting section and the adjacent regions. Fig. 3.20 shows a north-south, west looking structural cross section presenting a range of structural features displaying their geometries. The structures include foliation fabrics, fold styles, shear zones and interpreted thrust planes and associated imbricate structures. From north to south, the dominant structural features are inferred as recumbent structures in Zone I, folded curvilinear axial planes in Zone II, tight isoclinal fold structures in Zone III, very tight isoclinal folds in Zone IV and folded axial planes with near recumbency in Zone V. All the zones are separated by south verging imbricate thrust zones marked by mylonitic fabrics. It is also possible that all these imbricate thrusts are linked to roof and floor thrusts suggesting that they could be duplex structures. It is also possible that the folds often show sheath fold geometry. This kind of structural pattern is similar to structures described in a north-south cross section constructed for the area between Mahadevi and Manamedu Ophiolite complex, 25 km east of the present study area, described by Chetty et al (2011).
All the foliations like gneissic foliation and mylonitic foliation are plotted in stereo plots (Fig. 3.21a). The foliation poles are dominantly clustered in the southern sector indicating north and north easterly dips with values ranging from 20° to 80°, some of the poles also fall in north eastern sector indicating south westerly moderate dips. All the lineations including the fold plunges mesoscopic fold structures and stretching lineations are plotted in the stereo plots (Fig. 3.21b). The lineations are spread mostly in the northern sector but some of them are seen either in the eastern or in south eastern sector. The plunges vary from 20° to 60° in all the directions with the exception of the western sector.
Fig. 3.20: Regional north-south structural cross section along the rail cutting section showing south verging thrusts associated with mega duplex structures that show distinct lithological associations and fold styles.
Fig. 3.21: Stereo plots of planar and linear structural element from the rail cutting section.