Chapter - V

Stratigraphy
and
Correlation
Dharwar Craton has a number of volcano-sedimentary sequences preserved in the form of linear belts ranging in age from early (3.0 Ga) to late Archaean (2.7 Ga to 2.5 Ga). These belts are recognised as "greenstone belts".

The Dharwar Craton is divided into the western and the eastern tectonic blocks, based on the differences in the styles of evolution of the contained greenstone belts and also on basement cover relations and relative abundance of younger granites (Viswanatha and Ramakrishnan, 1976). The narrow N-S trending closepet granite is considered to be the dividing zone between the two tectonic blocks (Naqvi and Rogers, 1987).

The western block greenstone belts are of the Dharwar style (Shackleton, 1976) and referred to as secondary greenstone belts (Glikson, 1976), younger greenstones (Radhakrishna, 1976; Radhakrishna and Vasudev, 1977). Most of the western greenstone belts reflect younger proterozoic characters. The eastern block exhibits definite older attributes or features similar to the classic greenstone belts, i.e., keewatian type (Ramakrishnan and Swaminath, 1981). These are also known as "true greenstone belts" (Naqvi, 1981) "early greenstone" (Radhakrishna, 1976) and "primary greenstone" (Glikson, 1976). The eastern Dharwar Cratonic block (ED) contains numerous narrow greenstone belts dominated by volcanic rocks. The Peddavuru schist belt is one of the greenstone belts in the eastern Dharwar Craton. An attempt is made in this chapter to discuss the stratigraphy and correlation of the Peddavuru schist belt with the other eastern greenstone belts, taking lithological, structural and chemical information.
The Peddavuru schist belt is having the typical keewatian type (Ramakrishnan and Swaminath, 1981) of setting. The keewatian characters are:

The volcano-sedimentary belts of Dharwar Craton known as 'Schist Belts' are described as greenstone belts by Swaminath et. al., (1974) consequent upon conceptualization as greenstone belts in south Africa by Anhaeusser et. al., (1969). In view of their innate lithostratigraphic differences the greenstone belts of Dharwar Super group were classified into 'Dharwar type' (in western block) and keewatian type (in eastern block) by Ramakrishnan et. al., (1976) who also recognized another older group of schists and called them as high grade schists or older metamorphics or ancient supracrustals of super group (Swaminath et. al., 1976).

Stockwell (1973) divided the greenstone belts of Canada into lower volcanic group called keewatian and an upper unconformable sedimentary group called 'Timiskaming'; based on the studies in Abitibi belt of superior province in the same province they are called as 'yellow knife group A' and 'yellow knife group B' representatively. Subsequent detailed stratigraphic studies were carried out by Stockwell (1973) and Goodwin (1968). Though the Abitibi and Yellow-knife greenstone belts generally conform to the generalized successions in such belts i.e., volcanic rocks predominating towards the base and metasediments to the top yet there is no basis for direct stratigraphic correlation from one belt to another.
Ramakrishnan (1976) simply compared the ‘eastern block’ Kolar style greenstone belts with the keewatuab group of Abitibi belt because of their similarities i.e., volcanic–granitic dominated terrane. This need not imply that these belts were formed in same tectono-magmatic domains. In different cratons of the world there are ‘greenstone and greenstone belts’ ranging in time space lithology and tectonic setting and sites of intense geological activity under higher geothermal conditions and dynamics. However, the tectonic setting of greenstone belts is highly debated because rocks deposited at different tectonic setting are present side by side in these belts.

In the present thesis the term “Keewatin type” have been used based on Ramakrishna’s ideas that the eastern Dharwar block of Craton is volcanic dominant and endowed with rich gold deposits while the schist belts of western block are more & sedimentary dominated. Hence these analysis are made with the lower and upper sequences of Abitibi belt of Canada.

1. Absence of the basal conglomerate which reflects basement – cover relationship:

All the eastern greenstone belts do not exhibit any basement – cover relation ship. The moot point is that, no conglomerate is seen at the base of these belts.
2. Less Volcanic cycles are conspicuous:

The sedimentary cycles which are conspicuous in the western greenstone belts are negligible in the eastern greenstone belts. This is a major constrain in working out the stratigraphy. However, the volcanic cycles are common in eastern greenstone belts and they are established with the help of petrochemistry. The Mg nos point to the primitive and evolved nature of the volcanics. It is found that basic volcanics with higher Mg no (>60) gradually grade into volcanics having lower Mg no (<60) and again followed by volcanics of higher Mg no; and this cycle is repeated. These volcanic cycles are more in the lower and the middle stratigraphic levels and are comparatively less in the higher stratigraphic levels. Viewed in this context, the Peddavuru schist belt represents the higher stratigraphic level in Anhaeusser greenstone model as it has less volcanic cycles and the absence of primitive ultramafic dominant sequence.

3. Ultramafic component is less:

Ultramafic rocks are komatitic affinities are seen only in the lower stratigraphic levels of the eastern greenstone belts like Kolar and Ramagiri. In the present study area no ultramafics are exposed, thereby indicating the higher stratigraphic level in the triple division of classic greenstone belts of Anhaeusser et. al., (1969).
4. **Higher stratigraphic levels have meta sedimentary sequence:**

Meta-sedimentary rocks, mainly quartzite, BIF and bedded cherts are generally seen in the higher stratigraphic levels as seen in the Hungund and the Sandur belts. The presence of U-shaped banded iron formation in the southern part of the Peddavuru schist belt pointing to the higher stratigraphic level.

5. **Diapiric domal structure of the intrusive granitoids are common:**

Diapiric plutons forming domal features are best seen in the Ramagiri, Gadwal, Velligallu, Hungund, Grugunta and Kadiri belts. The morphology of domes reflects the various phases of tectonic activity. The diapiric intrusive granitiods show fabric parallel to the fabric in the schist belt with more intensity along the margins; this feature is best seen in Peddavuru schist belt. Anhaeusser et.al., (1969) (Fig-41) considered that diapiric plutons is one of the characteristic feature of classic greenstone belt.

6. **Granitoids are of intrusive nature and hold the enclaves of the schist belt components:**

All the granitoids in and around the eastern greenstone belts are intrusive in to the schist belts. The tongues and apophyses of granitoids in the schist belts of Ramagiri, Kolar, Kadiri, Gadwal, Jonnagiri, Peddavuru etc. are observed. Besides this, the components of the schist belts are present as enclaves in the adjoining granitoids of these schist belts.
7. The eastern greenstone belts are narrow and linear cut and swamped by the late to post tectonic granitoids:

This is another moot point which reflects the possible continuity and the lateral link of these belts. The narrow linear greenstone belts of Dharwar Craton represent different litho package associations and represent the preserved stratigraphic levels because of extensive granitic activity. Inspite of this many belts have common associations like bimodal volcanics based on this a correlation has been attempted. Their linear, ribbon like configuration indicates that they are relicts of once united major sequence. The present isolation is due to the intrusive granitoid activity.

8. Amygdaloidal features and pillow structures are common in basic volcanics:

Basic volcanics have both subaerial features in the form of vesicles, amygdales, etc., and submarine characters like pillows. Pillows of various dimensions are noticed in these belts. Amygdaloidal and pillow metabasalts are common in Peddavuru schist belt.

STRATIGRAPHY

Stratigraphy can be studied in three different styles i.e., Litho stratigraphy, Bio stratigraphy and Chrono stratigraphy. Litho stratigraphy is based on the lithological sequence, Bio stratigraphy is established based on the fossils present in the rocks and Chrono stratigraphy is based on the age of the
rocks determined by certain elements present in the rocks. In the absence of geochronological data, as is in the present study area the stratigraphy can be established by means of lithostratigraphy only.

The litho stratigraphic unit is distinguished and delimited on the basis of lithological characters.

Litho stratigraphy will have Supergroup, Group, Formation, Member etc. Two are more groups constitute a Supergroup. The hierarchy of formal lithostratigraphic units is as follows.

**Supergroup**

**Group**

**Subgroup (rarely used)**

**Formation**

**Member**

**Bed/Beds (rarely used as a formal unit)**

**Supergroup:** An assemblage of naturally related or associated group or groups and formations constitute a Supergroup.

**Group:** A Group consists of two or more successive and naturally related or associated formations and is higher in rank than a Formation.

**Formation:** A formation is a mappable unit. It is the fundamental unit in the lithostratigraphic classification characterized by a typical lithological association and homogeneity.
**Member:** This is next in rank below a formation. It is not defined by specific shape, extent or thickness.

**Bed:** This is the lowest in rank in the formal lithostratigraphic unit.

Further, in working out the lithostratigraphy the local type areas should be stressed as it forms the basis for any type of correlation which is done subsequently.

The terminology that is followed is as follows: 1. **Type area** 2. **Type section.**

1. **Type area:** This is the area which typifies the area for the lithology noted against it. Its geographical position should be detailed. Its approach, geomorphology, its elevation with reference to MSL should also be given. This information makes anybody to study the area in detail if needed.

2. **Type section:** It is the geological section which clearly reflects all the units described under one group. This also should be given with clear details of approachability, the sequence of the lithologies etc.

The Litho stratigraphy of standard Keewatin type of greenstone belt was worked by Anhaeusser et al., (1969). It is the standard reference to work out the stratigraphy of any greenstone belt. The classification proposed by Anhaeusser et. al., (1969) is given below for reference.

<table>
<thead>
<tr>
<th>Sedimentary Group</th>
<th>------</th>
<th>BIF, tuffs, rhyolites etc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenstone Group</td>
<td>------</td>
<td>Meta basalt, amphibolite etc</td>
</tr>
<tr>
<td>Ultramafic Group</td>
<td>------</td>
<td>Ultramafic, amphibolite etc</td>
</tr>
</tbody>
</table>
The eastern style greenstone belts have the above said set up either in parts are in full. For example the Kolar and Ramagiri have the full sequence of Anhaeusser et al., (1969), whereas the Gadwal and the Kadiri have only the middle and the top sequence of Anhaeusser et al., (1969) respectively.

Considering the above preamble as a base and considering the field relationships, the following lithostratigraphy of the Peddavuru schist belt has been worked out.

**Cuddapah Super Group**
---Unconformity ---
Quartz reefs
Mafic dykes
Younger granitoids
Intrusive contact
Banded Iron Formation
Metarhyolites
Metabasalt (Pillowed)
---Non Conformity---
Banded Gneiss (Basement?)

Considering the Keewatian characters of the Eastern greenstone belts especially, the first one i.e., absence of the basal conglomerate and not recognisable basement - cover relationship, the moot question that arises from the above statement is as to why conglomerate is absent when the gneiss is seen at the contact with the greenstone belt? Similar set up with the greenstone belts exposed on the western part of the Dharwar Craton have the basal oligomictic, quartz - pebble conglomerate.
This observation has been studied critically and found that the entire stretch of the gneiss with the greenstone belt do not have any conglomerate. When compared to western block, the greenstone belts of eastern block of Dharwar Craton do not have basement cover relationships. At present most of the gneiss belts are in tectonic contact with the schist belts though at places intrusive relationship is noticed. As pointed out by the author the basement need not the present also such as Moris or backarc basalts and most of the belts could be floating arcs. However there are certain older ages available i.e., ~ 3 by in gneiss of Kolar greenstone belt. Based on this the author's postulated banded gneiss (TTG) as the basement for Peddavuru schist belt.

Yet another important aspect is the nature of disposition of the greenstone belt. It is mostly ribbon like with a linear disposition. If each greenstone belt is considered as a discrete one deposited in an individual basin the question arises is as to what was the basement to the greenstone belt? And the other question is how each basin could get different lithologies? Was Nature so partial to give different rocks to different basins?

The scrutiny of literature suggests that though a basement is necessary for these rocks of the greenstone belts to be deposited, it is not recognizable in the present set up. The reason could be that it might get recrystallised due to the subsequent tectonic disturbances and even if any relict is present it is not in the recognisable state. The different lithologies in different belts again points to the fact that they represent different cycles at different stratigraphic levels. The
present isolation in the form of thin ribbon like Greenstone belts could also be partly tectonic-intense isoclinal folding of the crust at the same time as voluminous granitoid emplacement.

Based on the above analysis a model has been attempted to show the relation of the Peddavuru greenstone belt with the other greenstone belts in space and time. The model suggests that the Peddavuru greenstone belt is only a part of the pre existing plate like body.

The major problem faced in establishing the litho – stratigraphy of the Peddavuru schist belt is the alternation of basic and acidic volcanics in such close proximity. It is still an enigma. The possibility of minor parallel thrusts at the contacts are not ruled out. However, both the basic and acidic volcanics are included under one 'Formation'.

**Nature of the Basement:** The nature of basement to the greenstone bets is unknown being obscured by the later granitoid plutonism and deformation. As stated earlier there is no clear field evidence to suggest any basement – cover relationship. Typical metasediments in the eastern greenstone are almost absent or very low in percentage and some of the units which are identified as metasediments are basically volcanic clasts/tuffs. However, thin quartzite bands are noticed at the base of a few eastern greenstone belts pointing to the ensialic nature of the basement.
THE GRANITOIDS Vs EASTERN GREENSTONE BELTS

The Peninsular gneiss was considered as a basement to the eastern greenstone belts as well as to the western ones. The oligomictic, quartz pebble conglomerate present at the base of western greenstone belts reflects the basement – cover relationship between the PGC and the greenstone belts, whereas, similar relationship does not exist in the eastern greenstones. Further, contrary to that, there is an intrusive relationship between the PGC and EGB which is noticed in the area south of Nallakonda in the Ramagiri greenstone belt. In this area, there is a parallelism between the fabric in the schist and the gneissosity in the granitoid, but when traced along the strike the gneisses intrude into the belt reflected by tongue like features of the gneisses. Number of enclaves of the schist belt of various magnitude are seen in the Peninsular gneiss. These enclaves occasionally occur as clusters and sometimes as individuals ones. The trend of the enclaves when traced along the strike merges with the main belt as noticed on the east and west of the Ramagiri greenstone belt. Similar set-up exists between the Raichur and Gadwal belts. The Gadwal belt when traced in the northwest direction joins with the Raichur belt through a series of discontinuous enclaves occurring within the gneiss. Similarly the Kadiri belt is the northern extension of the Kolar belt. Further, there is a link between Ramagiri – Penakacherla and Sandur belts, established by ground check and by geophysical method.
The scrutiny of the geological maps suggest that the Peddavuru belt could be the top of the Tsundupalli greenstone belt, where in it has mostly basic volcanics (Fig-42). The geophysical studies are carried out by the National Geophysical Research Institute (NGRI), Hyderabad in collaboration with the Geological Survey of India (GSI) carried out by airborne magnetic surveys over parts of the middle to late Proterozoic Cuddapah basin and the adjoining Archaeans during (1980-1982) as part of mineral exploration programme of the GSI over the granite-greenstone terrain of south India (Babu Rao et. al., 1987). The unusually large amplitude of the magnetic anomalies promoted them to take up an integrated study of the airborne magnetic, landsat and photogeological studies over the Cuddapah basin. The results of an integrated study brought out extension of schist belts such as structural continuity between Kadiri and Kolar similarity link has been established between Velligally and Gadwal in a similar way linking of the Tsundupalli and Peddavuru underneath the Cuddapah basin has been established (Fig. 44). This analysis leads to the fact that the Peddavuru belt is only a relict of major plate like body and represents the top units. Hence, the lithostratigraphy of the belt indicates the meta sedimentary part of the Anhaeusser et. al., (1969) classification.

CORRELATION OF EASTERN GREENSTONE BELTS

The documentation in earlier paragraphs shown that these belts reflect characters of classic greenstone belts. Hence, the correlation of these belts can
be attempted by considering the Anhaeusser et al., (1969) model of triple division of classic greenstone belts (Fig-42). This model has lower ultramafic (Um), middle Greenstone (Gst) and upper Sedimentary (Sed) groups (the terms lower, middle and upper are used in an informal way). In view of the absence of Geochronological data and tectono-magmatic environs of all the schist belts it is difficult to correlate each belt from the other. Right now the attempt is only as a preliminary in nature. This correlation figure assumes the simple variation up stratigraphy of many greenstone belts. The scrutiny of the figure (Fig-42) clearly indicates the each belts fits into one of the divisions mentioned above. Belts like Ramagiri and Kolar have all the three divisions (Um-Gst-Sed), where as belts like Raichur, Gadwal, etc., have two divisions (Gst-Sed). Some have exclusively ultramafic like Gurugunta and some have mainly greenstones like Jonnagiri and some others mainly sedimentary like Kadiri (Padmasree, 2001), Hungund, Peddavuru etc.

The said observation clearly indicates that the present lithological setup or assemblage is mainly due to their stratigraphic position in the triple division namely, ultramafic, greenstone and sedimentary groups. It also reflects that these belts indicate a consolidated stratigraphy which forms the basis for an evolution.

The lithological setup of all the eastern greenstone belts indicate the broad sequence as detailed below.
(Upper) Sedimentary Group - Tuffs, BIF, bedded cherts, Quartzite, rhyolites, rhyodacites.

(Middle) Greenstone Group - Metabasbats, amphibolite, BIF, tuffs.

(Lower) Ultramafic Group: - Ultramafics (pillowed), Amphibolite, tuffs, BIF, Chlorite schist, metabasalt.

This sequence of the lithological units has helped in evaluating a model for the evolution of the eastern greenstone belts.

EVOLUTION OF THE EASTERN GREENSTONE BELTS

For the origin of magmatic rocks the present day platetectonic process are simply adopted for Archaean times though there is controversy. The geochemical signatures of the schist belt rocks suggest Island arc and active continental margin tectonic setting. The evolution of the eastern greenstone belts in Dharwar Craton can be studied in four phases (Fig-43) as detailed below.

I-Phase: On to a thin ensialic basement, there was extrusion of the ultramafic magma followed by basic volcanics and very little acid volcanics. Granitoids mostly of TTG suite intruded into the setup.

II-Phase: Localised upliftment and deposition of minor amounts of sediments and mostly pyroclastic. Formation of granitoids, conglomerates and eruptions of acid volcanics characterised the second phase.
III-Phase: Gravity sliding and thrusting caused due to compression marks the third phase.

IV-Phase: Final compression and vertical and transcurrent faulting leading to upright structures. Simultaneous granitoid intrusion, formation gneissic rock, qualifies the fourth phase.

The setup is subjected to erosion which leaves the schist belts occurring as linear bands in gneissic and granitoid country. This also explains the variance in lithology in each belt.

From these observations, it may be inferred that all these belts are linked and can be connected laterally. Thus, the present isolation of once united sequence and exposure of various stratigraphic levels in various eastern greenstone belts perhaps is the result of the combined action of tectonism and erosion.
Fig. 41: IDEALIZED MAP OF A TYPICAL ARCHAEN GREENSTONE BELT
(AFTER ANHAEUSSER et al., 1969)

Late potassium-rich granite
Regional dips (usually steep 90°)
Concentric faults
Major faults parallel or sub-parallel to axis of greenstone belt
Diapiric granite responsible for acute margins of greenstone belt (often soda-rich)
Foliated margins of diapiric plutons
Kernitic fragments of greenstone belt aligned parallel to contact of diapiric granite
Tightly folded acute synclinal 'keel'
Mafic schlieren
Gneissic-migmatitic granite
Abrupt truncation trends caused by intrusion of late potassium-rich granite
F
F
F
F

Major folds (usually synclinal)
Phases:

Phase 1. Extrusion of komatiitic to tholeiitic volcanics followed by minor scale acid volcanic and simultaneous granitoid intrusion.

Phase 2. Localized uplift and deposition of minor amounts of sediments and pyroclasts, conglomerates etc along with acid volcanic eruptions.

Phase 3. Initial compression causing gravity sliding and possible thrusting in the upper levels.

Phase 4. Final compression and vertical and transcurrent faulting leading to upright structures, simultaneous granitoid intrusion formation of gneissic rocks, giving false impression that the schist belts are rift oriented / generated.

Fig. 43: Evolution of the Eastern Greenstone Belts (>3000 my)

(Island arc and active continental margin tectonic setting)
Fig 44: AEROMAGNETIC ANOMALIES OF CUDDAPAH BASIN AND ADJOINING GRANITE GREENSTONE TERRAIN

SOURCE: NGRI (BABU RAO et al., 1987)