CHAPTER 2 STRATIGRAPHY OF THE DELHI SUPERGROUP

A. General statement

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CHAPTER 2 'STRATIGRAPHY OF THE DELHI SUPERGROUP'.

A. General Statement

The rocks of the Delhi Supergroup are exposed all along the 'Delhi Synclinorium' from Ajmer Southwestwards upto Phulad-Deogarh (vide Fig. 1.1, vide Heron, 1953, pls. 37 and 38). The basic and ultrabasic rocks constitute the basal part of the Delhi Supergroup in Phulad-Deogarh cross-section. In this section the author has attempted to establish the tectono stratigraphic succession of the Delhi Supergroup of rocks, to recognise the lithounits within the Banded Gneissic Complex and to examine the basement-cover relation.

Two selected outcrops have been mapped on a scale of 1:300 to show the nature of contacts between the Delhi rocks and the units of the Banded Gneissic Complex. The terms 'B.G.C. East' and 'B.G.C. West' have been used to denote the B.G.C. rocks to the east and west of the 'Delhi Synclinorium'.

B. Stratigraphic Classification of the Delhi Supergroup

In the Phulad-Deogarh section the lithostratigraphic units trend NE-SW parallel to the regional schistosity of the Delhi Supergroup. Here the lithoboundaries are not contorted on major scale by folding or faulting; only local mesoscopic distortions have been observed (Map 1, parts 1 and 2; Map 2, parts 1 and 2).

In the Delhi sediments primary structures such as current bedding and ripple marks are few and the scattered observations,
do not permit determination of younging of strata except locally. Although the overall inclination of the bedding and bedding-cum-schistosity is eastwards in the region. An antiformal anticline defined by Goramghat quartzite has been recognised (Fig. 2.1a).

Thus the E-W Phulad-Deogarh cross-section demonstrates the tectono-stratigraphic sequence of lithounits. The Delhi Supergroup overlies the 'B.G.C. West' on a modified unconformity (discussed in section 'D' of this chapter). The contact between 'B.G.C. East' and Delhi Supergroup is a fault (vide section 'D').

The Delhi Supergroup of rocks show variation in facies both regionally and locally. Regionally it is found that the conglomeratic and arenaceous character of the basal part of the Delhi Supergroup (Alwar Group at Barr region) is absent around Phulad (vide Fig. 1.1). Its place is taken up by basic and ultrabasic rocks. The basic and ultrabasic bands at the western part of the 'Synclinorium' around Phulad have been classified as 'Alwar Group'. The thin band of knotted marble at the western extremity of the 'Synclinorium' has also been included within this Group. Incidentally this marble band was included in 'Other limestones in Delhi system' by Heron (1953, pl. 38) and was assigned to neither 'Ajabgarh series' nor 'Alwar series' by him (vide Fig. 1.1).
FIG. 2.1a. E-W Cross section from Phulad to Deogarh showing the Structural Superposition of different lithological units within Delhi Supergroup.
In order to assess the composition of the crust across the 'Delhi Synclinorium' a geochemical traverse has been made from Phulad to Deogagh (Fig. 2.1b.1). Here distance is plotted along the abscissa and percentages of major oxides are plotted along the ordinate. An interesting observation is that the curves for the major oxides show fluctuations, suggesting rapid variation in chemical composition of the sediments of the Delhi Supergroup. Another interesting feature here is that at Goramghat garnetiferous marble the percentages of all the oxides such as SiO₂, Al₂O₃, Fe₂O₃, MgO, TiO₂, K₂O, Na₂O decrease appreciably whereas CaO attains a peak. From this marble horizon eastwards upto Deogarh the percentages of all the oxides increase while CaO decreases. In this geo-graverse Na₂O dominates over K₂O except minor variation such as at Piplighat tremolite schist horizon. TiO₂% is fluctuating and attains higher values at Deogarh hornblende schist horizon.

The same fluctuation is also reflected within Phulad basic and ultrabasic rocks. It is found that the wt. percentage of CaO decreases westwards whereas all the wt. percentages of other oxides increase eastwards.

This compositional variation of the crust can be compared with that at Barr-Sendra horizon (Fig. 2.1b.2: also vide Gangopadhyay and Lahiri, 1983). There also the percentages of all the oxides except CaO decrease upto a marble horizon called 'Nandna marble' situated within the heart of the 'Delhi Synclinorium' and increase again eastwards. These observations
FIG. 2.1b.2 - An E-W cross-section from Barr to Sendra, showing the plots of distance vs. wt. percentages of major oxides. (After Gangopadhyay & Lahiri, 1983)

FIG. 2.1b.1 - An E-W cross section from Phulad to Deogarh showing the plots of distance vs. wt. percentages of major oxides.
suggest that the lithounits occurring at the western and eastern parts of the marble horizons at the heart of the 'Delhi Synclinorium' can be included within Ajabgarh Group (vide Heron, 1953, pp. 253-300) in which a notable facies change is present.

A few samples of basic rocks at Phulad region have been radiometrically dated at the Institut of Precambrian Geology and Geochronology, Leningrad, by Dr. V. Khiltova by Mass Spectrometre Ml-1330, using 40K/40Ar method. The ages obtained are the mineral ages of primary amphibole of the unaltered basalts. The results are given in Table 2.1.
### Table 2.1: Geochronological Age for Primary Amphibole

<table>
<thead>
<tr>
<th>Age (Ma)</th>
<th>Amphibole</th>
<th>metastable</th>
<th>Monoclinic</th>
<th>Orthoclase</th>
<th>Quartz</th>
<th>K-feldspar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10</td>
<td>1290 ± 20</td>
<td>1.25</td>
<td>0.94</td>
<td>0.064</td>
<td>0.255</td>
<td>0.18</td>
</tr>
<tr>
<td>0.98</td>
<td>860 ± 20</td>
<td>1.23</td>
<td>0.94</td>
<td>0.058</td>
<td>0.155</td>
<td>0.16</td>
</tr>
</tbody>
</table>

- Present in samples.
- Texture-apatitic to subophitic.
- Texture-apatitic to subophitic.
- K-feldspar-amphibolite present.
- Monoclinic amphibolite present.
- Orthoclase-quartz-phlogopite present.
- Metastable amphiboles more.
- Numerical age is uncertain.
- Petrographic examination.

Note: The table entries represent the geochronological age for primary amphibole in the context of the rock's mineralogy and texture.
This result suggests the ages are Proterozoic and show a span from $800 \pm 20 - 1290 \pm 20$ Ma. If these ages reflect the time of crystallisation from a parent magma (vide chapter 3, Part-I, Section D) then they should indicate the time of emplacement of the basic rocks of Phulad. So a middle lower Proterozoic age for the Phulad basic rocks which are lower part of the 'Alwar Group', resting unconformably over the Precambrian Banded Gneissic Complex may be accepted.

All these lithounits are finally intruded by pegmatite and post-Delhi Granite, Chaudhary et. al (1984) dated some of intrusive post-Delhi granites from Bara-Sendra region of Central Rajasthan. These ages range from 750 to 850 Ma. The stratigraphic units recognised in the Phulad - Deogarh section has been represented in Table 2.2.
Table 2.2: Stratigraphic Column

**Pegmatite**

Phulad Granite (Intrusive)

<table>
<thead>
<tr>
<th>Deogarh Formation</th>
<th>Hornblende schist and amphibolite with bands of metaultrabasic rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phulad knotted marble</td>
<td>Deogarh mica schist (with bands of quartzite) Deogarh diopside marble</td>
</tr>
<tr>
<td>Khamblighat Formation</td>
<td>Khamblighat tremolite schist</td>
</tr>
<tr>
<td>Khamblighat actinolite schist</td>
<td>Piplighat tremolite schist</td>
</tr>
<tr>
<td>Goramghat Formation</td>
<td>Goramghat garnetiferous marble</td>
</tr>
<tr>
<td>Goramghat quartzite</td>
<td>Goramghat quartzite</td>
</tr>
<tr>
<td>Conformable junction</td>
<td>Phulad basic and ultrabasic rocks</td>
</tr>
<tr>
<td>modified Unconformity ....../ Sheared junction</td>
<td>Phulad knotted marble</td>
</tr>
</tbody>
</table>

B.G.C. West = Phulad Gneiss

| Deogarh augen gneiss and Anjna Granite |
| Tekhi Gneiss |
| Sand Mata gneiss |
C. Recognition of lithounits within the Banded Gneissic Complex

The B.G.C. West and the B.G.C. East are lithologically different. B.G.C. West is a sheared granite gneiss and the B.G.C. East has several lithological components including granites and migmatites. Within the B.G.C. East no top-bottom criteria could be recognised in the Sand Mata gneisses because the primary structures are totally destroyed due to the total conversion of the rocks to gneisses. But proceeding from Deogarh to Sand Mata it is found that lithologic components within B.G.C. East is consistently dipping to the east. So a structural succession can be made within the B.G.C. East.

From Deogarh to Tekhi occur augen gneisses, then at Tekhi migmatites dominate, and finally at Sand Mata high-grade gneissic rocks and granulites occur. The augen gneisses of Deogarh was intruded by Anjna Granite whose granitoid nature is apparent.

D. Nature of contacts between Delhi Supergroup of rocks and the Banded Gneissic Complex

In Phulad - Deogarh Section the Delhi Supergroup of rocks are bounded by the Banded Gneissic Complex both at the western part at Phulad and at the eastern part at Deogarh (vide Fig. 1.1). The descriptions of the nature of the contacts both at Deogarh as well as at Phulad are given below.
l) Nature of contact between Delhi Supergroup and B.G.C. East

The contact between the Delhi Supergroup of rocks and B.G.C. East is exposed 1.5 km east from the Deogarh town (vide Map 1, parts 1 and 2). The NE-SW trending contact is sharp. It is affected by the E-W trending transverse faults parallel to the trace of axial planes of F3 folds. The Delhi Supergroup of rocks are exposed to the west of the contact. At Deogarh basic and ultrabasic rocks, quartzites are exposed. The quartzites here are affected by crushing and mylonitisation. The larger grains of quartz and feldspar are broken down to smaller fragments particularly at the margin (Fig. 2.2). The smaller grains of quartz and feldspar then contribute to development of banded mylonite (Fig. 2.3). Cataclasis is exhibited in larger grains of quartz and feldspar which are fragmental and marginally granulated, strong undulose extinction is developed (Fig. 2.4). This event of mylonitisation can be noticed in almost all the lithounits near the immediate vicinity of the contact at Deogarh. This band of mylonite has been later folded by F2 phase of folding (Fig. 2.5).

An outcrop map in the scale of 1:300 has been made (Fig. 2.6). Here the contact is cut across by the late pegmatites occurring in chess-board patterns. Within the pegmatites no effect of crushing is noticed. They are shhistose. An unaltered dyke like basic body is noticed. This rock retains subophitic texture and the dyke must be post-faulting. The band of schistosity, S2 of the Delhi rocks is directly traceable from
Fig. 2.2 Photomicrograph showing marginal granulation of quartzofeldspathic grains within Delhi Supergroup of rocks at Deogarh; Q-Quartz, F-Feldspar (crossed nicols).

Fig. 2.3 Photomicrograph showing the development of banded mylonite by the smaller quartzofeldspathic fragments; M-Mylonite (parallel light).

Fig. 2.4 Photomicrograph showing the cataclastic texture with angular to subangular grains of quartz and feldspar in a smaller quartzofeldspathic matrix; Q-Quartz, F-Feldspar (parallel light).

Fig. 2.5 Photomicrograph showing the mylonites folded by F_2 (parallel light).

Fig. 2.7 Photomicrograph showing the sheared small quartzofeldspathic grains around a large feldspar grains in streaky gneiss showing at the outcrop map (Fig. 2.6); F-Feldspar (crossed nicols).

Fig. 2.8 Photomicrograph showing the mylonite fabric in streaky gneiss showing at the outcrop map in Fig. 2.6 (crossed nicols).
FIG. 26 - OUTCROP MAP SHOWING THE CONTACT BETWEEN DELHI SUPER GROUP OF ROCKS AND B.G.C EAST AT DEOGARH.
the west of the contact to the east where the augen gneiss and streaky gneiss are noticed. Dip of schistosity is steep (72° - 84°) near the contact and it is persistantly inclined easterly within the gneissic rock.

At the northern part of the outcrop some strips of strongly deformed streaky gneiss occur within the Delhi rocks within sheared junctions (vide Fig. 2.6). The schistosity, S₂ within the outcrops of gneisses dip steeply (70° - 85°) to the east. Microscopically it is found that the feldspars, quartz and micas are strongly sheared (Fig. 2.7). Part of the fabric is strongly sheared to produce strips of mylonite (Fig. 2.8).

Further southwards along the contact within the basic rocks the microscopic evidence suggests that the amphibole and biotite (Fig. 2.9) and the flaky minerals define the schistosity, S₂. The blastomylonitic rock contain quartzo-feldspathic bands which show marginal granulation and brecciation of minerals (Fig. 2.10). Epidotisation affects all the litho-units.

These evidences suggest that the contact between the Delhi Supergroup and the B.G.C. East at Deogarh is affected by a very early phase of mylonitisation which was pre-F₂ in nature.
2) **Nature of contact between the Delhi Supergroup and the B.G.C. West**

This contact is noticed about 175 metres west of Phulad village (vide Map 1, parts 1 and 2). The Western contact is sharp. Further south-west that contact is covered by the alluvium. The contact here is exposed mainly between Phulad knotted marble and the Phulad gneiss. Around Phulad village that contact is affected by the E-W trending faults parallel to \( F_2 \) axis. An outcrop on the scale of 1:300 has been mapped in the south of Phulad village to determine its nature of contact (Fig. 2.11). Here the contact is NE-SW trending. To the eastern part of the contact the Delhi rocks are represented by the Phulad knotted marble and to the west there is a zone of intense feldspathisation and further south-west of it two patches of Phulad gneiss (\( \sim \) B.G.C. West) are marked. To the west of the contact some lenticular streaks of pegmatite band is noticed. They are parallel to the contact. The schistosity, \( S_2 \) is traceable from Delhi rocks to Phulad Gneiss. It is NE-SW trending and dips steeply to the east. Within the Delhi rocks the schistosity shows low to moderately high angular relationship with the bedding of the Delhi rocks. The bedding here shows a persistent angular relationship with contact. The Delhi rocks are affected by both \( F_1 \) and \( F_2 \) folds. Map pattern suggests that the \( F_1 \) and \( F_2 \) are co-axial in nature and axial planes of \( F_2 \) are NNE-SSW trending. So the resulting interference pattern is hook-shaped. Within the Delhi rocks one pegmatite band is noticed. It has been later affected by \( F_2 \) folds.
Fig. 2.9 Photomicrograph showing the development of schistosity, \( S_2 \) defined by the flaky minerals like amphibole, biotite etc. shown at the outcrop map (Fig. 2.6); Am-Amphibole, Bt-Biotite (crossed nicols).

Fig. 2.10 Photomicrograph showing blastomylonite (M) along with the marginal granulation of quartzofeldspathic grains around a large quartz grain (Q) in the basic rock of Fig. 2.6 (crossed nicols).

Fig. 2.12 Photomicrograph showing folded bedding within marble containing carbonates, quartz and feldspar; C-Carbonate, Q-Quartz, F-Feldspar (crossed nicols).

Fig. 2.13 Photomicrograph showing granulation of quartz and feldspar within Phulad Gneiss (crossed nicols).
The Delhi knotted marble horizon appears to indicate the commencement of the Alwar Group just above the unconformity above the Phulad Gneiss. Together with the basic and ultrabasic rocks in the vicinity of this junction this marble represents commencement of a volcano-sedimentary succession (Alwar Group). The fragments may represent porphyroclast as well as volcanic ejecta which have been embedded in the layered carbonate rock with cherty partings (vide chapter 3, part 1, section C). The matrix is mostly chemical precipitates, association of cherty material, calcareous precipitates and basic intercalations is remarkable. This thin volcanogenic layer is followed by outpouring of vigorous vesicular basalt. Thus an approach to ancient shore line at the western flank of the 'Delhi Synclinorium' is indicated. It may be pointed out here that Heron did not specify the stratigraphic status of this marble horizon and placed it in between Alwar Group and Ajabgarh Group in the legends of maps prepared by him (Heron, 1953, Vol. 79, plates 37 and 38) but the present work confirms it to be the basal horizon of the Alwar Group.

Microscopic observations suggest that the Delhi marbles are made of aggregates of carbonate, quartz and subbedral feldspar (Fig. 2.12). Microscopic observations also suggest cataclasis and granulation of constituent minerals both in the marble and Phulad Gneiss adjoining the contact. The recrystallised minerals, forming schistosity, $S_2$ have been affected (Fig. 2.13).
In contrast to the eastern contact there is no effect of early shearing or mylonitisation (i.e., pre-D₂) at the western contact. These observations suggest that though there is no effect of early movement still it happens to be modified and late shearing at Phulad due to emplacement of pegmatites. Map pattern suggests that the contact is parallel to the trend of schistosity, S₂. The angularity between the bedding of the Delhi rocks with the contact suggests it to be a modified unconformity. This observation indicates that the unconformity traced between Barr conglomerate and B.G.C. West at Barr area in Pali Dt., about 100 km NW of Phulad, by Gangopadhyay and Lahiri (1983) extends upto Phulad and continues further south west wards. From the above observations it may be suggested that:

i) the western junction between the Delhi Supergroup of rocks and the Banded Gneissic Complex is an unconformity modified by shearing and pegmatisation during and after D₂ phase of deformation of the Delhi Supergroup.

ii) the eastern contact between the Delhi Supergroup and the Banded Gneissic Complex (B.G.C. East) is a sheared one and had long continued history. It suffered an early phase of mylonitisation at Pre-D₂ stage and a late intense shearing at post-D₂ stage.

An important deduction that can be made from the study on the contacts on both the flanks of the 'Delhi Synclinorium' is that the configuration of the Delhi basin cannot be defined
merely on the occurrence of the Delhi rocks at the present level of exposure. As the eastern contact is a fault of regional extent and as mygmatised metasediments have been observed within the B.C.C. country to the east (Heron, 1953, B.C.Gupta, 1934) the basin boundary cannot be demarcated by the eastern fault 'FF' (Map 1, parts 1 and 2). The western limit of the basin, however, can be deduced from the still recognisable unconformity. The Delhi basin need not necessarily be a NE-SW linear tract as often assumed and its true shape can only be determined after locating subsurface and surface relics of Delhi rocks east of the eastern contact. The 'Delhi Synclinorium' is therefore, an incomplete structure if the eastern fault 'FF' is not accepted as the limit of deposition of the Delhi Supergroup.