Chapter VII

CONCEPTUAL MODEL FOR THE GEOLOGICAL EVOLUTION OF THE DEBARI GROUP

Stratigraphic Position

The Precambrian conglomerate, arkose and quartzite exposed at Jaisamand between Bhilwara Supergroup (Banded Gneissic Complex) and the flysch like sequence of Aravalli Supergroup (see, Poddar and Mathur, 1965) were initially assigned to Alwar Series of the Delhi System by Heron (1953) and were considered as a tectonic slice brought to its present position by thrusting from the west. The revisional mapping and the present study has brought out that the conglomerate, arkose, quartz-arenite sequence exposed around Jaisamand, stratigraphically form part of the Aravalli sequence. Based on tectono-environmental setting, lithological homogeneity and structural concordance the rocks have been included under the Debari Group of the Aravalli Supergroup (see, Anon, 1981). For purpose of stratigraphic correlation the lithotypes have been assigned to Delwara, Jaisamand and Dakankotra formations of the Debari Group. The magmatic events have been assigned as intrusives, following the code of stratigraphic nomenclature adopted by the Geological Survey of India (1981).

Stratigraphically, the rocks of Debari Group have been considered as the basal sequence of the Aravalli Supergroup resting over the pre-Aravalli gneisses and schists with a
first order erosional unconformity. Temporally the unconformity has been placed at 2500 Ma (Anon, 1981). The unconformity at the base of the Debari Group represents the Eparchaean break and the Jaisamand Formation herald the dawn of Proterozoic sedimentation in the Jaisamand sector of the Aravalli geosyncline.

Sedimentary Model

Tectonic Framework of the Debari Group

The Debari Group represents clastogenic, chemogenic and organogenic coastal and shelf sediments deposited over a peneplain Archaean basement of the Bhilwara Supergroup in Rajasthan. The sequence represents the beginning of the Aravalli Geological Cycle. The clastics are at places associated with synsedimentational shoreline spilitic volcanics corresponding to the early depositional volcanic episode of the geosynclinal phase (see Anon, 1981).

Sedimentary Facies

The clastic population of the Debari Group in Jaisamand sector represents two dominant clastic modes (phenoclasts and sand & silt) deposited in the surf zone. The coarser sediments were possibly carried in the undertow of the backwash transport
towards the breaker zone from the continental block provenance. The finer sediments were brought to the breaker zone from the open sea by winds, waves, tides and currents coming towards the coast. The abundance of coarse sediments in the Jaisamand Formation is a function of beach dynamics. The phenoclast in the coarse matrix debouched by the surface drainage from the craton was distributed along the coast by longshore drift. The phenoclast and the coarse matrix which were in equilibrium with the surf zone and longshore drift survived in the Jaisamand Formation as facies-B and facies-D. The finer modes represented by the sediments of facies A were transported to swash and backwash zone while the clastics of facies-C, E and F were brought from the open sea towards the coast by swelling waves.

The bedding plane inhomogeneities and bedding characteristics of the Jaisamand Formation suggest foreshore coastal environment of deposition. The low angle discordance between evenly laminated sets of stratification, characterized by erosional discordance and reactivation surfaces are indicative of bipolarity of the flow regime characteristic of tide dominated wave dynamics (see, Thompson, 1937; McKee, 1957b; Klein, 1970a; Sellwood, 1975; Reineck and Singh, 1980).

The bimodal clastic population in the conglomerate corroborates the above environment. The coarser population represents backwash and the arenaceous matrix represents swash of the wave induced process (see, Reineck and Singh, 1980). The reverse grading and interlayering of coarser
material with the evenly laminated sand showing low lenticularity index in the pebbly beds of Jaisamand Formation are suggestive of coastal wave controlled dynamics (see, Vollbrecht, 1957; Hayes and Boothroyd, 1969; Clifton, 1969; Greenwood and Davidson-Arnott, 1979).

The bedding plane inhomogeneities observed as ripple marks with rounded crest in the facies-D of the Jaisamand Formation are also indicative of wave action under a bipolar regime.

The quantification of bed lenticularity index and phenoclast segregation factor (Clifton, 1973; Iqbaluddin, 1977) suggest a higher phenoclast segregation factor and low lenticularity index are characteristic of Jaisamand conglomerate. These parameters indicate wave worked dynamics during the deposition of Jaisamand conglomerate (Fig. 15).

The dominance of quartz and paucity of lithic fragments in the QFL modes of arenites in the Debari Group (Fig. 14) suggest sedimentation along continental block provenance. The presence of feldspar is suggestive of decrease in stability of the provenance (Dickinson and Suczek, 1979) during the sedimentation of Debari Group.

The bedding characteristics, internal organization, external inhomogeneity of stratification, bipolarity of flow regimes and QFL modes of the mineralogic population are suggestive of wave dominated coastal sedimentation along an unstable continental block provenance during the deposition of Debari Group.
Deformation and Metamorphism

First Phase of Deformation

The sedimentary sequence representing the Debari Group of rocks, deposited in the shadow of an unstable continental block provenance in the coast and beach environments, experienced basinal instability triggered by synsedimentational shoreline volcanism (Delwara volcanics), caused possibly by the partial melting of the oceanic crust. The basinal instability in the shelf possibly triggered the sliding process in the sedimentary prism. This earliest deformation developed as a result of creep of the sedimentary pile down the palaeo-slope is manifested as AS\textsubscript{1} foliation, corresponding to AD\textsubscript{4} deformative episode of the Aravalli Tectonic System.

M\textsubscript{1} Phase of Metamorphism

The earliest deformative event was synchronous with the first phase of metamorphism in the rocks of the Debari Group. The shearing stresses which were developed in response to creep, led to rotation of sericite flakes sub-parallel to plane of stratification. Chlorite-I developed during this phase of metamorphism. Subsequent to simple shear, pure shear appears to have been operative which led to flattening strain and resulted in elongation of quartz-I in the $\lambda_1\lambda_2$ plane of
strain ellipsoid. The plastic deformation during the \( M_1 \) phase took place under the super incumbent load of the sedimentary pile under low temperature and pressure.

**Second Phase of Deformation**

The second deformative episode \( (AD_2) \) took place under a compressive stress environment. Regionally the \( \sigma_1 \) trajectory was directed from NW-SE in the Aravalli region. The local trends exhibit variations in conformity with the basement inhomogeneities and sectorial trends of the strand. The deformation took place in near surface environment as is evident by the dominance of flexural slip mechanism (see, Fourmarier, 1953, in Whitten, 1969), which controlled the kinematics of \( AD_2 \) deformative episode. The deformation led to buckling of the sedimentary prism into open to tight sub-horizontal to moderately plunging, upright to steeply inclined folds; about NNW-SSE generators and strongly developed \( AS_2 \) axial plane foliation.

The particle strain studied in the Jaisamand sector suggest that the Debari rocks underwent flattening in conformity with the \( \lambda_1, \lambda_2 \) plane of strain, corresponding to the orientation of the regional foliation. The strain was flattening \( (K<1) \) in 64% of the population, 28% of the population reflects constrictive strain and 6% population has recorded plane strain (Fig. 27). The plane strain represents
tendency towards constriction in the area around Jaisamand while it tend to be flattening in the area northwest of Dhimri Bag (Fig. 29).

Regionally the strain was flattening during $AD_2$ deformative episode in the Jaisamand sector. The plots of $X/Y$ and $Y/Z$ represent a high scatter (Fig. 26) which possibly reflects the competence contrast in the particle population. Partly the flattening and constrictive effects in the pheno-clast population are due to the axial discordance between the clastic axes and the strain axes in the area.

$M_2$ Phase of Metamorphism

Syntectonic to $AD_2$ deformative episode the second phase of metamorphic recrystallisation took place under a directed compressive stress field which developed flattening strain, as a result the mineralogenic population underwent recrystallisation and the existing mineral assemblages responded to flattening. The allogenic quartz flattened in $\lambda_1\lambda_2$ plane of strain corresponding to $AD_2$ deformative episode. The point contacts of quartz grains modified to elongated and sutured contact. The sericite from the clastic field underwent recrystallisation and grew in size with rugged terminations. It developed fabric anisotropy in the plane of flattening and defines the $AS_2$ foliation in the Debari Group. The chlorite porphyroblasts from $M_1$ metamorphic phase also underwent recrystallisation...
and grew in size at the cost of sericite and magnetite, in conformity with the general pattern of flattening strain. The chlorite flakes developed parallel arrangement with $\text{AS}_2$ foliation. The iron oxide recrystallised to magnetite, carbonates together with impurities were recrystallised and tremolite appears to have developed along the foliation plane. The carbonaceous matter responded to the P and T changes in the lower horizon of Debari Group and was converted to graphite.

**Third Phase of Deformation**

The Aravalli rocks of Jaisamand area have been subjected to sinistral regional shear which is manifested on macro, meso and micro scales. The shear possibly developed at a latter stage of $\text{AD}_2$ deformative episode. The progressive rotation of the sedimentary pile led to gradual increase in the value $\tau$ in relation to $\sigma$. Thus post-tectonic to $\text{AF}_2$ folding and $\text{AS}_2$ planar tectonic anisotropy the third phase of deformation of the Debari Group was initiated under sinistral shearing stress field. The $\text{AS}_2$ foliation acted as slip surface for the third deformative phase. The manifestation of the third phase are $\text{AF}_3$ folds developed as puckers and drags. $\text{AS}_3$ foliation is expressed as crenulation foliation. The $\text{AP}_3$ lineation is defined by b-axis of $\text{AF}_3$ puckers, intersection lineation of $\text{AS}_3/\text{AS}_2$ or $\text{AS}_3/\text{AS}_1$ and fabric anisotropy of phenoclasts in the Jaisamand conglomerate.
The AF\textsubscript{3} folds of the area developed as kink bands and chevron folds by flexural slip mechanism in a strongly anisotropic medium characterised by closely spaced AS\textsubscript{2} foliation acted as glide surface during the shear (see, Paterson and Weiss, 1966).

The AS\textsubscript{3} crenulation foliation was initiated by flexural slip mechanism which was replaced by shear mechanism after the failure of the limbs of the AF\textsubscript{3} puckers (see, Fairbairn, 1949; Wickham and Anthony, 1977; Anthony and Wickham, 1978; Sarkar, 1982 and Iqbaluddin, 1984). The shortening of the hinge and asymmetry of the limbs of AF\textsubscript{3} puckers facilitated the shearing of the limbs where AS\textsubscript{2} subtended nearly orthogonal relationship with the directed shear, along these failure surfaces the close spaced AS\textsubscript{3} crenulation foliation developed as strain slip cleavage.

The sinistral regional shear facilitated the mechanical rotation of the flattened and elongated phenoclasts resulting in the development of fabric anisotropy of the longer axis of phenoclasts which exhibit high axial direction stability (see, Table XI).

The kinematic plan during the third phase of deformation was such that the b-kinematic axis of the AF\textsubscript{3} folds coincided with the 'X' axis of the particle strain after mechanical rotation in the third phase of deformation.
**M₃ Phase of Metamorphism**

The third phase of metamorphism was synchronous to the third deformative phase. It took place as a late tectonic event during the AD₂ deformative episode. The bulk mineralogical composition of the rocks in the Debari Group during M₃ metamorphic phase comprised biotite, quartz, chlorite, magnetite and sericite. The garnet developed syntectonic to the AF₃ crenulations under sinistral shear as is evident from the Si-Se relationship (Pl. X, Fig. 3). The garnet developed at the cost of chlorite and quartz (see, Tilley, 1926; Atherton, 1968). The rotational shear generated 'snowball' structures in the garnet. Quartz-II recrystallised in the pressure shadow zone from quartz-I in response to rotational shear (Pl. V, Fig. 4). Quartz-I, sericite and chlorite were mechanically rotated along the AS₃ slip surface and acquired tectonic anisotropy at acute angle (Pl. VIII, Fig. 3) to the regional foliation (AS₂).

**M₄ Phase of Metamorphism**

The M₄ metamorphic phase appears to be the last event in metamorphic and petrogenetic evolution of the Debari rocks in Jaisamand area. It is characterised by rise of the geo-isotherms, post-tectonic to AD₂ deformative episode around 2000 Ma (see, Trawford, 1969; 1970, 1975; Gopalan, et al., 1979). The rise
of the geo-isotherm led to basement remobilization and
emplacement of the Ahar river and coeval granites in the
Udaipur area (see, Anon, 1981). The emplacement of these
granites was accompanied by a widespread phase of static
recrystallisation in the Debari rocks. During this phase
of static metamorphism quartz-III recrystallised in the
Debari rocks. Chlorite-II developed post-tectonic to AS$_3$
foliation by thermal metamorphism (Pl. X, Fig. 2) and its
progressive recrystallisation led to the development of
biotite-II. The feldspars were introduced into the sediments
as neosomes during the migmatization of the rocks in the
Jaisamand and adjacent areas.

The geo-isothermal rise during M$_4$ phase led to tensile
regime manifested by the development of fracturing at meso
and micro-level, exhibiting strain corresponding to $\lambda_1>\lambda_2>1$
(see, Ramsay, 1967). This strain field is manifested by the
fracturing of the quartz grains (Pl. VIII, Fig. 1) and joints
in the rocks of Debari Group.
EPILOGUE

The isolated occurrences of foliated hornblende granite with xenoliths of hornblendite are exotic to the geotectonic setting of the Salumbar granite which has been classed as synorogenic (Anon, 1981). The data are not adequate to make any meaningful assertion for a Precambrian plate-tectonics model to explain the geotectonic evolution of the Aravalli Proterozoic supra-crustals. It is possible that the hornblende granite with patches of hornblendite which occur as xenoliths within the aplo-granite (grano-diorite) might be the signatures of a consuming plate margin, obducted during the emplacement and vertical rise of the magma. The granites and the spilitic volcanics of the Debari Group might be the petrographic expressions of the partially melted subducting oceanic crust along the Delwara lineament (which has been interpreted as endogenic crystal grain with mantle connection; see, Anon, 1981). The petrochemistry of the granitic rocks and associated magmatic events might provide key to the reconstruction of the palaeoplate margins and movement across them for resurrecting the forces and movement during the Proterozoic plate-tectonics in the Aravalli Region of northwestern Indian Shield.