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LITHOSTRATIGRAPHY OF DEFORMED PROTEROZOIC ROCKS FROM AROUND THE CONFLUENCE OF THE GODAVARI AND INDRAVATI RIVERS, SOUTH INDIA

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ABSTRACT

Six formations can be formally recognised within the deformed sequence of the Somanpalli Group occurring around the confluence of the Indravati and Godavari rivers in the eastern Proterozoic (Purana) belt in the Pranhita-Godavari Valley, South India. Stated in general ascending order, they are : i) the Bodela Vagu Formation, dominantly a carbonate unit; ii) the Somnur Formation, mainly terrigenous; iii) & iv) the Tarur Nala Formation, thick sequence of ash beds and graywacke-shale, and contemporaneous but laterally separated Pedda Gutta Chert Formation; v) the Kopela Shale Formation; vi) the Po Gutta Formation, sandstone-shale alternations. The Bodela Vagu Formation and the Somnur Formation defining the lower part of the Somanpalli Group appear to have been formed in adjoining facies belts on a mixed siliciclast-carbonate platform and indicate a fair degree of progradation of the latter over the former. The Tarur Nala Formation is limited to a fault-bounded trough which separates the Bodela Vagu Formation from the Somnur Formation. The fault-bounded troughs resulted from extension and subsidence of the platform on which the sediments of the Bodela Vagu Formation and Somnur Formation were deposited. The troughs acted as repositories for the Tarur Nala Formation and the Pedda Gutta Chert Formation. The upper part of the Somanpalli Group consists of Kopela Shale Formation and the unconformably overlying Po Gutta Formation. The Tarur Nala Formation and the Pedda Gutta Chert Formation are products of deep water sedimentation. All other formations are marked by shallow water depositional features. The stratigraphic position of the Somanpalli Group *sans* the Po Gutta Formation seems to be below the Albaka Sandstone which seems to lie unconformably below the Sullavai Group in the eastern Proterozoic belt. The Somanpalli Group, therefore, has a stratigraphic position similar to that of the Pakhal rocks of the type area in the western Proterozoic belt.

Key-words : Ash beds and graywacke, fault-bounded troughs, lithostratigraphy, mixed siliciclast-carbonate platform, Pakhal, Proterozoic.

INTRODUCTION

With the exception of some inliers, the Proterozoic rocks of the Pranhita-Godavari (P-G) Valley are deposited along two parallel NW-SE trending belts with an intervening strip of Gondwana rocks. The stratigraphy of the western Proterozoic belt has been reasonably well documented (King, 1881; Basumallick, 1967; Chaudhuri, 1985; Chaudhuri *et al.*, 1989). A formal classification scheme for the Proterozoic sequence of the eastern belt outcropped in the Albaka Ranges in the southeastern part is available (Srinivasa Rao *et al.*, 1979), but a formal stratigraphy is yet to be established for a

large part of the belt northwest of the Albaka Ranges. The present work is intended to be a comprehensive study of the geology of an area northwest of the Albaka Ranges in the eastern Proterozoic belt around the confluence of the Indravati and Godavari rivers (inset in Fig. 1). The Proterozoic rocks of the Pranhita-Godavari Valley were originally grouped together under the Pakhal Series (King, 1881) and were devided into a lower Pakhal stage, developed mainly in the western belt and an upper Albaka stage, largely forming the eastern belt. Later workers classified the rocks of the western belt under Pakhal Group (Basumallick, 1967) and defined Albaka Group from the eastern belt (Chaudhuri *et al.*, 1989; *cf.* Albaka Sandstone of Srinivasa Rao *et al.*, 1979). Though the Pakhal Group in the type area is generally regarded as an unmetamorphosed sedimentary sequence with little deformation, the southern extremity of the western belt in the Yallandlapad area is characterised by a highly deformed and metamorphosed rock sequence (Rammohana Rao, 1971). Detailed stratigraphic work is needed to identify the probable equivalents of the Pakhal Group in the deformed Proterozoic strata of the eastern belt.

UNIT NAMES AND THEIR TYPE SECTIONS

The Proterozoic sequence of Somanpalli shows faulted boundaries against the Gondwana rocks on the west and Albaka Sandstone and basement gneisses in the east (Fig. 1). Deformation of the sequence has given rise to large scale folds, cleavage, and high and low angle faults. The style of deformation is characteristic of the external zones of a mountain belt (Saha, 1989, 1990). Low grade metamorphism has given rise to chlorite, muscovite and chloritoid in the pelitic rocks of the sequence.

The following are the six stratigraphic units of formation rank that have been recognised in the Proterozoic sequence of the area, arranged in ascending order:

6. Po Gutta Formation (sandstone-shale alternations)
5. Kopela Shale Formation
4. Pedda Gutta Chert Formation
3. Tarur Nala Formation (includes thick ash beds and laterally persistent graywacke shale intercalations)
2. Somnur Formation (mixed siliciclast-argillite dominant).
1. Bodela Vagu Formation (carbonate dominant)

A higher ranking unit which includes the above six formations has been recognised and named as the Somanpalli Group (see also Ghosh, 1986; Saha and Ghosh, 1988).

Table 1 gives the location of the type sections of the stratigraphic units and their thicknesses.

Since the strata are more often than not vertical or steeply dipping, the type sections incorporate the data obtained

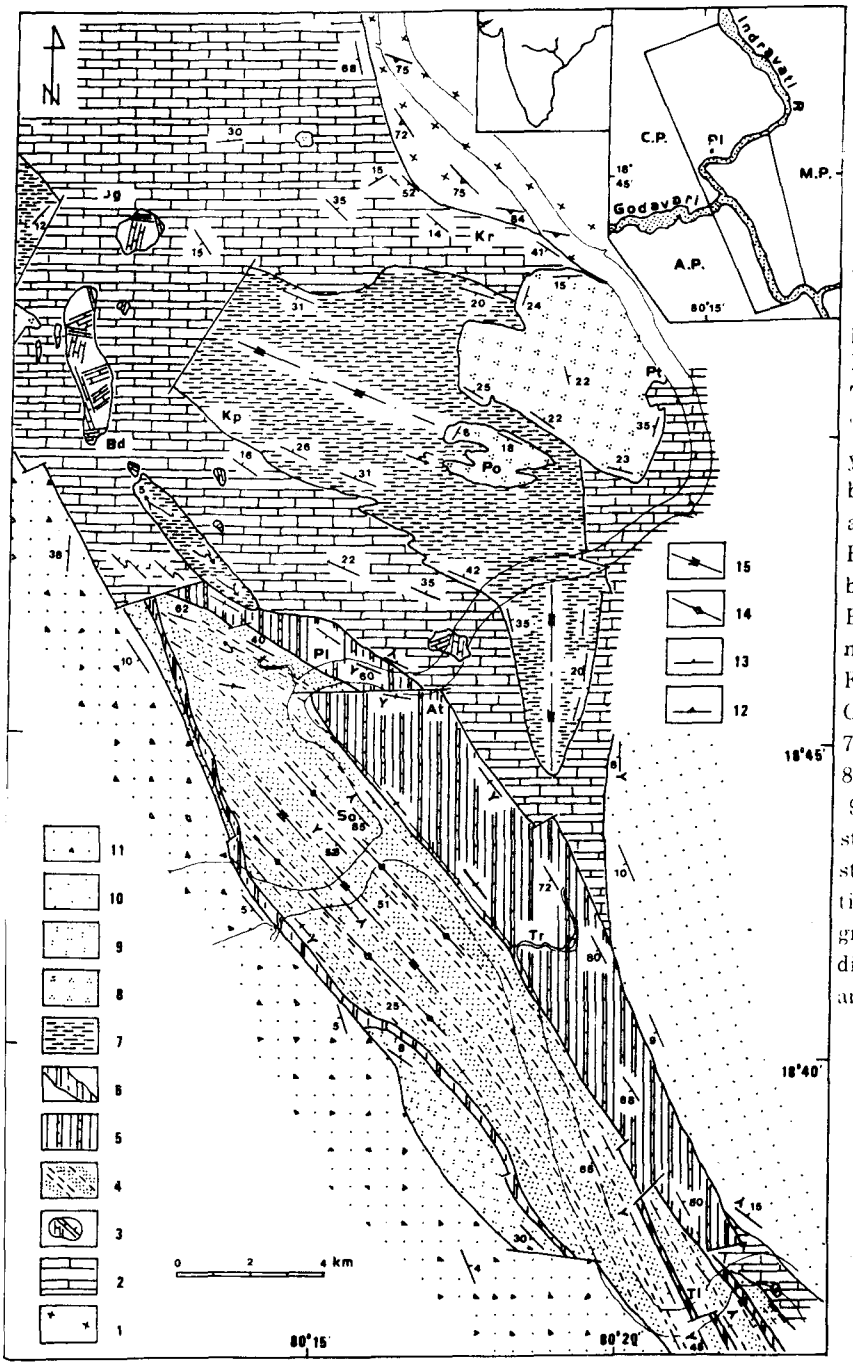

Fig.1. Geological map of the study area. Inset shows the geographic location of the mapped area. C.P. = Maharasthra, M.P. = Madhya Pradesh. A.P. =Andhra Pradesh. At = Atkapalli, Bd = Bodela. Jg= Jinganur, Kp=Kopela. Kr = Korla, Pl = Somanpalli, Po = Po Gutta, Pt = Patagudem, So= Somnur, Tl=Tarlagura, Tr=Tarur. "Y" for stratigraphic younging direction. 1 = basement gniess (? Archaean), 2= Bodela Vagu Forma-tion (BVFm), 3 = breccia bodies within BVFm, 4 = Somnur Formation, 5 = Tarur Nala Formation, 6 = Pedda Gutta Chert Formation, 7=Kopela Shale Formation, 8=Po Gutta Formation, 9 = Eranna Gutta Sandstone, 10=Albaka Sandstone, 11=Chikiala Formation (Gondwana); 12 = gneissic foliation, 13 = bedding, axial traces, 14 = antiform, 15 = synform.

Table 1
Formation names and their type sections

Formation	*Type section and equivalent*
Po Gutta Formation (c. 155 m)	Po Gutta, south of Kopela - Patagudem Road (18°40'N:80°15'07"E) Alto Gutta and Kosa Gutta north of Kopela-Patagudem Road
Kopela Shale Formation (c. 450 m)	Nala sections east of Kopela (18°50'10"N:80°13'40"E) traverse between points (18°49'50"N:80°14'45"E) and (18°49'43"N:80°13'40"E)
Pedda Gutta Chert Formation (c. 250 m)	Northern slopes of Pedda Gutta, 374 m peak (18°40'N:80°15'07"E); Sarvaipet Nala mouth on the southern bank of the Godavari River, off Sarvaipet village (18°42'N:80°14'30"E)
Tarur Nala Formation (c. 1250 m)	Tarur Nala (Daddalsari Nala) between longitudes 80°19'30"E:80°18'10"E ; Godavari River sections near Tarlagura, between longitudes 80°21'20"E and 80°21'25"E
Somnur Formation (c. 1100 m)	Godavari River bank opposite Somnur, between longitudes 80°15'50"E and 80°16'20"E; Godavari River bank around Gangaram between longitudes 80°20'30"E and 80°21'40"E
Bodela Vagu Formation (c. 220 m)	Bodela Vagu (nala) and its tributaries from Jinganur (18°54'05"N : 80°11'55"E) through Bodela (18°49'50"N : 80°11'55"E) to the northwest of Somanpalli (18°47'15"N : 80° 11'55"E); Indravati River section southeast of Pendlaya between longitudes 80°19'10"E and 80°19'30"E.

Table 2
Relative stratigraphic position of the formations belonging to the Somanpalli Group

			Po Gutta Formation
			Kopela Shale Formation
Pedda Gutta Chert Formation		Tarur Nala Formation	
	Somnur Formation		Bodela Vagu Formation
West	← *geographic shift of depocentre* →		*east*

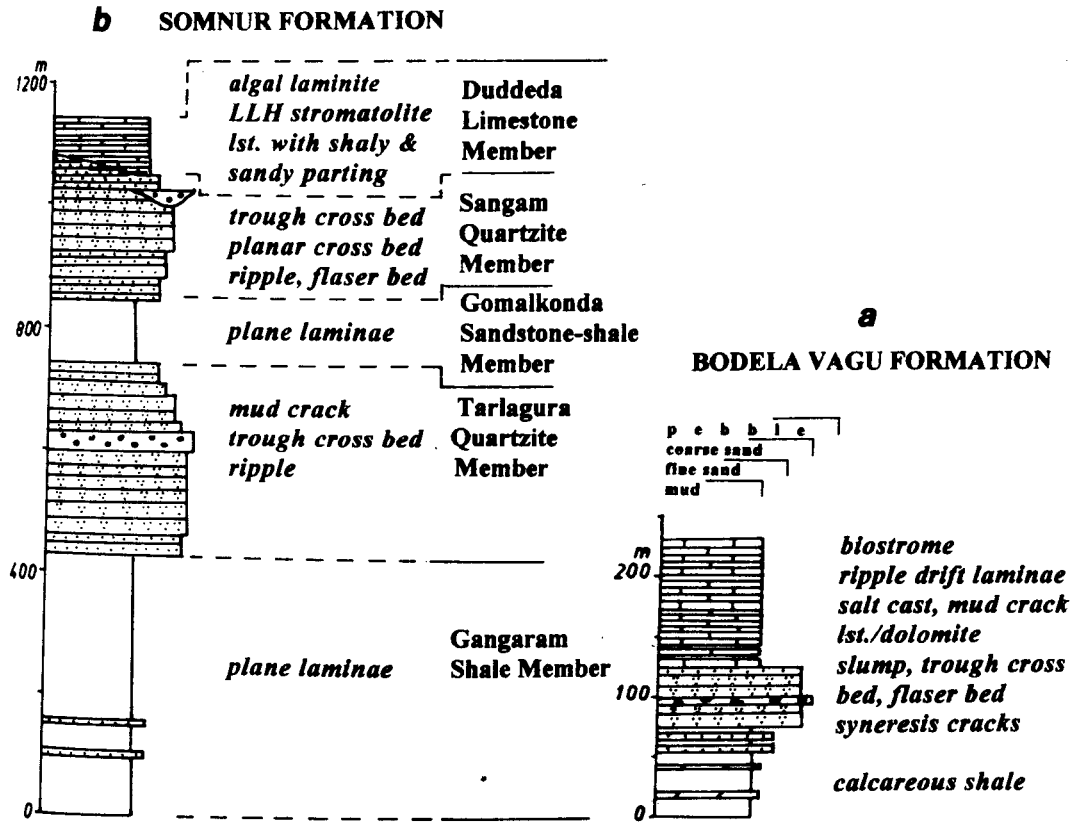

Fig. 2. Generalised Lithologs of the Rodela Vagu Formation (a) and the Somnur Formation (b).

from representative ground traverses across the respective units in places, which are so selected as to be as free from structural discontinuities as possible. Unless otherwise indicated, the estimated thicknesses are the minimum for the respective units and not corrected for any tectonic strain. Subdivision of the units into members has been possible where the original stratigraphic relations can be discerned, and lithostratigraphic distinctiveness of certain portions of the units demands finer classification.

BODELA VAGU FORMATION

The Bodela Vagu Formation is an association of argillaceous limestone, dolomitic limestone and dolomite. Siliciclastic intercalations are common in the lower half of the formation and dolomitic algal laminite-stromatolite assemblage constitutes the other half [Log (a) in Fig. 2]. Carbonate breccia complexes varying in size from a few tens of meters to a few kilometers and having roughly circular to elliptical outline show

cross cutting relation with the surrounding bedded carbonate rocks. These breccia bodies are often associated with small patches of quartzofeldspathic material.

The siliciclastic intercalations range from breccia-conglomerate through gritty quartzite to fine grained quartz-arenite and are commonly interbedded with dolomitic limestone. Partings of calcareous mudstone are occasionally present and salt peudomorphs are often abundant. The sandstone beds are commonly trough, cross stratified to ripple laminated, while the breccia-conglomerate or gritty units are thick and massive. Calcareous mudstone or siliceous limistone units often show asymmetric ripples, polygonal shrinkage cracks, and water escape features in the Bodela Vagu section. The top of the Bodela Vagu Formation consists of a 5-6 meter thick unit of algal laminite-stromatolite, which is marked by development of molar tooth structure, stylolites, syneresis cracks filled by sparry calcite, and stromatolite heads (mostly partially linked hemi-spheroids, LLH) in abundance.

SOMNUR FORMATION

The rocks of the Somnur Formation are disposed in a number of NW-trending large antiforms and synforms with faulted limbs. Five members have been recognised within the formation, namely, Gangaram Shale Member, Tarlagura Quartzite Member, Gomalkonda Sandstone-shale Member, Sangam Quartzite Member and Duddeda Limestone Member, stated in ascending order [Log (b) in Fig. 2]. The Gangaram Shale Member is a 460 m thick plane-laminated dark shale unit with sparse and thin sandstone intercalations. The sandstone layers are laterally continuous for a few tens of meters and vary in thickness from a few millimeters to a few decimeters. Shales are locally metamorphosed into phyllites of greenschist facies and show a cleavage cutting across the bedding lamination. The basal part of the Gangaram Shale Member in Somnur section is calcareous and light green in colour.

The Tarlagura Quartzite Member (thickness c. 320 m) consists of coarse to fine grained quartz-arenites showing well rounded to well sorted terrigenous material and occasional thin shale partings. Trough and herringbone cross stratification, asymmetric to interference ripples. and desiccation cracks are characteristic of the quartzarenites.

The Gomalkonda Sandstone-shale Member is about 120 m thick and consists of interstratified sandstone-shale. which often display wavy, flaser bedding and syneresis features. Excellent exposures of this member are available along the banks of the Godavari River between Somnur and Gomalkonda.

The Sangam Quartzite Member is 200 m in thickness and shows nearly the same facies association as the Tarlagura Member. Planar cross beds and flasers.

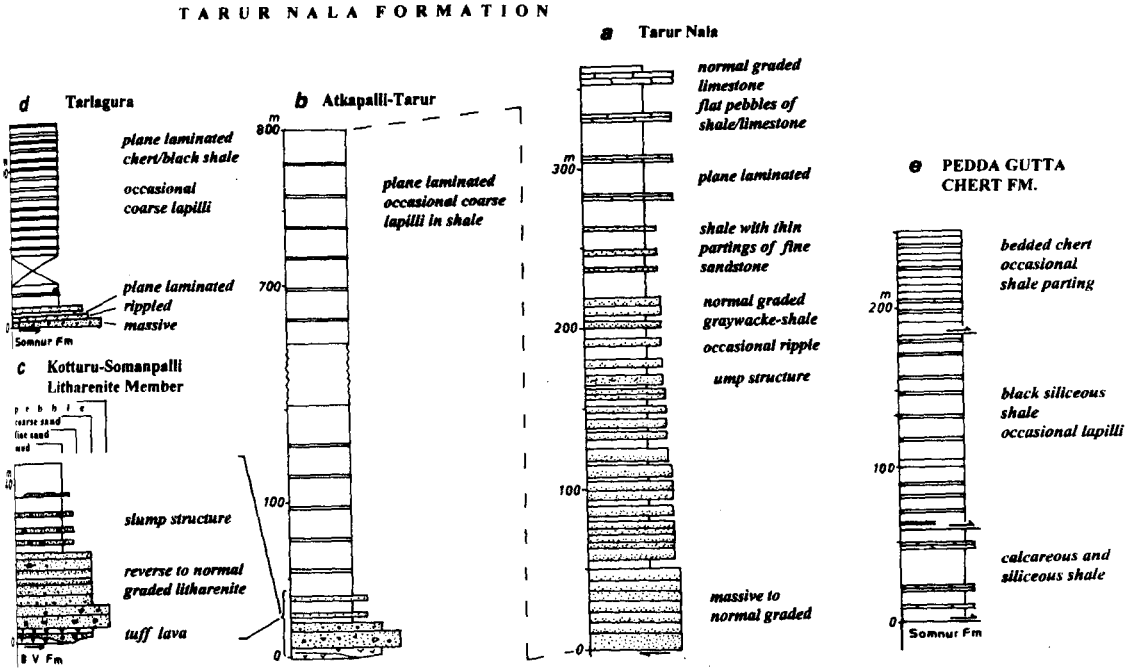

Fig. 3. Lithologs of the Tarur Nala Formation from Tarur Nala and other sections, and generalised log for the Pedda Gutta Chert Formation. Arrows indicate fault contacts.

however, are more abundant in the Sangam Quartzite Member. Lateral and vertical gradation into the Duddeda Limestone Member is distinct.

The Duddeda Limestone Member is 100 m in thickness and consists of a number of thin (<1 m) stromatolite biostromes alternating with argillaceous and siliciclastic sediments. Algal lamination and small domal stromatolites are locally abundant. Mention may be made of the river bed sections of Godavari west of village Duddeda.

TARUR NALA FORMATION

The Tarur Nala Formation consists dominantly of ash beds and graywacke-shale grading to intercalated shale-limestone (Fig. 3). Around Kotturu Somanpalli, the basal part of the formation is defined by a 50 m thick sequence of volcaniclastics, litharenite and slumped shale bordering the argillaceous limestone of the Bodela Vagu Formation (Log (c) in Fig. 3). The sandy units contain pebbles of argillaceous limestone and tuffaceous lava in the basal part, and are generally very coarse to medium grained.

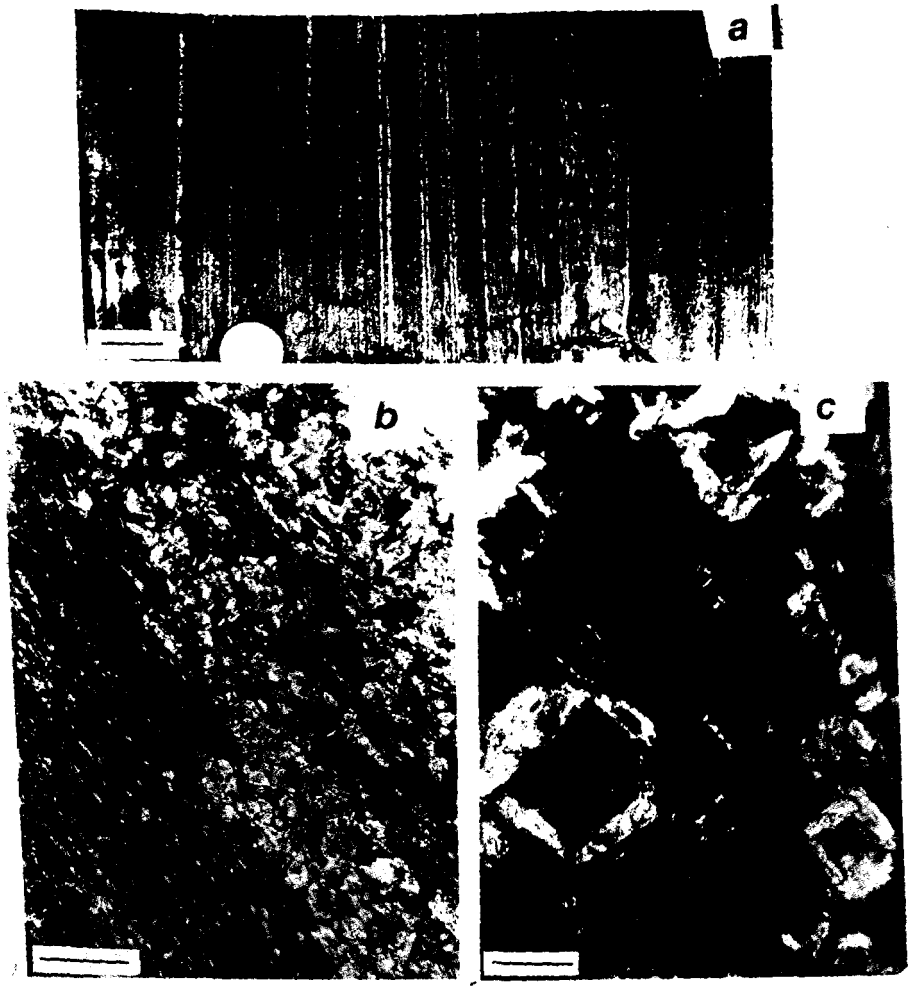

Fig. 4. Ash beds, Indravati River bed off Kotturu-Somanpalli. (a) Field photograph showing plan view of near vertical beds;trace of bedding laminae is ESE-WNW. Bar scale is 20 mm. (b) Microphotograph (XPL) showing relatively coarser lamina of altered crystal tuff corresponding to a brighter lamina in (a); adjoining finer lamina consists of microcystalline quartz and sericite. (c) Tessellated muscovite flakes replacing rectangular to square sections of feldspar crystals in altered crystal tuff lamina; microphotograph, XPL. Bar scale is 100 micron in (b) & (c).

They are characterised by massive or normal to reverse graded beds and are topped by slumped shales grading laterally to ash beds. The formal name of Kotturu Somanpalli Litharenite Member is proposed for the basal part of the Taru Nala Formation.

The ash beds of Kotturu Somanpal continue southwards and attain a max

mum thickness of 800 m in the Atkapalli-Tarur Nala section [Log (a)-(b) in Fig. 3]. The ash beds are altered fine crystal tuffs with occasional relicts of coarser lapilli (Fig. 4) and have the appearance of laminated shales. Blue, green or red coloured laminae are traceable for tens of meters. The ash beds are overlain by a sequence of massive to normally graded fine grained dirty sandstone-shale intercalation passing upward to plane laminated calcareous shales with normally graded thick bedded pyritiferous calcarenite. A lateral facies variant of the ash beds is represented by bedded chert inter-stratified with siliceous black shales, locally with thin interbeds of limestone exposed around Tarur Nala mouth. In the Tarlagura section, about 150 m of chert-black shale sequence overlies a breccia facies showing wavy to irregular massive beds and consisting of silicified pebble size fragments in a quartzose sandy matrix. The latter grades upward through a fine sandstone to siliceous shale [Log(d) in Fig. 3].

PEDDA GUTTA CHERT FORMATION

The Pedda Gutta Chert Formation lies between the Somnur Formation in the east and the Proterozoic Eranna Gutta Sandstone-conglomerate sequence or the Mesozoic Chikiala Sandstone in the west and defines a fault–bounded outcrop. Excellent exposures are available on the northern slopes of Pedda Gutta (374 m peak) and the southern bank of the Godavari River near the confluence with Sarvaipet Nala. The sequence is gradational from calcareous shale to bedded chert through varying proportion of interstratified shale and chert [Log (e) in Fig.3]. The thickness of the formation measured in the outcrop is about 250 m. Stratigraphic repetition on varying scales has been ascribed to internal folds and thrusts (Saha, 1990). The formation has a striking similarity in lithologic characters with a part of the Tarur Nala Formation exposed near the mouth of the Tarur Nala and around Tarlagura.

KOPELA SHALE FORMATION

The Kopela Shale Formation consists largely of gray-green shale with occasional interstratified flat lenses of cross bedded sandstone in the lower part, and is capped by interbedded sandstone shale unit displaying wavy and flaser bedding, asymmetric ripples and shrinkage cracks [Log (a) in Fig. 5]. Ferruginous concretions are common in the shales in the nala sections west of Kopela. The outcrop pattern is controlled by E-W-trending folds, which are associated with pencil cleavages.

PO GUTTA FORMATION

The Po Gutta Formation consists mainly of sandstone-shale intercalation grading to quartzite in the upper part. A thin basal conglomerate is of local development and contains pebbles of shale, sandstone, vein quartz, and feldspar set in a micaceous sandy matrix [Log (b) in

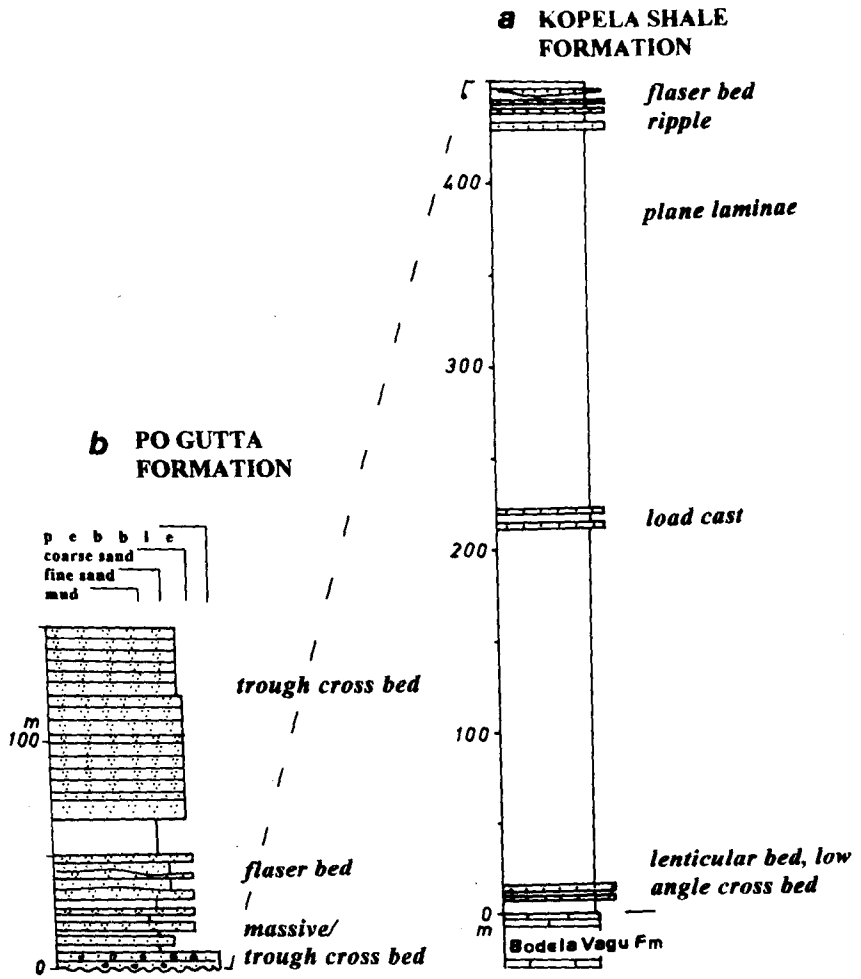

Fig. 5. Generalised lithologs of the Kopela Shale Formation (a) and the Po Gutta Formation (b).

Fig. 5]. The components of the intercalation are gritty sandstone and micaceous siltstones which commonly display wavy bedding and asymmetric ripples. The quartzites to which they are gradational are massive to trough cross bedded. The basal conglomerate facies overlies the basement gneisses and contain gneissic fragments. Excellent exposures are available around the village Korla c the bank of the Indravati River. Tl conglo-merate- sandstone sequence Eranna Gutta, exposed discontinuous along the western margin of the Pedc Gutta Chert Formation, represents lithofacies association similar to th of Po Gutta, though being poorer in tl shale content.

DISCUSSION

Formation Boundaries

The mixed siliciclastic-carbonate strata of the Bodela Vagu Formation and the Somnur Formation represent a facies association characteristic of peritidal environment (Saha and Ghosh, 1988). The rocks of the Tarur Nala Formation occur in a fault-bounded trough and separate the outcrops of the Bodela Vagu Formation from the Somnur Formation (Fig. 1). The Pedda Gutta Chert Formation lying west of the Somnur Formation also occurs in a fault- bounded trough. The bounding faults appear to have originated as extensional stage normal faults and reactivated during the contraction of the belt (Saha, 1992a,b). Progradation of the siliciclast-dominant Somnur Formation onto the carbonate-dominant Bodela Vagu Formation is demonstrated in the upfaulted blocks of siliceous dolomite facies of the Bodela Vagu Formation, which defines inliers within the Somnur Formation at Gangaram and also within the Tarur Nala Formation outcrop at the Indravati River bed between Somanpalli and Regudani Gutta. It seems that the Somnur Formation and the Bodela Vagu Formation were deposited as two adjoining facies belts, although a progradation of the Somnur Formation over to the Bodela Vagu Formation is demonstrated by the Gangaram and the Indravati River sections.

The basal part of Tarur Nala Formation in the Kotturu Somanpalli section contains pebbles which appear to have been derived from the Bodela Vagu Formation. The Bodela Vagu Formation, therefore, was deposited earlier than the Tarur Nala Formation. In the Tarlagura section,the base of the Tarur Nala Formation is juxtaposed against the Somnur Formation along a fault and contains matrix supported debris flow conglomerate. The association suggests control of deposition by synsedimentary faulting. The Tarur Nala Formation is, thus, younger than both the Somnur Formation and the Bodela Vagu Formation.

The Pedda Gutta Chert Formation shows a lithofacies association comparable to a part of the Tarur Nala Formation and occurs west of outcrop of the Somnur Formation across a fault contact. After the deposition of the Bodela Vagu Formation and the Somnur Formation, extension and subsidence of the basin floor led to the formation of fault- bounded troughs, which acted as repositories for the Tarur Nala Formation and the Pedda Gutta Chert Formation.

The Kopela Shale Formation conformably overlies the Tarur Nala Formation and onlaps the Bodela Vagu Formation. The Po Gutta Formation abuts against the Precambrian basement gneisses and onlaps the Bodela Vagu Formation and the Kopela Shale Formation. A summary of the stratigraphic relations described above is given in Table 2.

Regional Stratigraphic Framework

A two fold classification of the Purana (Proterozic) sequence of the Pranhita-Godavari Valley into a lower Pakhal Series and an unconformably overlying Sullavai Series was proposed by King (1881). Further classification of the Pakhal Series led to the recognition of a lower Pakhal subdivision consisting of rock strata which is confined to the western part of the basin and an upper Albaka subdivision, which occupy the eastern part. The Pakhal subdivision was later redefined as the Pakhal Group and was further classified into lower Mulug Subgroup and upper Mallampalli Subgroup, on the basis of the occurrence of a regional unconformity separating the two subgroups (Basumallick, 1967; Chaudhuri, 1985). A sequence of limestone and shale occurring north of the Godavari River in the western belt and "traceble to the Pakhals of the type area" were designated as the Penganga Beds (A. M. Heron, quoted in Pascoe, 1973) and later renamed as the Penganga Group (Chaudhuri *et al.*, 1989). The Pakhal rocks around Yellandlapad in the southern part of the western belt is different from the rest of the belt in being deformed and metamorphosed, and have been assigned to a separate unit of group status—the Yellandlapad Group (Chau-dhuri and Chandra, 1990).

The sequence consisting of the Cherla Formation, Somandevra Quartzite and Tippapuram Shale, and lying below the Albaka Sandstone in the Albaka Range, was correlated with the Pakhal Group. Accordingly, the Albaka Sandstone came to be regarded as an equivalent of the Sullavai Group (Srinivasa Rao *et al.*, 1979). Chaudhuri and Chandra (1990), however, questioned the above correlation and proposed that all the rock formation of the Albaka Ranges be grouped together to define a new stratigraphic unit. The name Albaka Group has been assigned to this unit.

Intrabasinal Correlaion of the Somanpalli Group

The Tippapuram Shale occurring below the Albaka Sandstone in the Albaka Ranges is lithologically similar to the Kopela Shale Formation. An outlier of the latter is the Depali shales which is laterally traceable to the type outcrops of the Tippapuram Shale in the western foothills of the Albaka Ranges. Therefore, the Somanpalli Group *sans* the Po Gutta Formation lies stratigraphically below the Albaka Sandstone. The Po Gutta Sandstone is considered to be equivalent to the Albaka Sandstone. We propose that the term Albaka Group (Chaudhuri and Chandra, 1990) should be dropped, as the Albaka Sandstone is a formally established stratigraphic unit of formation rank.

In view of the fact that the Sullavai Group overlies the Albaka Sandstone in

the eastern belt, the Somanpalli Group may be considered to have the same position in the stratigraphic sequence as the Pakhal Group in the western belt. Rock sequences of the Pranhita-Godavari Valley older than the Sullavai Group witnessed varying degrees of contractional deformation. Examples are provided by the deformed sequence at Yellandlapad in the southern sector of the western belt, which are comparable to the Pakhal Group in lithological make up, the Penganga Group (Sarkar, 1990), deformed rock sequences of the Albaka Ranges (Srinivasa Rao *et al.*,1979; Saha, 1988), and the deformed Somanpalli Group of the eastern belt.

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