A BRIEF OVERVIEW OF PALAEOPROTEROZOIC GEOLOGY OF THE SINGHBHUM CRUSTAL PROVINCE, EASTERN INDIA

A REPORT OF RECENT FIELD INVESTIGATION IN THE SINGHBHUM CRUSTAL PROVINCE

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Introduction:

This report gives account of one week reconnaissance fieldwork performed in the Singhbhum Province, as a part of the UNESCO IGCP 509 "Palaeoproterozoic Supercontinents and Global Evolution". We hope to stimulate research in this region and to convince others follow our example and investigate the magnificent geology of India, one of the most interesting and economically and culturally booming countries in the world.

We left Kolkata on 5th March at 6.00 a.m. by Ishpat Express train to Jamshedpur (also called Tata), an industrial city famous for its steel and car industries. Jamshedpur is a pleasant place after the chaotic Kolkata, offering several (4-5) western style hotels, with good facilities, general infrastructure, internet, excellent Indian but also European and Chinese food and a possibility to organise further travel, car rentals and even probably small conferences.
We were able to rent a small car with a driver for a week, at a reasonable price. All vehicles organised from the Hotel, were in good conditions and the drivers were reliable, making fieldwork and travelling relatively easy. Daily distances between 300 and 100 km had to be driven, however, because of partly catastrophic road and traffic conditions, a drive of 150 km to the outcrops can take as much as 4 hours, even if the road is marked as a high rank National Highway.
Outcrop conditions are generally good, the outcrops visited being located close to the road and reachable by car in most cases. Mapping in the entire area was found to be largely insufficient and far away from being detailed. All exposures requiring some walking or climbing of forested hills, with up to c. 300m altitude difference from the road level, were probably never visited by a geologists. Because of limited time we have as well refrained from such exercises, but it seems certain that few moths of systematic mapping in the Singhbhum Province would reveal a profusion of new results and eventually lead to a better understanding of stratigraphy and structure in the area. Work with postgraduates should thus be relatively easy and very rewarding in the area, best fieldwork season being November to February.

General geologic setting:

The basement of the Singhbhum metasedimentary rocks can be traced in a broadly elliptical pattern of granitoids, with patches of TTG rock assembly, surrounded by metasediments and metavolcanics of Greenstone Belt association (Fig. 1). Most of the intrusive rock area is occupied by the Singhbhum granodiorite, dated at 3.1 Ga, (Saha, 1994) and crosscut in rectangular pattern by voluminous Neoarchaean mafic and ultramafic dike swarms (Roy et al., 2004). An ancient core to the Singhbhum rocks is built by the relatively small remnant of the Older Metamorphic Group (OMG) and Older Metamorphic Tonalite Gneis (OMTG) rocks, dated between 3.4 and 3.5 Ga and metamorphosed to amhibolite facies (Sharma et al., 1994; Saha, 1994). The Singhbhum granodiorite is intrusive into these old rocks and to younger, mid Archaean metasediments, at upper greenschist facies, including iron formations, schists and metaquartzites and siliciclastics of the Iron Ore Group (IOG).

The Palaeoproterozoic Dhanjori Formation overlies the Singhbhum granite and is in turn overlain by the Chaibasa and Dhalbhum Formations constituting the Singhbhum Group (Mazumder, 2005). Age constraints of this Palaeoproterozoic stratigraphic succession are very poor. The few km thick, largely terrestrial Dhanjori Formation includes lavas in its upper part, which were dated at 2100 Ma (Roy et al., 2002a). The following 6 to 8 km thick marine Chaibasa Fm. lacks datable rocks. The following Dhalbhum Fm. includes 2 to 4 km thick quartzites, schists and tuffs of an unknown age and the following Dalma Formation with thick lava and volcaniclastic rocks was dated at a minimum of 1600 Ma (on intrusives, Roy et al., 2002b). The minimum age of the Chandil Fm. is 1500 Ma (Sengupta et al., 2000). The entire metasedimentary succession thus may cover more than 500 million years of supracrustal sedimentation history and is described to have suffered from severe thrusting and multiphase folding and metamorphism. The rocks were thrusted towards the craton core, along the prominent and laterally extensive semi-circular Singhbhum Shear Zone (SSZ) which encompasses mainly Dhanjori quartzites and schists and can be followed for some 200km along strike and for few km in width.

The thrusting, folding and metamorphism are generally thought to thoroughly obliterate stratigraphic and sedimentary facies relationships. In our experience however, this is entirely not the case. Despite of thrusting and

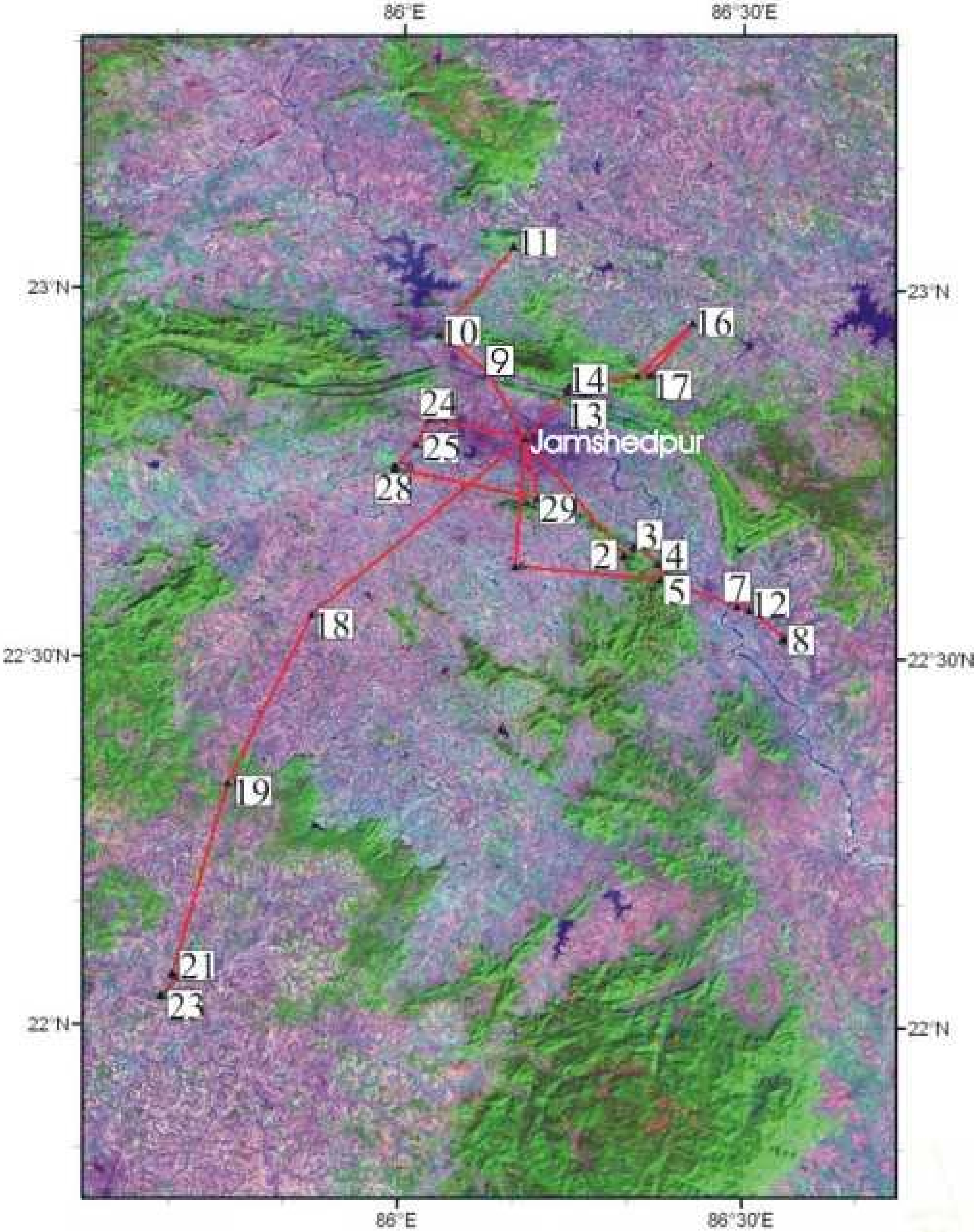


Figure 1: satellite image of the visited area of the Singhbhum and nNorthern orissa provicnes and the relevant localities/waypoints.

folding on large scale, the stratigraphic succession is largely preserved. Sedimentary structures, in many cases, can be easily recognised on the weathered bedding surfaces in mixed pelitic and arenitic rocks, but are not recognisable in the formerly massive pelites that were turned to almandine-mica lustrous schists, displaying schistosity and crenulation cleavage. Conspicuously, the degree of metamorphism decreases markedly towards the top of the section and is much lower in the Dalma and Chandil Formations, probably reaching lower greenschist facies at the top. The timing of one of the metamorphic events is around 1600 Ma, as is the age of the shearing/thrusting along the Singhbhum Shear Zone (Krishna Rao et al., 1977; Sengupta and Mukhopadhaya, 2000).

Archaean components:

Older Metamorphic Group (OMG) and Older Metamorphic Tonalite Gneiss (OMTG):
We have visited the well known outcrops of the Older Metamorphic Group at Champua town, along the Baitarini River section (waypoint 21). The outcrops reveal a tightly and irregularly folded amphibolite with alternating dark, greenish and pale, grey layers in contact to coarse-grained gneiss (Fig. 2). Tonalitic gneiss apophyses crosscut the amphibolite in which metamorphic stretching and boudinage structures are common. Both rock types are intruded by a mafic dike that appears undeformed and forms the rapids across the river.
Further to the south, towards Ramula Village on the NH 75, a low ridge of fine tuffs (or deeply weathered shale?) is outcropping, highly altered, and intruded by a thick quartz vein along the strike (waypoints 22, 23). Bedding is hardly recognisable in this thoroughly weathered yellow-brown and soft metasediment. Some 300 m further South along the highway an outcrop of quartzite overlying the fine, weathered tuff crops out as a ridge perpendicular to the highway. The c. E-W striking quartzite is massive, thickly bedded and all together, at least 50 m thick. The entire matasedimentary succession including the underlying tuffs might be more than 500 m thick. This is probably the “orthoquartzite” described by Misra et al. (1999) that contain zircons of 3.5Ga. The upper horizons in this outcrops exhibit a 1-2m thick chert, concordant to the quartzite. The chert is dark brown-red, brecciated and exhibits no sedimentary structures or bedding but only fine white quartz veining (Fig. 3).

Figure 2: Dark amphibolitic lenses within a coarse grained Gneiss in the OMG Champua town, along the Baitarini river

Figure 3: Brecciated red chert covering in orthoqartzite

Singhbhum granodiorite and the Iron Ore Group (IOG):
The Singhbhum granodiorite (Fig. 4) constitutes the low lands in the province and makes only outcrops as very flat rock pavements between the fields or in direct contact to the intrusive mafic dikes that crosscut the granite in a rectangular pattern. The mafic dikes are most probably of Neoarchaean age (2.8 Ga; cf. Roy et al., 2004) and strike NE-SW and NW-SE. The coarse grained granodiorite is deeply weathered and the dikes build large hill ridges resistant to weathering and often several hundred metres across. The metasediments of the Iron Ore Group consist of lenticular BIF bodies, from which iron ore is extracted on local scale, and of metasedimentary graywackes to quartzites and mica schists. The metasedimentary rocks form hills along the way from Jamshedpur to Hata, just few km outside of Jamshedpur, where some quartzite and extensive outcrops of schists with amphibole needles and large micas, two schistosity plains and feldspar blasts were encountered (waypoint 29; Fig. 4)

Figure 4: The Singhbhum granodiorite forms usually poor outcrops in wide plains interrupted only by hills of crosscutting thick, intrusive mafic dikes, like the hill in the far back (left photograph). To the right outcropping amphibolitic schists of the Iron Ore Group in the vicinity of Jamshedpur.

Proterozoic Supracrustals:

Dhanjori Fm.:

The sedimentary contact of the basal Dhanjori Fm. on the Singhbhum granodiorite can be observed in the vicinity of Rohinibera village, south of Jadugorah, (close to and west of waypoint 3) where steeply N- dipping gritty quartzite and mica schists directly overly the granodioritic batholith. Schists, and matrix supported but clast-rich conglomerate lenses are intercalated before the section passes upward to micaceous quartzites (Fig. 5). The bedding and lamination in quartzites are even, flat, with some preserved ripple lamination and cross bedding. In the upper part of the probably exclusively terrestrial, fluvial to lacustrine Dhanjori Fm., basalts and andesitic basalt flows are intercalated, which are mined by the local population for road building materials. From the exposures visited by us, the definite assignment of facies preserved in the quartzites is not possible. The fine and largely very mature rocks could be anything from fluvial to aeolian. They are usually however, described as of terrestrial environments Mazumder and Sarkar, 2004; Mazumder, 2005).

At the Rakha Mines Station (cased Cu-Mine) we have visited outcrops within the Singhbhum Shear Zone. The SSZ dips steeply to the N and exhibits strongly sheared micaceous schists and quartzite beds, which are strongly recrystallised. Vein quartz is common in the shearzone and folded together with the brown-reddish-grey phyllitic schists into small scale "ptygmatic" folds (Fig. 6).

Figure 5: Lens of conglomerate in schists at the base of the Dhanjori Formation

Figure 6: Folded vein quartz in schists within the Singhbhum Shear zone

Chaibasa Fm.:

The Chaibasa Fm. is described as transgressive over the basement and the Dhanjori Formation. The Chaibasa consists of repeated intercalation of precursor sandstones, fine-grained sandstone/siltsone-mudstone intercalations and mudstone on dcm to mm scale, which are metamorphosed to lustrous mica and garnet (almandine) bearing schists and micaceous quartzites. Despite of severe metamorphic overprint the weathering surfaces of the laminites and thick quartzite beds display excellent preservation of sedimentary structures on millimetre to metre scale.

We have visited outcrops of this formation at three different localities, at Harindungri Village, at the Ghatshila Town and at the old airport runway 10 km east of Ghatshila (Dhalbhumgarh) (waypoints 8 and 12).

At the Harindungri village quartzites exhibit distinct planar cross bedding with abundant reactivation surfaces, sigmoidal foresets, tidal sand-mud couplets, rare wave ripple marks on bedding surfaces and dish structures superimposed directly on straight, large crossbed foresets (Fig. 7). Overturned cross bedding is abundant and very conspicuous. In many cases several overturned cross bedded layers are erosively superimposed one on another and in some cases an overturned cross bedded set is truncating a lower, overturned crossbed foreset within the same sedimentary layer. The overturned cross bedding sets are between 15 and 40 cm thick and stretching and boudinage or fading of the overturned portion of the foresets is common (Fig. 8). Common are also beds with oversteepened cross bed foresets. This clearly tidally influenced facies is overlain by micaceous schists and intercalated quartzites displaying interbed slump and convolute structures on various scales. Large ball and pillow structures intermingle with elongated, laterally stretched convolutes. Liquefaction of sandy sediment between layers of mud is obvious and might have been triggered by seismic activity or via slope oversteepening and overloading of sedimentary strata. Such structures can be followed within the same layers for at least several tens of metres of outcrop extend, in layers of varying thickness from 10 to 50 cm (Fig. 9). Some structureless massive sandstone beds might represent mass low deposits in which the liquefaction of the formerly finely bedded to laminated layer entirely destroyed the original sedimentary structure. Other massive sandstone beds display some rip up clasts inclined in the same direction as generally the crossbed foresets and concentrated at certain levels within the bed, like pearl chains, but matrix supported.

About 2 km E' of Ghatshila the Chibasa Fm still displays similar convolute and ball and pillow structure but intercalated with mud layers of constant thickness of several decimetres and of continuos lateral extent over hundreds of metres of outcrop. Sandstones in this facies can be sedimentary boudinaged and pinch and swell but are also arranged in laterally very continuos beds attaining up to a metre of thickness. This deposit most probably represents submarine mass flow deposits and turbidites and thus a deep water facies correlative to the tidal flat facies described above (Fig. 10).

At the old British airport runway near Dhalbhumgarh, the Chaibasa Fm., consists mainly of mica-almandine schists (mudstone facies) intercalated with fine laminations of fine quartzite and with thinly bedded siltstone to fine quartzite beds (waypoint 8). These outcrops display abundant synsedimentary deformation structures such as convolutes, slump and sag structures and cracking of underlying layers, whereby the cracks are filled with laminated and convoluted sediment from above and from below (Fig. 11). Synsedimentary thrusting on dcm to metre scale and deformation structures related to this phenomenon are abundant. Oversteepening of single ripple cross beds and boudinaging in ripple trains are common (Fig. 12). No wave ripples were found in this facies and as all ripples are distinctly asymmetrical current ripples. The facies most probably represents seismites at deeper, below fair weather wave level to shelf waters. (Mazumder et al., 2006)

Figure 7: sigmoidal foresets in the Chaibasa quartzite

Figure 8: overturned cross bedding passing upward into slump structures in the Chaibasa quartzites

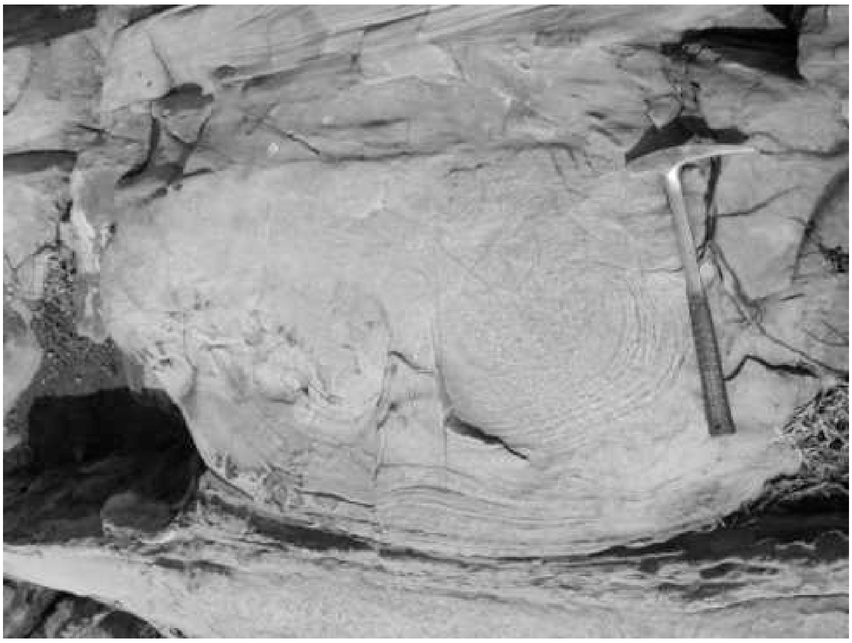
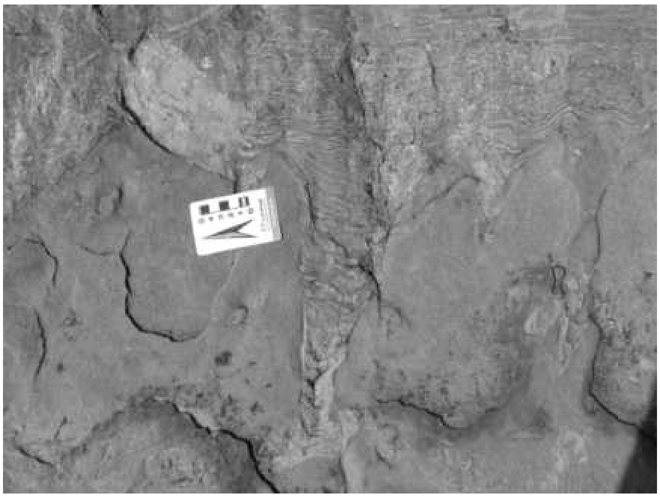


Figure 9: Ball and pillow structures in quartzite schists, Chaibasa Fm.

Figure 10: boudinaged turbiditic quartzite schists in the Chaibasa Fm.



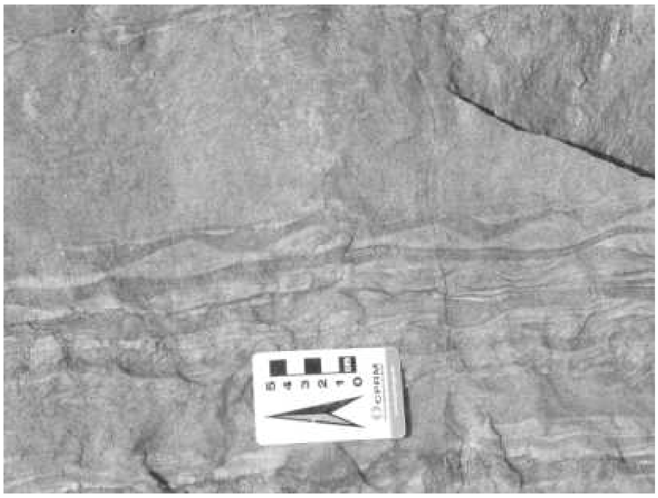


Figure 11: Synsedimentary crack in lustrous schists, filled from above by laminated silt (now fine quartzitic schists)

Figure 12: Ripple train and sismite-deformed beds below

Dhalbhum Fm.:

The Dhalbhum Formation was visited at the shores of the Dimna lake (waypoit 13), NE of and close to Jamshedpur and along the road towards west and southwest of Jamshedpur, in the region of Tiraldih and Dugani villages, and at Sanjay River section (waypoints 25-28). The Dimna lake outcrops are strongly weathered and the nature of the sandy to shaly metasediments is difficult to ascertain (Fig. 13). All other outcrops however, display beautifully preserved fluvial and aeolian structures in thick beds of fine and mature quartzites outcropping in lenses of hundreds of meters in length and several tens of metres thickness, intercalated with micaceous schists, forming extensive flats occupied by villages and fields between the quartzite hills. The strata dip steeply towards north. The fine quartzites are arranged in flat, tabular beds (Fig. 14) with rare streaks of resedimented clay rip up clasts. Some very low angle trough cross bedding is recognisable on metre scale (Fig. 15) in few beds and passes again upward into tabular bedding, with some very flat, low angle planar cross beds and truncation surfaces. Adhesion ripples, formed by wetted sediment are discernible in these strata and flat ripple cross bedding is associated with these surfaces (Fig. 16). Translatent strata formed by migration of very low amplitude aeolian ripples was recognised. Conspicuous in some quartzite beds, are pearl chains of few millimetres to up to 1 cm large, idiomorphic K-feldspar blasts, grown during the metamorphism (Fig. 17). The facies is interpreted as largely aeolian, as described by Simpson et al. (2004), with some intermittent fluvial episodes. The sand dunes were

probably migrating on extensive flats in which interdune sediments, now forming the intercalated mica schists was accumulated.
Of interest is that an undeformed mafic dike intrusions in to the Dhalbhum Formation were found, which might represent feeder dikes to the overlying Dalma volcanic belt.

Figure 13: Weathered Dhalbhum quartzites at Dimna lake

Figure 14: Dhalbhum quartzite with planar bedding

Figure 15: Trough crossbed sets in the Dhalbhum. quartzite

Figure 16: Adhesion ripples, formed by wetted sediment in aeolian quartzite of the Dhalbhum Formation.

Dalma and Chandil Formations:
Dalma Fm. outcrops were visited at two sites. At the Dimna lake's northern hills (waypoint 14) the Dalma Fm. consists of vesicular basalts (Fig. 18) and fine and thin basaltic flow beds intercalated with fine and coarse tuffs and agglomerates in which mafic minerals like hornblende are visible with a naked eye. At the road from the lake towards the Gopalpur village (waypoint 16), before entering the flat topography, the uppermost Dalma Formation forms hills in which dark, silicified shales, black chert (in veins and in beds) and fine grey to whitish quartzite are exhibited along E-W strike, with almost vertical dip (waypoint 17). The quartzite is very fine and thinly bedded, intercalated with grey, fine silicified shale or very fine-grained siltstone. One gentle, asymmetric

fold of c. 2 m amplitude is visible in the few tens of metres thick quartzite bed, which could be a slump fold, as lenses of dark shale and small scale slump folds and convolutes are found in the same outcrop(Fig. 19). The quartzite attains up to 100-200 m thickness and can be traced laterally for more than 500 m along strike. This lithology is underlain and probably also covered by thick and extensive black coloured schists which make poor outcrops. It is envisaged that the onset of basaltic volcanism in the Dalma marks a rift stadium that lead to the development of a local basin in which pelites accumulated together with occasional coarser grained, sandy slump deposits. The black chert is probably of hydrothermal origin as it makes dikes in the schists and in the quartzite (Fig. 20).

Figure 17: K-Feldspar blasts in the Dhalbhum quartzites

Figure 18: Vesicular Dalma basalt at the bottom of the Formation, N of Dimna lake

The second site of Dalma exposures is along the National Highway 33, where the Dalma volcanic belt attains an approximate thickness of 5 km (waypoint 9). Here coarse tuffs and agglomerates with large bombs were found (Fig. 21). Above these tuffs, at the crossing with NH 32 near Chandil, carbonaceous phyllites are exposed in a road section below the bridge. The entire section of shales outcropping along the road and some side roads, is several hundred metres thick, to perhaps one kilometre (waypoint 10). These shales and C-rich phyllites (Fig. 22) are assigned to the Chandil Fm., however no clear distinction between the two formations has been yet established and some authors put them together with the Dalma volcanics. The carbonaceous shales make only a small part of this section but C-rich intervals occur sporadically and repeatedly within the thick dark grey to greenish grey shale section. All these shales show almost no sedimentary structures besides of occasional bedding at cm scale and the schistosity largely obliterates the thin bedding and laminae. The almost complete lack of sedimentary structures hints to deposition below wave/storm wave base.

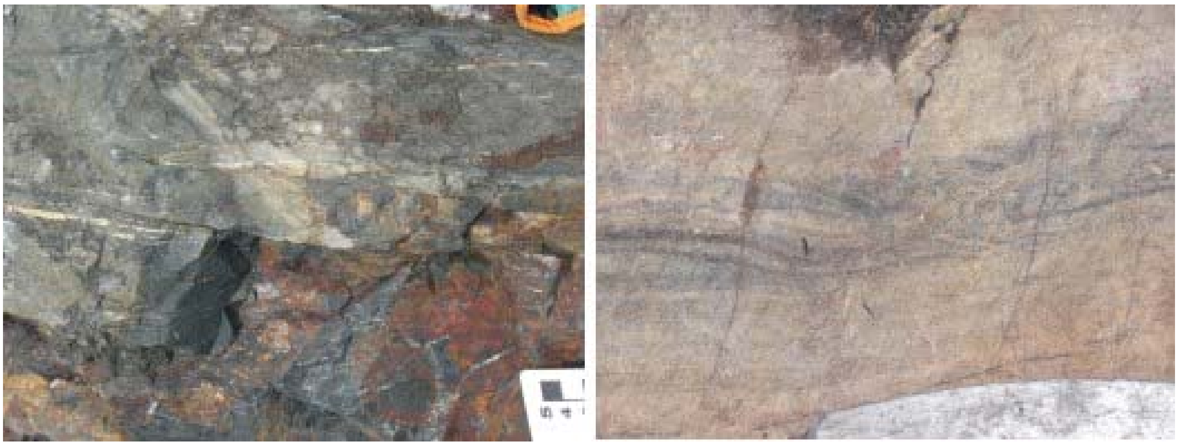


Figure 19: Slump structures in black silicified chert (left) and in quartzite (right) of the Dalma Formation.

Figure 20: Black chert dikes in the Dalma quartzites

At the Malti Mines location further away from Jamshedpur on NH 32 (waypoint 11), fine, partly silicified tuffs in thin to dcm thick beds are mined by the local inhabitants (Fig. 23) for road building and for home made clay pottery purposes. The tuffs are pale grey to greenish grey, often white through weathering and bleaching processes and exhibit no sedimentary structures other than bedding. Although they are very fine, their hardly develop schistosity, but distinct cleavage and thus demonstrate a continuos decrease of metamorphic overprint from the mica schists of the Dhalbhum Fm., the phyllitic schists of the Dalma Fm. to the slaty tuffs of the Chandil Fm.
In summary, the Dalma and Chandil Formations exhibit a clear tendency of deepening of the basin towards the top and mark a rift stage and a basinal development above the terrestrial Dhalbhum Formation.
The upper possible age of the Chandil Fm is marked by the 1.5Ga intrusion of the Kuilapal granite (Sengupta et al., 1994, 2000).

Conclusion:
The visited outcrops are an ideal site for an international research project on the geology of the Singhbhum crustal Province. The Singhbhum Province and its geology await your engagement and seek a solution to its many geological problems. We hope very much that the IGCP 509 will trigger several international projects and will not only end as a travel agency for renowned geologist and a project compiling old data. We are looking towards new enterprise and new results!

Acknowledgements
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Figure 21: Tuff with large bombs, lower Dalma Fm.

Figure 22: Black carbonaceous phyllites, Chandil Fm.

Figure 23. Village women working a quarry in the upper Chandil Fm. slates and quartzites.

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