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PRESENCE OF CONTACT METAMORPHIC ASSEMBLAGES IN CALCAREOUS METASEDIMENTS OF SAUSARS FROM WESTERN BALAGHAT AREA AND THEIR IMPLICATION IN SAUSAR STRATIGRAPHY

[1] D.C.Banerji, [2]S.Majumder, [3] R.K.Shrivasta, [4] M. Fulmari, [5] Adhir Kumar Basu
[1,2] 21F, SSEA-2, Renaissance Township, Burdwan - 713102
dilipchandbanerji@rediffmail.com

Abstract— Geology of the Sausar Group of rocks is known from the days of P.N.Bose (1986) who initiated geological mapping of the rocks and was followed by P.N.Dutta (1893), accredited with the discovery of the associated manganese deposits. Since then, workers like Sir Lewis Fermor, W.D. West (1936), Straczek et.al. (1956), Naryanaswami et.al. (1963) and many others have dealt with the geology of Sausar Group. A review of the available literature points to a number of disagreements amongst the workers. This includes - Stratigraphic status of Tirodi biotite gneiss, correlation of the low grade phyllite-sericite schist of Bharweli-Ukwa belt, sedimentary versus autoclastic nature of conglomerates and igneous versus metamorphic origin of the amphibolites/granulites, especially of the western part of the belt.

The calcareous metasediments of Sausars have maximum representation in the western part of Balaghat district where, apart from plenty of smaller metacarbonate lenses, three major bands, each covering more than 15 sq km of area, are exposed within gneissic (Tirodi biotite gneiss) country. These metacarbonates have been classified as Bichua Formation. The major metacarbonate bodies preserve contact metamorphic assemblages, distributed in distinct zoned aureoles, having lower temperature assemblages in the core and highest temperature assemblages along the periphery. The zonation is more pronounced where metacarbonate lenses are wider. They preserve an outer calcite-dolomite-forsterite (serpentinized)-diopside-chondrodite-spinel-tremolite assemblage followed by an intermediate calcite-dolomite-tremolite-biotite-white mica-spinel assemblage and an inner calcite-dolomite-tremolite -white mica-chlorite assemblage. Chondrodite, resembling garnet in physical appearance, is distinct in its anisotropism, however, is less common in the northernmost Paraspani-Pitesur band. The outer high temperature aureole extends for about 250m of width and grades into the intermediate zone of about 500m, finally passes into a core of low temperature assemblages. The high temperature zone of the periphery, at places, shows the presence of dark greyish-green coloured patches, just at the gneissic contact, with predominance of diopside over calcite / dolomite, and having accessory quartz, sphene, zoisite, epidote and calcic plagioclases. These patches, probably representing the special variety of calc-silicates, known as 'skarns' (Yardley,1989), are possibly formed by metasomatic interaction between marble and the enclosing biotite gneiss of probable intrusive origin. They have striking mineralogical and textural similarity with the numerously occurring calc silicate lenses present within the surrounding biotite gneiss.

Presence of contact metamorphic assemblages in the Sausar metacarbonates, embedded within biotite gneiss of western Balaghat area, and their arrangement in an increasing metamorphic order, from core to periphery, is a clear indication of thermal effect caused by the enclosing biotite gneiss. Additionally, development of calc silicate assemblages at the contact zones and their ubiquitous presence, as lenses, along with the presence of numerous smaller metacarbonates patches, well within the surrounding gneiss further strengthens the possibility of the biotite gneiss being intrusive within the calcareous rocks of Sausar Group. This warrants an all out effort to re-examine the Sausar geology as a whole, especially in the light of the doubts raised by Banerji et.al. (2007) towards the origin of the manganese mineralisation associated with the Sausar rocks, to have a better understanding of its depositional history.

Keywords— Sausar Group, Metamorphic assemblages, Calcareous metasediments, Calc silicates, Zonation.

I. INTRODUCTION

Geological mapping of the Sausar rocks was initiated in 1886 by P.N.Bose (in Shukla and Anandalwar,1973) and was followed by P.N.Dutta who is also accredited with the discovery of the associated manganese deposits (in Narayanaswami and Venkatesh, 1971). Sir Lewis Fermor, through a series of publications between 1904 and 1909, brought out a detailed account of his "Sausar Series" (phyllite, schists, gneisses, crystalline limestone/marble and calc-silicates/granulites and associated manganese ore deposits) of Central India. In general, the stratigraphic succession suggested by Fermor (1909) and improved upon by West (1936, in Pascoe, 1950) and by Naryanaswami et.al. (1963) is largely accepted for the gneiss and schist belt of Sausar group of Central India. West (0p.cit) suggested that the gneisses of Sausar Group are composite in nature and are produced by the intrusion of igneous material either into the pre-existing igneous rocks or into the metamorphosed sediments belonging to Sausar Group. Straczek et.al. (1956) included these migmatitic gneisses within the Sausar group, as the basal

member, and named them "Tirodi biotite gneiss". Notwithstanding, Shukla and Anandalwar (1973) and Narayanaswami et.al. (1963) considered the "Tirodi gneiss" to be the basement for the Sausar group with a disconformity between the two.

Furthermore, correlation of the low grade phyllite-sericite schist of Bharweli-Ukwa belt and the conglomeratic beds associated with it were also a subject of debate from the beginning. Fermor(1909) differentiated the manganiferous low grade metamorphites of Bharweli-Ukwa belt of Balaghat from rest of the Sausars and preferred to call them Chilpi Series, confirming the observation of P.N.Bose (op.cit). He, however, during his subsequent visits, suggested that this low grade belt could possibly represent a low grade facies of his "Sausar Series". Fermor, initially, considered the gritty rocks present to the south of the ore horizon as conglomeratic grits of sedimentary origin but reconciled his view after Burton (in Fermor, 1940; Pascoe, 1950; Shukla and Anandalwar, 1973) opined that the part of the grits, along the contact, could be of 'crush' origin, formed due to the thrusting of the manganiferous schist belt over the gneiss. Fermor, later, changed his earlier view and suggested the possibility of whole of the gritty conglomeratic formation of Ukwa-Bharweli belt to be of 'crush' origin (in Shukla and Anandalwar, 1973). Narayanaswami et.al. (op.cit) included the manganiferous rocks of Bharweli-Ukwa Within the Sausar Group and correlated them with the Mansar Formation. Shukla and Anandalwar (1973) favoured the view of Naryanaswami with the rider that this classification is valid till the Chilpi Group is considered to be a low grade equivalent of Sausar Group. They favoured a sedimentary origin for the gritty-conglomeratic zone though; Shukla initially (1950-51) mapped them as crush conglomerates. Jain et.al. (1990), accepting it to be difficult to decide the origin, have favoured a sedimentary origin for these debatable rocks and considered the manganiferous schist belt of Bharweli-Ukwa, resting over these conglomerates, to be younger to Sausar Group and coined a new name 'Bharweli Group' for these rocks.

Also, there remains ambiguity about the origin of calc-silicates/granulites of the Sausar belt, occurring along the periphery of metacarbonates and within the biotite gneiss. Pascoe (1950) refers to the fact that in strike continuity calc-granulites grade into marble, through banded calciphyres. Though, initially it was thought that the rocks were hybrids of calcareous sediment and an acid intrusive; Dr W.D.West later opined that such rocks could be of purely sedimentary origin and the presence of variety of minerals in such cases were presumed to have formed by reactions between the dolomite itself and the original impurities it had. It needs mentioning here that the dolomitic suite of Bichua stage, as mentioned in Pascoe (Op.Cit), contained dolomitic-marbles, forsterite-marbles, spinel-marbles, chondrodite-marbles, diopsidites, tremolite-schists, actinolite-schists, wollastonite-schists, scapolite-granulites and scapolite-diopside-marbles. Later, Subramanyam (1972) observed that at many a places amphibolites (of supposedly igneous origin), present in the western part of Balaghat (toposheet 55 O/10), have a gradational relationship with calc-silicates/granulites and they could be metamorphic variants of marbles and/or calc silicates. Naryanaswami and Venkatesh (1971) also, have reported about the lateral grading of Lohangi marble into the calc gneisses and about the presence of some bands having close mineralogical and textural similarity to the calc gneisses, within the Tirodi biotite gneiss of the same area.

In this paper, the authors intend to bring forth certain selective observations which may prove helpful in clearing ambiguity regarding hierarchy between the different members of Sausar group. Emphasis, here, is being given on the western part of Balaghat district (toposheet 55 O/10), especially, because of excellent and wide spread exposures of metacarbonates which are otherwise negligible in other parts of Sausars. Moreover, as the purpose of this paper is to highlight interrelationship between metacarbonates and the biotite gneisses, narration of other irrelevant lithotypes have been skipped for making it more meaningful.

II. Geological Considerations

The rocks of the Sausar Group have been sub-divided (after Narayanaswami et. al., 1963) into a basal Sitasaongi quart-muscovite schist and gneiss Formation, followed upward by Lohangi marble and calc-silicate/granulite/gneiss Formation, Mansar phyllite and muscovite schist/gneiss Formation having manganese horizon at bottom, middle and top of the formation, Chorbaoli quartz-muscovite schist/gneiss and quartzite Formation, Junewani biotite-muscovite schist/gneiss and biotite granulite Formation and the youngest Bichua marble and calc-silicate Formation (Fig. 1). Naryanaswami et. al. (op.cit) has considered the Tirodi biotite gneiss to be the basement for the Sausar Group and the contact between the two has been taken to be disconfirmable.

A. Metacarbonates

The calcareous metasediments of Sausars, variously known as crystalline limestone and marble, have maximum representation in the western part of Balaghat district (Fig. 2). All these white coloured metacarbonates have been classified as Bichua Metacarbonates. However, a small (0.75 km x 0.5 km) metacarbonate body occurring near Kharpariya ($21^0$41':$79^0$42'), lacking representation in earlier maps because of its size, is pinkish white in colour and, because of its colour, is correlatable to Lohangi Formation. Apart from plenty of smaller metacarbonate lenses, three major bands, each covering more than 15 sq km of area, are exposed within gneissic (Tirodi biotite gneiss) country. The Ambajhiri ($21^0$37':$79^0$35') - Hathigarh ($21^0$38':$79^0$31') band, oriented along WNW-ESE trend, extends for more than 15km with an average width of 2.5km. A second, Piparwani ($21^0$40':$79^0$34')

- Dhobitola ($21^0$42':$79^0$39') band extends for about 10 km, with a maximum thickness of 1.5 km, along NE-SW regional trend. The third, Paraspani ($21^0$41':$79^0$35') – Pitesur ($21^0$45':$79^0$37') band, oriented NE-SW, extends for about 11 km with an average width of 2km.

Presence of minerals like forsterite, spinel, chondrodite, scapolite and wollastonite, within the metacarbonates of this area, has been noted by Pasco (1950), each considered to be representing separate varieties of marble. Closer examinations of these metacarbonates, however, reveal presence of the aforesaid minerals as distinct contact metamorphic assemblages, distributed in zoned aureoles, encompassing the metacarbonates. Lower temperature assemblages occupy the core while highest temperature assemblages occur along the periphery. The zonation is more pronounced in the wider metacarbonate lenses. Thus, the three major metacarbonate bodies, referred above, preserve an outer calcite-dolomite-forsterite (partly serpentinized)-diopside-chondrodite-spinel-tremolite assemblage, an intermediate calcite-dolomite-diopside-tremolite-biotite-white mica-spinel assemblage and an inner calcite-dolomite-tremolite -white mica-chlorite assemblage. Chondrodite, resembling garnet in physical appearance, is distinct in its anisotropism, and is rare in the northernmost Paraspani-Pitesur band. The outer high temperature aureole extends for about 250m of width and grades into the intermediate zone of about 500m, before passing into a core of low temperature assemblage. The high temperature assemblage bearing metacarbonates of the periphery, at places, become dark greyish green coloured, just at the gneissic contact, with predominance of diopside over calcite / dolomite, along with the appearance of quartz, sphene, epidote and calcic plagioclases with a characteristic granulose texture, inherited from the carbonates during grain to grain replacements. Occasional appearance of wollastonite and/or scapolite, in such darker patches, is characteristic of the Paraspani-Pitesur band. These patches have striking textural and mineralogical similarity with the calc silicate lenses present within the surrounding biotite gneiss. Mineral assemblages present in the three major metacarbonate bands are listed below.

B. Mineral Assemblages of the Ambajhiri- Hathigarh metacarbonate:-

1. Calcite-dolomite-forsterite (partly serpentinized)/diopside
2. Diopside-calcite-dolomite-quartz-bytownite-oligoclase/andesine-sphene
3. Calcite-dolomite-tremolite-bytownite-quartz-biotite-sphene-spinel
4. Calcite-dolomite-forsterite-spinel-chondrodite-tremolite
5. Calcite-dolomite-tremolite/spinel/biotite/mica/quartz
6. Calcite-dolomite-mica-chlorite

C. Mineral Assemblages of the Piparwani- Dhobitola metacarbonate:-

1. Calcite-dolomite-forsterite (partly serpentinized)-diopside/chondrodite-tremolite-spinel/mica
2. Diopside-calcite-dolomite-quartz-bytownite-oligoclase/andesine-sphene
3. Calcite/dolomite-forsterite
4. Calcite-dolomite-tremolite-diopside-mica
5. Calcite-dolomite-tremolite-biotite-diopside-quartz-sphene
6. Calcite-dolomite- tremolite-mica-chlorite

D. Mineral Assemblages of the Paraspani- Pitesur metacarbonate:-

1. Calcite-dolomite-forsterite (partly serpentinized)-spinel/tremolite
2. Diopside-calcite-dolomite-wollastonite/scapolite-bytownite-oligoclase/andesine-sphene
3. Calcite-dolomite-quartz-bytownite-chlorite-biotite
4. Calcite-dolomite- tremolite-mica/quartz

Smaller, mapable, metacarbonate bands of the area range in length from 100 m to 3 km, and the width is variable from 100 m to 0.5km. These bands, embedded within biotite gneiss, have maximum distribution in the vicinity of the major bands discussed above. The contact with biotite gneiss is often occupied by a thin, greenish grey, rim comprising diopside, calcite/dolomite, quartz and bytownite with minor amount of epidote, sphene and apatite. There is not much spatial variation in mineralogy of these smaller metacarbonates comprising calcite/dolomite, forsterite (partly serpentinized), diopside and tremolite with minor amount of spinel, biotite and mica. Presence of chondrodite is restricted only along the quartzo-feldspathic veins.

The Ambajhiri – Hathigarh band hosts a small manganese occurrence, as exemplified by the abandoned quarry, 2.5km WNW of Ambajhiri. The dimension of the quarry is 150m x 20m x 10m and the walls and bottom of the quarry exposes metacarbonates, impregnated with lenses of manganese and pink feldspar bearing quartzo-feldspathic material. Small gneissic bodies, rich in white mica, crop out at three locations within this metacarbonate body. As mentioned earlier, this white metacarbonate band has been correlated with the Bichua Formation by Narayanaswami and Venkatesh (op.cit).

In the entire neighbourhood of white coloured Bichua metacarbonates of the area (toposheet 55O/10), a small pinkish white metacarbonate body, as discussed earlier, is well exposed in Dhoriya nala, south of Kharpariya ($21^0$41':$79^0$42'). This body, also, is enclosed within biotite gneiss and is traversed by pink feldspar bearing quartzo-feldspathic material on laminar as well as wider (3 m) scale. Stretching and boudinaging of these quartzo-feldspathic veins (Fig. 3) is indicative of ductile to brittle-ductile deformation. Horizontal disposition of the veins is attributable to later deformation. In

strike continuity to the north, the tapering metacarbonate body is traceable to continue as calc silicate, intimately associated with quartzo-feldspathic veins. The metacarbonate body comprises calcite, dolomite, quartz, plagioclase, tremolite and white mica with minor amount of diopside, epidote, spinel and chondrodite. Development of diopside, spinel and chondrodite is more near the quartzo-feldspathic veins. Calc silicate, in strike continuity, comprises diopside, hornblende, calcite/dolomite, quartz, and calcic plagioclases with minor amount of epidote, microcline, sphene and apatite.

The chemical analysis of the metacarbonates show high silica, high magnesium type with CaO variable between 24% and 36% (Table - 1).

III. Calc Silicates

Calc silicate bands/lenses, like the smaller metacarbonates, have higher distribution in the vicinity of the bigger metacarbonate bands. In general, there are innumerable lenses and bands of calc silicates distributed over the entire area. There is great mineralogical and textural resemblance between the calc silicates occurring at peripheral part of metacarbonate, and the lenses and bands present within the enclosing biotite gneiss. Some of these lenses, present in vicinity of metacarbonate bodies, have identifiable metacarbonate patches within them. Reference may be made of the Bawantheri Dam, located at Sitecasa (21^0 32':79^0 33'), where the river bed exposes thick (+ 10m) calc silicate enclosed within biotite gneiss. The sub surface data of the dam foundation, however, shows presence of metacarbonate in the core part of the calc silicate band.

The calc silicates are light green to dark green or greyish green in colour, medium grained, and have a characteristic granulose texture. Though, banding is common in calc silicates, especially in the central and southern part, resulting from alternate bands of quartzose and mafic minerals (Fig. 4); massive variety, especially in the northern part, is not uncommon. The banded variety often preserves angular folding (Fig. 5), possibly indicating tangential movement along shear planes. Contact between calc-silicates and biotite gneiss is gradational often having a hybrid zone of assimilation in-between. At many a places, especially in the northern part, dilation (Fig. 6) of the calc-silicates, resulting from shear deformation, is conspicuous along the mixed zones.

There is slight variation in the mineralogy of the calc silicate lenses from the south to north (55 O/10), having corroboration with the regional metamorphic grades. The calc silicate lenses of the southern part of the area is dominated by the assemblage hornblende-epidote-chlorite-quartz-bytownite, indicative of low to medium grade of metamorphism, followed by the medium temperature assemblage comprising diopside-zoisite, in the central part, while to the north the calc silicates are diopside and/or diopsie-augite rich, indicating a high temperature regime. Though, hornblende is persistently present throughout the area, they appear to be after pyroxenes in the northern part. The line of first appearance of diopside is not very sharp as some of the calc silicate lenses, well within the southern part show presence of diopside along with hornblende and epidote, much before the first appearance of zoisite. Similarly, overlapping of the assemblages viz. Diopside-augite quartz-bytownite-garnet bearing calc silicate occurring in the central part, and occurrence of zoisite bearing assemblage near the northern edge is not uncommon. A granulose texture is common in all the varieties. Important assemblages of the calc silicates of this area are as follows.

Low to medium temperature assemblages of the southern part:

1. Hornblende-quartz-bytownite/andesine-chlorite-epidote-sphene-apatite
2. Hornblende-diopside-epidote-quartz-bytownite-oligoclase-microcline-calcite-chlorite-sphene-apatite

Medium temperature assemblages of the central part:

1. Diopside-zoisite-hornblende-quartz-andesine/bytownite-garnet-calcite-sphene-apatite
2. Diopside- hornblende-epidote-quartz- bytownite- sphene -calcite-apatite- garnet

High temperature assemblages of the northern part:

1. Diopside-hornblende-bytownite/andesine-sphene
2. Diopside-augite-quartz-bytownite-garnet
3. Diopsidites

Chemical analysis of the calc silicates (Table - 2) points to higher values of CaO, MgO and Fe2O3. Also, Na2O/K2O ratio is approximately 2:1, uncommon for an igneous parentage. Analysis of garnets from the calc silicates is suggestive of a calcareous parentage (Table - 3). It is difficult to explain high CaO and MgO values if an igneous parentage for these rocks is contemplated.

IV. Biotite Schist/Granulite

This litho unit has very limited representation in the area. The lone mapable band (1.0km x o.5km) is present near Sitekasa, trending NE-SW, grading to the north to biotite gneiss and to the south to calc silicate. The rock is sheared and closely folded, having straight limbs and sharp hinges (angular folds), and has small lenticles of calc silicates in the closure part. Near calc silicate contact, the rock is medium grained, comparatively harder and saccharoidal in texture; while in core part the rock is coarse grained and show development of biotite flakes in plenty. Near the gneissic contact towards north, numerous quartzose and quartzofeldspathic veins, boudinaged and folded, traverse through the biotite schist, and the rock finally grades to biotite gneiss. Presence of biotite schist/granulite in minor scale, however, is ubiquitous bordering the numerously available calc silicate lenses within the biotite gneiss. At such places also, the rock shows a saccharoidal texture near the calc silicates; while the outer

margin is rich in coarse biotite flakes and grades to biotite gneiss.

The biotite schist/granulite comprise quartz, biotite and oligoclase/andesine with accessory amount of apatite, calcite, tremolite, sphene and opaques. A granulose texture, defined by equigranular quarz and feldspars, is characteristic of this rock.

A. Biotite Gneiss

The most extensive litho unit of the area is biotite gneiss, wrapping the metacarbonates and calc silicates, and has been classified as 'Tirodi biotite gneiss' (Naryanaswami et.al., 1963). This coarse to medium grained rock often shows ophthalmic structure and contain innumerable bands/lenticles of calc silicates and biotite granulite and has abundance of metacarbonates, especially in this part of Sausars. A change in mineralogy and texture is also common in the gneisses, influenced mainly by the presence or absence of the calc silicate/biotite granulite patches and by ductile deformation. Amongst the textural variants, augen gneiss, banded gneiss, streaky gneiss and gneiss with granulose texture are common. On closer examination, it is observed that at many places augen gneiss (Fig. 7) and streaky gneisses (Fig. 8) are produced by ductile deformation. Similarly, schlieren rich biotite gneisses or the gneisses with ghost structures are produced by different degree of assimilation of the calc silicates/biotite granulite bodies.

Biotite gneiss, in general, is coarse grained and comprises quartz, perthite, microcline, oligoclase/andesine and biotite with minor amount of muscovite, apatite, sphene, calcite and hornblende. Presence of calcite and hornblende, however, is restricted near the contact with metacarbonates and calc silicates respectively. Chemical analysis of biotite gneiss (Table - 4) indicates higher values of CaO and MgO and higher ratio (2:1) of K2O/Na2O. The rock is exceptionally rich in CaO and MgO near metacarbonate bodies. The plot of TiO2 against SiO2 in 'Tarney's Diagram' (Fig. 9) indicate an igneous origin for the biotite gneiss.

Intrusive, younger, bodies of foliated greyish white granite and pink granite of very small dimensions also make their appearance in the south-western part of the area.

B. Shears

Shearing is an integral part of the Sausar terrain. Banerji et.al. (2007) have reported the presence of sinuous, folded, mylonite zones affecting the Sausar rocks of Balaghat. They visualized these mylonites to have generated during waning face of F1 fold movement and were affected by subsequent fold movements, responsible for imparting a sinuous map pattern to the mylonite zones (Fig. 1).

The area under discussion, representing the western part of Balaghat, has suffered brittle-ductile to ductile shearing along NE-SW to ENE-WSW trend. Later brittle shearing, evidenced by large scale silicification and fracturing is also recorded along WNW-ESE and N-S trends. The major brittle-ductile to ductile shears are marked by stretching and recrystallization of quartz along ' S ' and 'C' surfaces, rotation (anticlockwise) of the stretched boudins (Fig. 7) and by deformation of plagioclases by microfracturing. These shears are also closely associated with the well known manganese deposits of Tirodi and Sukli-Sitapathore. Of the major ENE-WSW shears, mention can be made of the Tirodi-Pauniya-Katangi Shear (Fig. 10) having a length of +10 km; Shukli-Sitapathore shear (Fig. 11) - traceable for more than 5 km; and the Sitekasa – Ambajhiri shear extending for more than 5 km. The imprints of these shears, especially because of the alignment of excavated pits for manganese, in the imagery are conspicuous.

V. INTERPRETAION AND CORRELATION

The mineral assemblages present in the metacarbonate bands are similar to those of the assemblages of impure dolomitic limestone, having undergone contact metamorphism, of Rice (1977). The fact that bigger metacarbonate bodies have aureoles of these mineral assemblages, wherein low temperature assemblages occupy the core and higher temperature assemblages occupying periphery, points to the existence of causative sources, encircling the metacarbonates, during post depositional period. Presence of calc silicates/granulites, as discontinuous patches in the metacarbonate periphery, and as rafts and lenses within the enclosing biotite gneiss, is an established fact. The frequency of these lenses, along with lenses of metacarbonates, is exceptionally high in vicinity of the bigger metacarbonate bodies. It is possible that these calc silicates represent special variety of rocks, formed by metasomatic interaction between metacarbonates and the enclosing biotite gneiss, commonly known as 'skarns' [Yardley (1989), pp. 126-146]. The saccharoidal/granular texture of the calc silicates is imbibed from the carbonates because of grain by grain replacement of the minerals during metasomatic changes. This well explains the presence of granulose texture even in low to medium temperature mineral assemblage bearing calc silicates of the southern area.

The calc silicate lenses enclosed within biotite gneiss show a general increase in regional metamorphic grade from south-east to north-west. This northerly increase in regional metamorphic grade is well understood from the map pattern of the rocks as explicitly depicted in figure-1. The belt of low grade rocks comprising phyllite and muscovite gneisses and schists, belonging to Mansar Formation, passes through the south-eastern part of the area with a NE-SW trend; while biotitie rich, higher grade, Junewani Formation is present to the north, bordering the vast country of Biotite gneiss. In this respect, all the major metacarbonate bands of the area are restricted in medium and high temperature zones of regional metamorphism, as depicted by the mineral assemblages of the

calc silicates present in the enclosing biotite gneiss. Enigmatically, core part of all the three metacarbonate bands discussed herein exhibit low temperature mineral assemblages, devoid of any effect of regional metamorphism.

West (in Pascoe, 1973, p. 182) was of the firm opinion that none of the composite gneisses of northern Nagpur is older than the 'Sausars Series' and are produced by intermixing of igneous material with pre-existing rocks. Phadke (1990), also, suggested emplacement of large scale anatectic melts into the Sausar metasediments, responsible for producing granitic gneisses. The mineral assemblage calcite-dolomite-forsterite-diopside-spinel-chondrodite of the metacarbonate periphery, as reported in the present work, indicate a temperature of around 600^0 C (Rice, 1977), approximately equal to that of a granite pluton. The calc silicates present within biotite gneisses also indicate a temperature range of 400^0 C (indicated by zoisite bearing assemblages) to 600^0C (indicated by diopside-augite bearing assemblages). This, together with the inferences from 'Tarney's Plot', is suggestive of an igneous parentage for the biotite gneisses of the area.

Thus, it appears more likely that an igneous melt of granitic composition got synkinematically emplaced within the pre-existing sediments (Sausars), predominantly calcareous in the present area, to produce biotite gneisses. Assimilation of these calcareous sediments, to the possible extent, made the gneisses richer in Ca and Mg. The sediments which escaped assimilation either remained as metacarbonate rafts, exhibiting signatures of thermal metamorphism and metasomatic reactions in the peripheral region, or remained as metasomatically altered calc silicates. Biotite granulites and biotite schists are also produced during this process, aided further by ductile/brittle ductile deformation. The banding in calc silicates could be compared with the siliceous bands introduced in the metacarbonates of Kharparia, where ductile deformation is responsible for the lit-par-lit injection of quartzo-feldspathic veins and for their further stretching. The increasing grade of metamorphism of the calc silicates from the south-east, where major low grade Mansar meta-sediments predominate, to biotite gneiss dominated north-west (Fig. 1) is possibly reflective of the temperature variation within the intruding granitic melt of large dimension. It is obvious to have lower temperature in the fringe area (SE) compared to the hot core (NW).

Based on the above facts, attempting a chronological arrangement of the metasediments viz. white and pink metacarbonates, biotite schists, biotite granulite and calc silicates is arbitrary and improper. Also, in the light of the doubts raised by Banerji et.al (2007) towards the origin of manganese mineralisation associated with the Sausars, an all out effort to re-examine the Sausar geology as a whole is warranted to have a clear understanding of the depositional history of the area.

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References

[1] Banerji, D.C., Majumder, S., Singhai, R.K., Shrivastava, R.K., and Fulmari, M., (2007): Manganese mineralization associated with folded shear zones in Balaghat district, Madhya Pradesh. Jour. Eco. Geo. and Georesource Management. Vol. 4. No. (1-2), pp. 128-141.

[2] Banerji, D.C., Shrivastava, R.K., Fulmari, M., Singhai, R.K., Devrajan, M.K. and Asfar Hakim (1996): Final report on special thematic mapping of Sausar belt in parts of Balaghat and Seoni districts of Madhya Pradesh. Geol. Surv. Ind. unpublished progress report.

[3] Fermor, L.L., (1909): The manganese ore deposits of India, Mem. Geol. Surv. Vol. 37 (IV) pp. 613-1287.

[4] Fermor, L.L., (1940): An attempt at the correlation of the ancient schistose formations of Peninsular India. Rec. Geol. Surv. Ind. Vol. 70, pt. 2, pp. 230-231.

[5] Jain, S.C., Yedekar, D.B., and Nair, K.K.K., (1990): A review of the stratigraphic status of Bharweli-ukwa manganese belt, Balaghat district, Madhya Pradesh. Geol. Surv. Ind. Spl. Pub. No. 28, pp. 332-353.

[6] Narayanaswamy, S. and Venkatesh, V., (1971): The geology and manganese deposits of northern Bhandara district, Maharashtra. Bull. Geol. Surv. Ind. Ser. A, 22(IV).

[7] Pascoe, E.H., (1950): A manual of the geology of India and Burma, Vol. 1, Third Edtn.

[8] Phadke, V. A., (1990): Genesis of the granitic rocks and status of the Tirodi Biotite Gneiss in relation to metamorphites of the Sausar Group and the regional tectonic setting. Geol. Surv. Ind., Spl. Pub. No. 28, pp. 287-302.

[9] Rice, J.M., (1977): Contact metamorphism of impure dolomitic limestone in the Boulder Aureole, Montana. Contributions to mineralogy and petrology. Springer Verlog.

[10] Shukla, K. D. and Anandalwar, M.A. (1973): The geology and manganese ore deposits of the manganese belt in Madhya Pradesh and adjoining parts of Maharashtra. Part VIII - The geology and manganese ore deposits of the Balaghat-Ukwa area, Balaghat district, Madhya Pradesh. Bull. Geol. Surv. Ind. Ser. A., No. 22.

[11] Straczek, J.A., Narayanaswami, S., Subramanyam, M.R., Dhukla, K.D., Vemban, N.A., Chakravarty, S.C., and Venkatesh, v., (1956): Manganese ore deposits of

Madhya Pradesh, India. 20th Int. Geol. Cong., Mexico Session, Symposium on Manganese, Vol. 4, pp. 63-96.

[12] Subramanyam, M.R., (1972): The geology and manganese ore deposits of the manganese belt in Madhya Pradesh and adjoining parts of Maharashtra. Part IV – The geology and manganese deposits of the Ramrama – Sonawani area, Waraseoni Tehsil, Balaghat district and parts of Seoni Tehsil, Chhindwara district, Madhya Pradesh. Bull. Geol. Surv. Ind., Ser. A, No. 22.

[13] Yardley, B.W.D., (1989): An introduction to metamorphic petrology. Longman Earth Science Series.

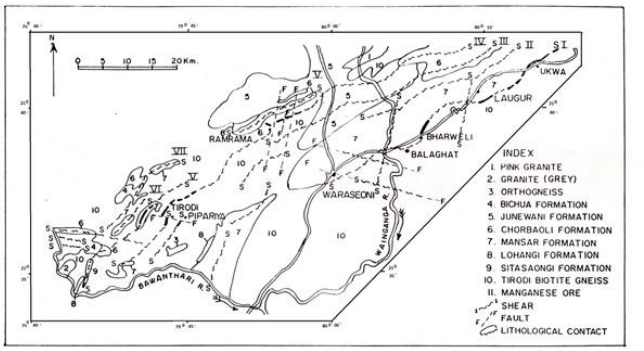

Fig. 1. Geological sketch map of Sausar rocks of Balaghat (M.P.) area (after Banerji et.al., 2007).

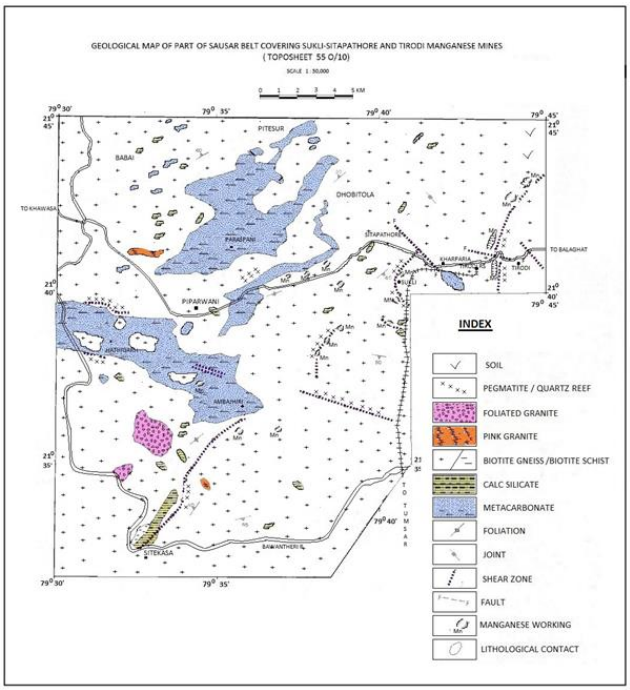

Fig. 2. Geological map of part of topo sheet 55 O/10 (after Banerji et.al. 1996).

FiG. 3. Exposure of pink metacarbonate in Dhoriya Nala, near Kharparia

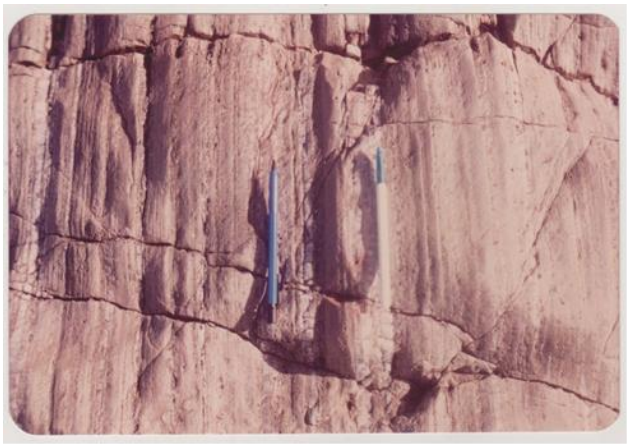

Fig. 4. Exposure of banded calc silicate in Bawantheri river, near Sitekasa

Fig. 5. Angular folding in banded calc silicate. Loc. Bawantheri river, near Sitekasa

Fig. 6. Dilation of calc silicate. Loc. North of Babai.

Fig. 7. Biotite gneiss showing shear deformation. Loc. Bawantheri river, east of Sitekasa.

Fig. 8. Streaky gneiss showing stretching of pink feldspar bearing QF veins. Loc. NW of Sitekasa

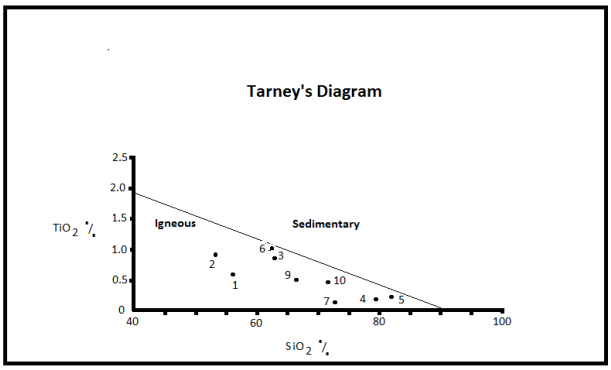

Fig. 9. Tarney's Diagram, showing plots of TiO2 Vs. SiO2 of biotite gneisses of the area.

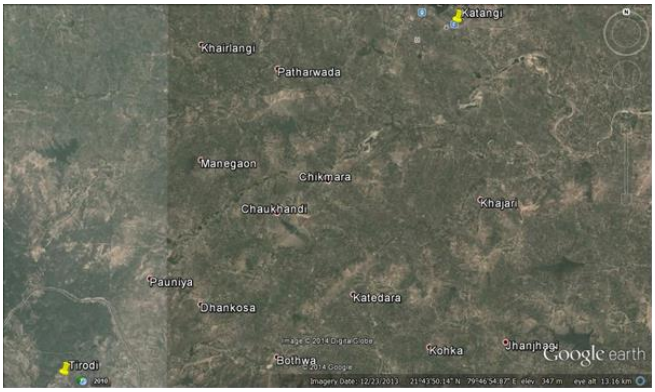

Fig. 10. Imprints of Tirodi-pauniya-Katangi shear in satellite imagery.

Fig. 11. Imprints of Sukli- Sitapathore shear in satellite imagery

Table 1.

Chemical analysis of metacarbonates from 55 O/10 (Courtesy GSI)									
Smpl. No.	1	2	3	4	5	6	7	8	9
SiO_2	8.30	3.87	15.96	10.65	30.01	2.90	11.17	14.11	23.16
Al_2O_3	0.30	0.51	1.37	2.54	0.30	0.82	1.61	2.04	4.42
FeO	-	-	-	1.44	-	0.54	1.80	0.72	0.81
Fe_2O_3	1.19	1.19	1.79	0.22	5.60	0.21	3.29	0.07	0.15
TiO_2	0.34	0.39	0.44	0.08	0.27	-	0.15	0.20	0.29
CaO	30.56	30.38	30.26	36.30	27.02	29.90	35.00	29.50	24.30
MgO	20.96	20.56	19.35	12.30	19.27	21.20	12.90	23.30	20.80
K_2O	0.12	0.14	0.15	0.11	0.14	0.22	0.11	0.13	1.02
Na_2O	0.42	0.47	0.61	0.13	0.40	0.09	0.09	0.12	0.15
MnO	0.08	0.07	0.04	0.37	-	0.05	0.22	0.06	0.04
P_2O_5	-	-	-	0.30	0.38	-	0.04	0.09	0.05
H_2O	0.17	0.08	0.20	0.84	-	0.30	3.41	2.72	0.15
CO_2	-	-	-	34.65	16.92	44.00	30.20	26.50	24.20
LOI	38.20	42.58	31.36	-	-	-	-	-	-

Table 2.

Chemical analysis of calc-silicates from 55 O/10 (Courtesy GSI)												
Smpl. No.	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	48.70	50.24	54.21	43.87	46.75	42.50	50.42	47.28	51.84	47.53	57.81	60.04
Al_2O_3	3.91	4.61	13.35	9.53	13.66	12.62	13.97	17.78	4.75	18.76	14.97	5.91
FeO	-	-	-	-	-	-	-	1.08	0.72	0.72	4.14	7.92
Fe_2O_3	7.18	14.2	16.0	25.6	17.6	17.80	12.8	1.00	9.77	9.5	3.5	3.83
TiO_2	0.63	0.43	1.41	0.68	1.51	2.31	1.41	0.26	0.6	0.43	1.41	0.76
CaO	24.78	12.45	6.72	11.77	12.33	13.45	10.64	14.38	16.25	18.8	10.5	12.4
MgO	9.27	15.24	3.44	6.89	5.17	8.18	5.6	12.0	14.1	0.9	1.72	6.63
K_2O	1.60	0.15	1.6	0.29	0.45	0.34	0.51	1.55	0.15	0.12	3.55	0.3
Na_2O	2.30	0.61	2.3	0.57	1.7	1.45	2.8	0.2	0.52	1.25	0.93	0.36
MnO	0.25	0.16	0.38	0.21	0.21	0.26	0.16	0.23	0.21	0.24	0.31	0.31
P_2O_5	-	-	-	-	-	-	-	0.14	-	0.45	0.18	0.12
H_2O	0.21	0.22	0.11	0.33	0.11	0.18	0.23	0.5	0.12	0.66	0.25	0.99
CO_2	-	-	-	-	-	-	-	-	-	0.5	-	-

Table 3.

Analysis of garnets from calc-silicates of 55 O/10 (Courtesy GSI)		
Smpl. No.	1	2
SiO_2	46.30	48.58
Al_2O_3	14.18	13.74
FeO	0.90	1.08
Fe_2O_3	8.22	7.06
TiO_2	0.56	0.70
CaO	27.40	25.20
MgO	0.37	1.14
K_2O	-	0.66
Na_2O	-	0.75
MnO	0.77	0.64
P_2O_5	0.30	0.28
H_2O	0.28	0.11
CO_2	-	-

Table 4.

Chemical analysis of biotite gneiss from 55 O/10 (Courtesy GSI)										
Smpl. No.	1	2	3	4	5	6	7	8	9	10
SiO_2	56.11	53.49	63.82	79.54	82.96	62.85	73.05	34.53	66.53	71.63
Al_2O_3	23.66	15.74	16.67	9.48	7.01	21.73	13.09	5.44	14.09	12.95
FeO	2.34	0.54	3.96	-	0.18	0.72	1.08	1.44	3.24	-
Fe_2O_3	1.69	13.21	0.27	1.59	0.60	0.20	0.30	0.05	1.60	5.60
TiO_2	0.52	0.81	0.72	0.21	0.26	1.09	0.10	0.25	0.50	0.48
CaO	5.40	0.36	2.83	1.12	1.68	0.42	3.40	23.40	4.60	2.10
MgO	1.28	2.61	2.54	1.20	0.21	0.68	0.37	18.30	2.17	1.29
K_2O	2.13	8.76	4.12	3.70	5.70	8.86	5.07	2.94	2.54	2.90
Na_2O	5.43	2.71	3.65	2.75	0.59	0.44	3.18	0.19	3.81	2.15
MnO	-	0.52	0.05	0.09	0.02	0.02	0.02	0.05	0.06	0.11
P_2O_5	0.30	0.30	0.27	-	0.09	0.49	0.15	0.15	0.30	-
H_2O	0.62	0.29	0.58	0.18	0.67	2.24	0.20	0.56	0.54	0.16
CO_2	-	-	-	8.13	-	-	-	12.30	-	0.18