Garnet–sillimanite–cordierite–quartz-bearing assemblages from early Archean supracrustal rocks of Bundelkhand Massif, Central India

S. P. Singh[1,]* and S. B. Dwivedi[2]

[1]Department of Geology, Bundelkhand University, Jhansi 284 128, India
[2]Department of Civil Engineering, Institute of Technology, Banaras Hindu University, Varanasi 221 005, India

The Bundelkhand gneissic complex includes the high-grade metapelites, amphibolites, calc-silicates and granite-gneisses, which are invaded by 3.2–3.3 Ga old tonalite–trondjemite–grainodiorite. Detailed petrographic studies and EPMA analyses of metapelites reveal the presence of garnet–sillimanite–cordierite–biotite–K-feldspar–plagioclase–quartz, biotite–sillimanite–cordierite–K-feldspar–plagioclase–quartz and garnet–sillimanite–biotite–K-feldspar–plagioclase–quartz mineral assemblages which belong to upper amphibolite to granulite facies rocks and have been reported for the first time from the Bundelkhand craton. The average *P–T* conditions estimated by different models of geothermobarometry yield the core composition at 730°C/5.4 kbar and rim composition at 640°C/5.1 kbar.

Keywords: Bundelkhand gneisses, high-grade metamorphism, mineral assemblages, mineral chemistry, *P–T* conditions.

THE Bundelkhand craton lies on the northern part of the Central Indian Shield. It is separated from Bastar and Chhotanagpur cratons by the east-west trending Son–Narmada lineament (SNNF and SNSF) and Central Indian Shear (CIS) in the south, from Aravali folded belt by NE–SW trending Great Boundary Fault (GBF) in the west and from the Gangetic Plains of the Himalayas by the WNW–ESE trending Yamuna fault in the north (Figure 1). The exposed cratonic part is more or less semi-arcuate in shape, where more than 2600 km^2 area is occupied by the Bundelkhand Palaeoproterozoic granitoids and even older rocks. The east-west trending early Proterozoic basins, viz. Gwalior and Bijawar characterized by thick volcanosedimentaries lie on the northern and southern boundaries of this craton respectively. It is followed by sedimentation of great Vindhyan deposits around the Bundelkhand craton. Recently two events of metamorphism and at least four phases of deformation for the Archean rocks of Bundelkhand, in the central part of the massif have been identified[1,2]. An angular relationship between the Bundelkhand Gneissic Complex (BnGC) and Bundelkhand Metasedimentary and Metavolcanics (BMM) has been established by them.

Rocks of the BnGC consist of garnet–sillimanite gneisses, biotite–sillimanite gneisses, garnet–biotite-amphibolite gneisses, amphibolites, calc-silicates, micaceous quartzite and granite–gneisses. These rocks are related to high-grade metamorphism of pelitic, carbonates, mafics and ultra mafics, mainly exposed along the Saprar river section, south of Mauranipur, near village Kuraicha, Dhaurra, east of Prithvipur, south of Babina and are characterized by multiphase deformation and folding. The F1 coaxial to F2, rootless folds and hook folds are common. The gneisses are also characterized by thick bands of quartzofeldspathic masses along with biotite–sillimanite flakes. The garnetiferous gneisses are comparatively darker in nature than biotite gneisses. The coarse to very coarse-grained garnet is found to be embedded in the matrix of dark bands. Lensoidal bands of magnetite were also noticed at some places in the gneisses. Coarse-grained bluish-grey-coloured rocks containing cordierite, garnet and sillimanite have been found for the first time in the Saprar river section. Besides this location, cordierite-bearing rocks were also seen at Bhagwantpur village, south of Jhansi town. Garnetiferous and non-garnetiferous amphibolites with and without biotite were identified along the cordierite gneisses and at some places they are intercalated with biotite–gneisses.

Garnet occurs as porphyroblast as well as small scattered granules in the gneisses of the Saprar river section. Sometimes the porphyroblastic garnet contains inclusions of biotite, magnetite and blebs of sillimanite (Figure 2 *a*). Cordierite is characterized by yellow pleochroic halos around zircon and polysynthetic and sector twinning. It

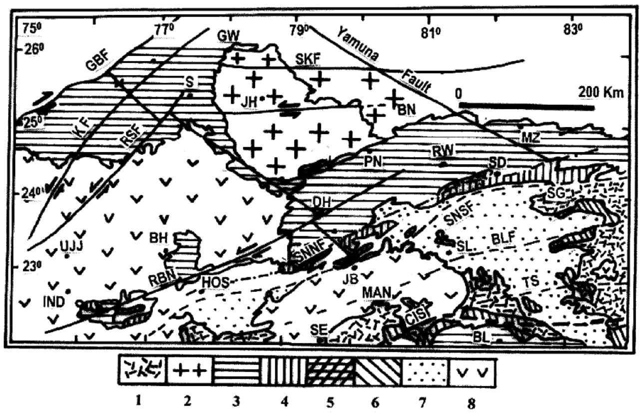

Figure 1. Geological map of Central India compiled after Ramchandra and Roy[26], Yadekar *et al.*[27], Jokhan Ram *et al.*[28], Raza and Casshyap[29], Acharya[30] and Singh *et al.*[2]. 1, Gneisses and migmatites with supracrustal rocks; 2, Bundelkhand granitoids with BnGC; 3, Vindhyan Supergroup; 4, Mahakoshal Group; 5, Bijawar and Gwalior Group; 6, Sausor Group; 7, Gondwana Supergroup, and 8, Deccan Traps. BH, Bhopal; BL, Bilaspur; BTF, Balarampur Tatapani Fault; BN, Banda; CIS, Central Indian Shear Zone; DH, Damoh; GBF, Great Boundary Fault; HOS, Hosanabad; IND, Indana; JB, Jabalpur; JH, Jhansi; KF, Kota Fault; MAN, Mandla; MZ, Mirzapur; PN, Panna; RBN, Ratlam–Basoda–Narsingargh Fault; RSF, Ratlam–Shivpuri Fault; RW, Rewa; S, Shipuri; SD, Siddhi; SE, Seoni; SG, Singrauli; SKF, Shivpuri Kalpi Fault; SL, Shahadol; SNNF, Son–Narmada North Fault; SNSF, Son–Narmada South Fault; TS, Tan Shear, and UJJ, Ujjain.

*For correspondence. (e-mail: spsinghbu@rediffmail.com)

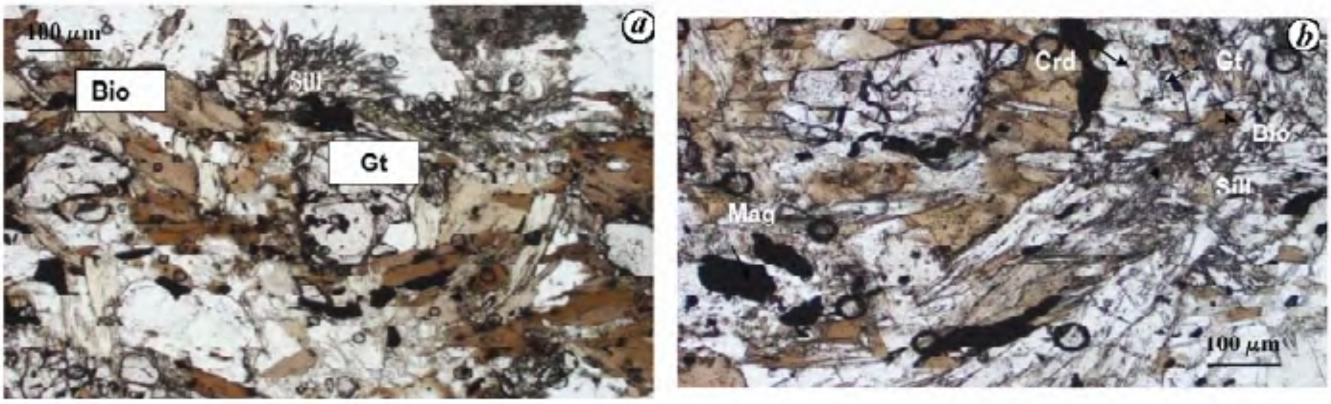

Figure 2. Photomicrographs of garnet–cordierite from the study area in plane-polarized light, ×32. ***a***, Inclusions of biotite, magnetite and hornblende and partially rimmed by biotite. ***b***, Coarse porphyroblast of cordierite with inclusions of garnet, biotite and sillimanite. Gt, Garnet; Bio, Biotite; Crd, Cordierite; Sill, Sillimanite, and Mag, Magnetite.

occurs typically as coarse porphyroblasts which are poikiloblastic containing trails of garnet, sillimanite, biotite and quartz (Figure 2 *b*). Symplectites of garnet–cordierite–biotite-K-feldspar were also observed in few types of gneisses. Biotite, usually medium to coarse-grained, defines the foliation trend in the gneisses and corroded relics of biotite also occur in the garnet. Sillimanite and magnetite are present along the cleavages of biotite. Muscovite flakes are rare and are observed in one sample of garnet–sillimanite gneisses, where needle-shaped sillimanite is present along its cleavages. Coarse-grained perthite and oligoclase crystals are present in the ground mass associated with garnet and biotite. Quartz occurs as medium to coarse-grained and occupy about 10% of all rock composition.

The microprobe analyses of coexisting phases along with their structural formulae are given in Table 1, for the high-grade garnet–cordierite–sillimanite gneisses. The EPMA data indicate that the chemical composition of plagioclase is quite constant. The anorthite composition ranges from An 25 to An 34 in the garnet–cordierite-sillimanite gneisses. Biotite has variable Ti content ranging from 0.74 to 1.5 wt%; the X_{Mg} ranges from 0.52 to 0.55 for garnet–cordierite–sillimanite gneisses, 0.33 to 0.34 for biotite gneisses and 0.52 to 0.60 for cordierite gneisses. The alkalies deficiency, i.e. $X < 2.0$ is present in most of the biotite. The deficiency is high in the garnet–cordierite gneisses ($\sum X = 1.58$ to 1.40) and low in garnet–biotite gneisses ($\sum X = 1.80$ to 1.90). Al_2O_3 ranges from 17 to 18% for garnet–cordierite gneisses, 16 to 17% for cordierite–sillimanite gneisses and 15 to 16% for garnet–biotite gneisses. Similarly, Al^{IV} ranges from 0.7 to 0.9 pfu for cordierite garnet–sillimanite gneisses and cordierite gneisses, and 0.43–0.5 for biotite garnet–gneisses.

Cordierite contains mainly SiO_2, Al_2O_3, FeO and MgO. The larger cations are nearly absent (Na_2O is less than 1%). The total major oxide value in cordierite did not exceed 98% (Table 1), indicating the presence of fluid. X_{Mg} ranges from 0.64 to 0.67 indicating the dominance of Mg end-member cordierite. Garnets from sillimanite–cordierite-bearing rocks consist mainly of almandine (Alm, 69–75%) and pyrope (Py, 15–25%), and low grossularite (Grss, 5–6%). Garnet from these gneisses has moderate values of Mn, without any major changes. The coarse-grained and garnets that formed early stage from cordierite–sillimanite gneisses are usually MgO and MnO-rich and show variation in chemical composition from core to rim, and also in coexisting phases. The granular aggregate of garnet involved in the formation of cordierite is usually characterized by moderate MgO (Py, 18–20%) and poor MnO. Garnet from biotite–K-feldspar gneisses has high MnO content (up to 8%) and grossularite (up to 25%), and low pyrope.

The pressure and temperature estimates experienced by the gneisses during prograde and retrograde metamorphism are given in Table 2. Various conventional models of garnet–biotite, garnet–cordierite geothermometers and garnet–sillimanite–plagioclase–quartz and garnet–biotite–sillimanite–plagioclase–quartz geobarometers are used to estimate the pressure and temperature conditions of metamorphism. These geothermobarometers record the average *P–T* conditions of metamorphism of core composition at 730°C/5.4 kbar and rim composition at 640°C/5.1 kbar. The textural study revealed that cordierite had developed around the coarse-grained garnet and sometimes granules of garnet and sillimanite in the coarse-grained cordierite. The internally consistent geothermobarometers involving the minerals cordierite, biotite, garnet, plagioclase, sillimanite and quartz have been also used, which suggests 687–719°C temperature and 4.9–6.2 kbar pressure (Table 2). On the other hand, the conventional geothermobarometers, viz. garnet–cordierite exchange geothermometer and garnet–cordierite–sillimanite–plagioclase–quartz geobarometers yield the metamorphic conditions from average core rim composition at 665°C/5.14 kbar.

The Bundelkhand craton is mainly dominated by the Palaeoproterozoic granitoids[3,4]. The high-grade metamorphics of Bundelkhand craton are confined to the central

Table 1. Representative electron micro probe analyses of coexisting mineral phases from the garnet–cordierite–biotite–sillimanite gneisss with the structural formulae (sample no. M232)

	Gt			
Domain no.	C1/2R	C1/4C	C4/1C	C4/4R
SiO_2	38.771	38.928	38.538	38.388
TiO_2	0.010	0.122	0.011	0.034
Al_2O_3	21.113	21.517	21.022	20.989
Cr_2O_3	–	0.023	0.002	0.024
NiO	0.003	0.006	0.003	0.016
FeO*	33.581	31.394	33.804	34.252
MnO	1.618	0.819	1.770	1.723
MgO	4.17	6.558	3.907	3.652
CaO	2.259	2.188	2.014	2.037
ZnO	–	0.024	0.011	–
Total	101.525	101.579	101.082	101.115
Structural formulae	12 oxygen			
Si	3.0413	3.0099	3.0419	3.0364
Al^{IV}	0.0000	0.0000	0.0000	0.0000
ΣZ	3.0413	3.0099	3.0419	3.0364
Al^{VI}	1.9521	1.9610	1.9559	1.9569
Ti	0.0006	0.0071	0.0006	0.0020
Cr	0.0000	0.0014	0.0001	0.0015
Ni	0.0002	0.0004	0.0002	0.0010
ΣY	0.0008	0.0089	0.0009	0.0045
Fe	2.2030	2.0301	2.2315	2.2659
Mn	0.1075	0.0537	0.1183	0.1154
Mg	0.4876	0.7559	0.4598	0.4306
Ca	0.1899	0.1812	0.1703	0.1726
Zn	0.0000	0.0014	0.0007	0.0000
ΣX	2.9880	3.0223	2.9806	2.9845
X_{Mg}	0.1631	0.2502	0.1543	0.1442
Pyrope	16.3186	25.0223	15.4300	14.4279
Almandine	73.7282	67.2018	74.8851	75.9223
Spessartine	3.5977	1.7776	3.9699	3.8666
Grossularite	6.3554	5.9982	5.7150	5.7832

	Crd		Bio		Fsp	
Domain no.	C1/2R	C4/1C	C1/2R	C1/4C	C1	C1/2
SiO_2	50.045	48.912	37.721	39.197	55.824	55.778
Al_2O_3	31.909	31.384	17.328	18.063	27.08	27.415
TiO_2	0.000	0.000	1.396	1.369	0.000	0.000
Cr_2O_3	0.000	0.000	0.028	0.006	0.000	0.000
FeO*	7.346	7.843	18.933	18.486	0.051	0.109
MgO	7.618	8.193	11.841	11.637	0.000	0.000
MnO	0.085	0.13	0.012	0.030	0.031	0.000
CaO	0.000	0.000	0.009	0.057	8.705	9.272
K_2O	0.000	0.000	8.600	6.255	0.057	0.059
Na_2O	1.005	0.316	0.394	0.176	6.382	6.337
Total	98.008	96.778	96.2340	95.2700	98.130	98.970
Structural formulae	18 oxygen		22 oxygen		8 oxygen	
Si	5.1459	5.1038	5.2630	5.7699	2.5500	2.5320
Al^{IV}	3.8674	3.8600	2.3770	2.2301	1.4581	1.4668
ΣZ	9.0133	8.9638	8.0000	8.0000	4..0081	3.9988
Al^{VI}	0.000	0.000	0.6696	0.9040	0.0000	0.0000
Ti	0.000	0.000	0.1565	0.1516	0.0000	0.0000
Cr	0.000	0.000	0.0033	0.0007	0.0000	0.0000
Fe	0.6317	0.6845	2.3604	2.2758	0.0020	0.0041
Mg	1.1677	1.2744	2.6312	2.5537	0.0000	0.0000
Mn	0.0074	0.0115	0.0015	0.0038	0.0004	0.0000
ΣY	1.8068	1.9704	5.8225	5.8896	0.0024	0.0041
Ca	0.000	0.000	0.0014	0.0090	0.4261	0.4510
K	0.000	0.000	1.6356	1.1747	0.0033	0.0034
Na	0.000	0.000	0.1138	0.0502	0.5633	0.4478
ΣX	0.000	0.000	1.7508	1.2339	0.9947	0.9022
X_{Mg}	0.6489	0.6506	0.5271	0.5288	0.0000	0.0000
X_{An}	0.000	0.000	0.000	0.000	0.4298	0.5018

Gt, Garnet; R, Rim; C, Core; X_{Mg}, Mg/Fe + Mg + Ca + Mn; FeO*, Total iron.
X_{An} is the anorthite content of feldspar = Ca/(Ca + Na + K); Crd, Cordierite; Bio, Biotite; Fsp, Feldspar; q, Quartz.

Table 2. Calculated temperature and pressure of garnet–cordierite gneiss (M232) from EPMA data through different geothermobarometers

	Temperature in (°C) at 5 kbar pressure				Pressure in kbar at 650°C temperature			
	Gt-Bio		Gt-Crd		Gt-bio-fsp-q		Gt-crd-sill-q	
	Core	Rim	Core	Rim	Core	Rim	P_{Mg}	P_{Fe}
K_D	3.0136	5.0363	9.0356	8.3516				
ln K_D	1.0132	1.6166	2.2011	2.1224				
A	800	626	632	655	5.4	5.1	6.59	5.88
B	860	618	623	644			6.06	5.62
C	722	643	694	710			4.44	
D	775	610	635	658			4.67	3.05
E	790	669	663	688			5.44 ± 1	4.85 ± 0.8
F	740	627	603	631				
G	759	635	688	711				
H	738	680	689	710			*687°C/4.9 kbar	
							**719°C/6.2 kbar	
Average	773 ± 44	640 ± 24	655 ± 35	675 ± 32				

Gt-Bio: A = Thompson[8], B = Ferry and Spear[9], C = Perchuk *et al.*[10], D = Dasgupta *et al.*[11], E = Aranovich *et al.*[12], F = Bhattacharya *et al.*[13], G = Holdaway[14], H = Dwivedi *et al.*[15].
Gt-Crd: A = Thompson[8], B = Perchuk *et al.*[10], C = Bhattacharya *et al.*[16], D = Perchuk[17], E = Aranovich and Podlesskii[18], F = Nichols *et al.*[19], G = Dwivedi[20], H = Dwivedi *et al.*[21].
Gt-Bio-fsp-q: A = Wu *et al.*[22].
Gt-crd-sill-q: A = Thompson[8], B = Wells[23], C = Perchuk *et al.*[10], D = Aranovich and Podlesskii[18].
*Result of internally consistent geothermobarometers: Dwivedi *et al.*[24]; **Holland and Powell[25] (Thermocalc V.3.21, 2001).

part of the Bundelkhand massif and consist of different varieties of rocks, namely garnet–cordierite–sillimanite gneisses, garnetiferous amphibolites, calc silicates and quartzites. The high-grade metamorphics are concentrated in a narrow zone. These metamorphics are invaded by multi-phase granitic and granodioritics activities[2–4] ranging in age from early Archeans (3300–3500 Ma) to Palaeoproterozoic (2600–2500 Ma).

The gneisses containing garnet–cordierite–sillimanite-quartz have been studied from different localities. It is concluded that the garnet–cordierite–sillimanite-bearing assemblages are related to the granulite facies rocks and serve as an indicator of high-grade metamorphism[5–7]. The geothermobarometric estimates and mineral chemistry for the present area of Bundelkhand suggest that high-grade metamorphic activities have taken place in the central part of the massif during the Archean period.

1. Singh, S. P., Singh, M. M. and Srivastava, G. S., Crustal evolution in Bundelkhand, Massif. In Abstract, International Conference on PGTG, Jhansi, 2005, pp. 242–243.
2. Singh, S. P., Singh, M. M., Srivastava, G. S. and Basu, A. K., Crustal evolution in Bundelkhand, Central India. *Himalayan Geol.*, 2007, **28**, 79–101.
3. Mondal, M. E. A., Goswami, J. N., Deomurari, M. P. and Sharma, K. K., Ion microprobe $^{207}Pb/^{206}Pb$ ages of zircons from the Bundelkhand massif, northern India. Implications for crustal evolution of the Bundelkhand–Aravalli protocontinent. *Precambrian Res.*, 2002, **117**, 85–110.
4. Sharma, K. K., Evolution of Archaean Palaeoproterozoic crust of the Bundelkhand craton, northern Indian shield. In *Research Highlights in Earth System Science* (eds Verma, O. P. and Mahadevan, T. M.), DST's Spl. 1, Ind. Geol. Cong., 2000, pp. 95–105.
5. Lal, R. K. and Moorhouse, W. W., Cordierite–gedrite rocks and associated gneisses of Fishtail lake, Harcourt township, Ontario. *Can. J. Earth Sci.*, 1969, **6**, 145–165.
6. Sharma, R. S. and MacRae, N. D., Paragenetic relations in gedrite–cordierite–staurolite–sillimanite–kyanite gneisses at Ajitpura, Rajasthan, India. *Contrib. Mineral. Petrol.*, 1981, **78**, 48–60.
7. Lal, R. K., Ackermand, D., Raith, M., Raase, P. and Seifert, F., Sapphrinine-bearing assemblages from Kiranur, southern India. A study of chemographic relationships in Na_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O system. *Neues Jahrb. Mineral. Abh.*, 1984, **150**, 121–152.
8. Thompson, A. B., Mineral reaction in pelitic rocks: 1 Prediction in *P–T–X* (Fe–Mg) phase relations. II. Calculations of some *P–T–X* (Fe–Mg) phase relations. *Am. J. Sci.*, 1976, **276**, 401–454.
9. Ferry, J. M. and Spear, F. S., Experimental calibration of the partitioning of Fe and Mg between biotite and garnet. *Contrib. Mineral. Petrol.*, 1978, **66**, 113–117.
10. Perchuk, L. L., Aranovich, L. Ya, Podlesskii, K. K. and Lavrenteva, I. V., Precambrain granulites of the Alden Shield, eastern Siberia USSR. *J. Meta. Geol.*, 1985, **3**, 265–310.
11. Dasgupta, S., Sengupta, P., Guha, D. and Fukuoka, M., A refined garnet–biotite Fe–Mg exchange geothermometer and its application in amphibolites and granulites. *Contrib. Mineral. Petrol.*, 1991, **109**, 130–137.
12. Aranovich, L. Ya and Podlesskii, K. K., Geothermobarometry of high-grade metapelites: simultaneously operating reactions. In *Evolutions of Metamorphic Belts* (eds Daly, J. S., Clf, R. A. and Yardley, W. V. D.), Geological Society of London, 1989, vol. 43, pp. 45–61.
13. Bhattacharya, A., Mohanty, L., Maji, A., Sen, S. K. and Raith, M., Non-ideal mixing in the phlogopite–annite binary solution: constraints from experimental data on Mg–Fe partitioning and a reformulation of the biotite–garnet geothermometers. *Contrib. Mineral. Petrol.*, 1992, **111**, 87–93.
14. Holdaway, M. J., Application of new experimental and garnet Margules data to the garnet–biotite geothermometer. *Am. Mineral.*, 2000, **85**, 881–892.

15. Dwivedi, S. B., Jimmy, L., Vanthanglana, V. and Lal, S. N., A refined garnet–biotite thermometer: constraints from empirically derived Margules parameters for garnet (ΔW_{Ca} & ΔW_{Mn}) and biotite (ΔW_{Al} & ΔW_{Ti}). *Indian Mineral.*, 2007, **41**, 97–111.
16. Bhattacharya, A., Mazumdar, A. C. and Sen, S. K., Fe-Mg mixing in cordierite: constraints from natural data and implication for cordierite–garnet geothermometry in granulites. *Am. Mineral.*, 1992, **73**, 338–344.
17. Perchuk, L. L., Derivation of a thermodynamically consistent set of geothermometers and geobarometers for metamorphic and magmatic rocks. In *Progress in Metamorphic and Magmatic Petrology* (A memorial volume in honor of Korzhinsky, D. S.) (ed. Perchuk, L. L.), Cambridge University Press, 1991, pp. 93–111.
18. Aranovich, L. Ya. and Podlesskii, K. K., The cordierite–garnet–sillimanite equilibrium: experiments and application. In *Kinetics and Equilibrium in Mineral Reactions* (ed. Saxena, S. K.), Springer-Verlag, Berlin, 1983, pp. 173–198.
19. Nichols, G. T., Berry, R. F. and Green, D. H., Internally consistent granitic spinel–cordierite–garnet equilibria in the FMASHZn system, geothermobarometry and application. *Contrib. Mineral. Petrol.*, 1992, **111**, 362–373.
20. Dwivedi, S. B., Non-ideal Mg–Fe binary mixing in cordierite: Constraints from experimental data on Mg–Fe partitioning in garnet and cordierite and a reformulation of garnet–cordierite geothermometer. *J. Earth Syst. Sci.*, 1996, **105**, 365–377.
21. Dwivedi, S. B., Mohan, A. and Lal, R. K., Recalibration of the Fe–Mg exchange reaction between garnet and cordierite as a thermometer. *Eur. J. Mineral.*, 1998, **10**, 281–289.
22. Wu, C. M., Zhang, Z. and Ren, L. D., Empirical garnet–biotite–plagioclase–quartz (GBPQ) geobarometry in medium to high-grade metapelites. *J. Petrol.*, 2004, **45**, 1907–1921.
23. Wells, P. R. A., Chemical and thermal evolution of Archean sialic crust, southern Greenland. *J. Petrol.*, 1979, **20**, 187–226.
24. Dwivedi, S. B., Mohan, A. and Lal, R. K., Internally consistent geothermobarometers in the system $FeO–MgO–Al_2O_3–SiO_2–H_2O$ involving garnet, cordierite, aluminosilicate and quartz and their application to metapelites. *J. Geol. Soc. India*, 1997, **49**, 647–669.
25. Holland, T. J. B. and Powell, R., An enlarged and updated internally consistent thermodynamic dataset with uncertainty and correlations: the system $K_2O–Na_2O–CaO–MgO–MnO–FeO–Fe_2O_3–Al_2O_3–TiO_2–C–H_2–O_2$. *J. Metamor. Geol.*, 1990, **8**, 89–124.
26. Ramchandra, H. M. and Roy, A., Evolution of the Bhandara–Balaghat granulite belt along the southern margin of the Sausar mobile belt of central India. *Proc. Indian Acad. Sci., Earth Planet. Sci.*, 2001, **110**, 351–368.
27. Yedekar, D. B., Jain, S. C., Nair, K. K. and Dutta, K. K., *The Central Indian Collision Suture in Precambrians of Central India*, Geological Survey of India, Special Publication, 1990, p. 28.
28. Jokhan Ram, Shukla, S. N., Pramanik, A. G., Varma, B. K., Chandra, G. and Murthy, M. S. N., Recent investigations in the Vindhyan basin. Implications for the basin tectonics. *J. Geol. Soc. India*, 1996, **36**, 267–286.
29. Raza, M. and Casshyap, S. M., A tectono-sedimentary model of evolution of middle Proterozoic Vindhyan basin. *J. Geol. Soc. India*, 1996, **36**, 287–300.
30. Acharya, S. K., The nature of Mesoproterozoic central Indian tectonic zone with exhumed and reworked older granulites. *Gondwana Res.*, 2003, **6**, 197–214.

ACKNOWLEDGEMENTS. Financial support provided by the Ministry of Mines, Govt of India to S.P.S. is acknowledged. S.B.D. thanks DST, New Delhi for financial support.

Received 6 October 2008; revised accepted 1 May 2009

MEETINGS/SYMPOSIA/SEMINARS

National Seminar on Frontiers in Biotechnology (NSFB 2009)

Date: 22–24 July 2009
Place: Coimbatore

Topics include: Clinical biotechnology; Molecular microbiology; Plant–microbe interactions; Proteomics and genomics; Molecular diagnostics; Genetic engineering; Food biotechnology.

Contact: Organizing Secretary (NSFB – 2009)
Department of Biotechnology
School of Biotechnology and Genetic Engineering
Bharathiar University
Coimbatore 641 046
Phone: 0422-2428294, 2428298, 2425716
e-mail: nsfb2009@gmail.com

Training Workshop on Environmental Pollutants and its Control Studies (TWO EPICS 2009)

Date: 27–30 August 2009
Place: Tiruchirappalli

The main focus of the workshop will be on to impart hands on training on the analysis of environmental samples using Gas Chromatograph coupled with Mass Spectrophotometer for detection and quantification of pesticides, PAHs, PPCPs, etc.

Contact: Organizing Secretary (TWO EPICS 2009)
Department of Environmental Biotechnology
School of Environmental Sciences
Bharathidasan University
Tiruchirappalli 620 024
Phone: 0431 2407088
e-mail: twoepics09@yahoo.in
Website: www.bdu.ac.in