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A Unified Model of Neoarchean-Proterozoic Convergence and Rifting of Indian Cratons: Geophysical Constraints

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ABSTRACT

Neoarchean and Proterozoic sutures and collision zones are identified in the Indian Peninsular Shield based on high seismic velocity; gravity highs and high conductivity in the upper crust due to thrusting while sub-ducted side are demarcated based on geophysical signatures of crustal thickening and back arc type basins. Some of them appear to form triple junctions. The Bouguer anomaly map of the south Indian shield when transformed to apparent density map through harmonic inversion, provided high density linear zones coin- ciding with the shear zone and the transition zone-the Moyar Bhavani Shear Zone (MBSZ) between the Eastern Dharwar Craton (EDC) and the Western Dharwar Craton (WDC) and the Dharwar cratons and the Southern Granulite Terrain (SGT), respectively. It is supported by high seismic velocity and high conductiv- ity suggesting them to be caused by high grade granulite rocks related to Neoarchean-Paleoproterozoic su- tures and collision zones. These investigations also suggest thick crust (~40 - 50 km) under the WDC and the SGT forming crustal root of 50 - 52 km in the south western part and thin crust of 31 - 32 km under the EDC indicating direction of convergence and subduction as E-W and N-S between the EDC and the WDC and Dharwar cratons and the SGT, respectively. It gave rise to contemporary lower crustal granulite rocks in the northern part of the SGT and Cauvery shear zone (CSZ) as collision related central core complex of various deep seated intrusive rocks of Paleo-Mesoproterozoic period. The second case belonging to Meso-proterozoic period is related to the collision of the Bundelkhand craton and the Bhandara-Bastar craton (BBC) and the Dharwar craton (DC) in Central India along the Satpura Mobile Belt (SMB) and the BBC and the DC along the Godavari Proterozoic Belt due to N-S and NE-SW convergences, respectively. This process has given rise to lower crustal granulite rocks of high density, high velocity and high conductivity along the SMB and the GPB. An upper mantle conductor delineated south of the western part of the SMB under Dec- can Volcanic Province and a regional gravity gradient almost sub parallel to it indicate an interface with flu- ids separating rocks of different densities that appears to demarcate the trace of the Proterozoic subduction and suture related to the SMB collision zone during Mesoproterozoic period. High reflectivity of the lower crust along seismic profiles across the SMB indicate an extensional phase prior to this convergence. The SMB is connected to the Aravalli Delhi Mobile Belt (ADMB) in the western part that is another collision zone of Meso-proterozoic period, forming an arcuate shaped collision zone between the Bundelkhand craton and Rajasthan block with E-W convergence. There are indications of a prior phase of convergence during Paleo-Proterozoic period followed by rifting during Paleo-Meso-proterozoic period (~1.9 - 1.6 Ga) along the SMB, the ADMB and the GPB that gave rise to large scale contemporary intrusive in these sections. The contemporary Mahakoshal-Bijawar and Pakhal group of rocks of Paleo Proterozoic period (~1.9 - 1.6 Ga) were deposited over the rifted platform of the Bundelkhand craton along the SMB and cratons along the GPB, respectively during the extensional phase as suggested above based on high reflectivity of the lower crust. It is followed by deposition of the Vindhyan sediments of Meso-Neoproterozoic period (~1.6 - 0.7 Ga) along the SMB and the ADMB as foreland basins during Meso-Neoproterozoic convergence. Simultaneous N-S and E-W directed convergences in the two cases, viz., the SMB and the ADMB that are connected forming an arcuate shaped collision zone suggest NE-SW directed primary stress direction similar to the GPB that is supported by NW-SE oriented large lineaments in Bundelkhand craton and Peninsular shield. The Eastern Ghat Mobile Belt (EGMB) also shows signatures of E-W or NE-SW directed Mesoproterozoic (~1.5 - 1.0 Ga) convergence with East Antarctica. This convergence was preceded by Paleo-Mesoproterozoic rifting (~1.9 - 1.6 Ga) that gave rise to contemporary activities of the EGMB and large scale volcanic activity that formed several basins west of it.

KEYWORDS
Indian Shield, Convergence, Collision, Triple Junction and Gravity Anomaly

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References

[1] R. A. Gibbs and M. D. Thomas, "Gravity Signature of Fossil Plate Boundaries in the Canadian Shield," Nature, Vol. 262, No. 5565, 1976, pp. 199-200. doi:10.1038/262199a0

[2] D. M. Fountain and M. H. Salisbury, "Exposed Cross Section through the Continental Crust: Implications for Crustal Structure, Petrology and Evolution," Earth and Planetary Science Letters, Vol.56, 1981, pp. 263-277. doi:10.1016/0012-821X(81)90133-3

[3] D. C. Mishra, "Building Blocks and Crustal Architecture of Indian Peninsular Shield Cratons and Fold Belts and Their Interaction Based on Geophysical Data Integrated with Geological Information," Journal Geological Society of India, Vol. 68, No. 6, 2006, pp. 1037-1057.

[4] GSI-NGRI, "Gravity Map Series of India" Geological Survey of India and National Geophysical Research Institute, Hyderabad, 2006.

[5] D. C. Mishra, B. Singh and V. M. Tiwari, "Gravity Studies in India," Golden Jubilee, Volume of the Geological Society of India Golden Jubilee Memoir of Geological Society of India, 2008, pp. 329-372.

[6] D. V. Subba Rao, "Resolving Bouguer Anomalies in Continents—A New Approach," Geophysical Research Letters, Vol. 23, No. 24, 1996, pp. 3543-3546. doi:10.1029/96GL03471

[7] D. C. Mishra and L.B. Pedersen, "Statistical Analysis of Potential Fields from Subsurface Relief," Geoexploration, Vol. 19, No. 4, 1982, pp. 247-265. doi:10.1016/0016-7142(82)90030-8

[8] A. P. Singh, D. C. Mishra and G. Laxman, "Apparent Density Mapping and 3-D Gravity Inversion of Dharwar Crustal Province," Journal Indian Geophysical Union, Vol. 7, No. 1, 2003, pp. 1-9.

[9] M. Jayananda, J. F.Moyan, H. Martin, J. J. Peucat, B. Au- vray and B. Mahabaleshwar, "Late Archean (2550-2520 Ma) Juvenile Magmatism in the Eastern Dharwar Craton, Southern India: Constraints from Geochronology, Nd-Sr Isotopes and Whole Rock Geochemistry," Precambrian Research, Vol. 99, No. 3-4, 2000,pp. 225-254. doi:10.1016/S0301-9268(99)00063-7

[10] D. C. Mishra and S. K. Prajapati, "A Plausible Model for Evolution of Schist Belts and Granite Plutons of Dharwar craton, India and Madagascar during 3.0-2.5 Ga: Insight from Gravity Modelling Constrained in Part from Seismic Studies," Gondwana Research, Vol. 6, No. 3, 2003, pp. 501-511. doi:10.1016/S1342-937X(05)71001-7

[11] B. Chadwick, V. N. Vasudev, G. V. Hegde and A. P. Nutman, "Structure and SHRIMP U/Pb Zircon Ages of Granites Adjacent to the Chitradurga Schist Belt: Implications for Neoarchean Convergence in the Dharwar Craton, Southern India," Journal Geological Society of India, Vol. 69, 2007, pp. 5-24.

[12] A. Kumar, Y. J. Bhaskar Rao, T. V. Sivaraman and K. Gopalan, "Sm-Nd Ages of Archean Meta-Volcanics of the Dharwar Craton, South India," Precambrian Research, Vol. 80, No. 3-4, 1996, pp. 205-216. doi:10.1016/S0301-9268(96)00015-0

[13] K. Arora, R. P. Rajasekhar and D. C. Mishra, "Density Models of Crust under Dharwar-Granite Greenstone Terrain and the Satpura Mobile Belt: Archean-Proterozoic Analogue of Plate Tectonics," Memoir Gondwana Research, Vol. 10, 2007, pp. 217-226.

[14] S. Kiselev, L.Vinnik, S. Oreshin, S. Gupta, S. S. Rai, A. Singh, M. R .Kumar and G. Mohan, "Lithosphere of the Dharwar Craton by Joint Inversion of P and S Receiver Functions," Geophysical Journal International, Vol. 173, No. 3, 2008, pp. 1106-1118. doi:10.1111/j.1365-246X.2008.03777.x

[15] S. Gupta, S. S. Rai, K. S. Prakasam and D. Srinagesh, "The Nature of the Crust in Southern India: Implications for Precambrian Crustal Evolution," Geophysical Research Letters, Vol. 30, No. 8, 2003, p. 1419. doi:10.1029/2002GL0167

[16] K. L. Kaila, R. K. Chowdhury, P. R. Reddy, V. G. Krishna, H. Narain, S. I. Subbotin, V. B. Sollogulb, A. V. Chekunov, G. E. Kharetcho, M. A. Lazarenko and T. V. Ilchenko, "Crustal Structure along the Kavali-Udipi Profile in the Indian Peninsular Shield from Deep Seismic Sounding," Journal of Geological Society of India, Vol. 20, 1979, pp. 307-333.

[17] S. G., Gokaran, G. Gupta and C. K. Rao, "Geoelectric Structure of the Dharwar Craton from Magnetotelluric Studies: Archean Suture Identified along the Chitradurga- Gadag Schist Belt," Geophysical Journal International, Vol. 158, No. 2, 2004, pp. 712-728. doi:10.1111/j.1365-246X.2004.02279.x

[18] Y. J. B. Rao, A. S. Janardhan, T. V. Kumar, B. L. Narayana, A. M. Dayal, B. N. Taylor and T. R. K. Chetty, "Sm-Nd Model Ages and Rb-Sr Isotopic Systematics of Charnockites and Gneisses across the Cauvery Shear Zone, Southern India: Implications for the Archaean- Neoproterozoic Terranes Boundary in the Southern Granulie Terrain," Memoir Geological Society of India, Vol. 50, 2003, pp. 297-317.

[19] D. C. Mishra and V. V. Kumar, "Evidence for Proterozoic Collision from Airborne Magnetic and Gravity Studies in Southern Granulite Terrain, India and signatures of Recent Tectonic Activity in the Palghat Gap," Gondwana Research, Vol. 8, No. 1, 2005, pp. 1-12. doi:10.1016/S1342-937X(05)70261-6

[20] E. J. Krogstad, S. Balakrishnan, D. K. Mukhopadhyay, V. Rajamani, G. N. Hanson, "Plate tectonics, 2.5 billion yeas ago: Evidence at Kolar South India," Science, Vol. 243, No. 4896, 1989, pp. 1337-1340. doi:10.1126/science.243.4896.1337

[21] P. R. Reddy, V. Vijayarao. B. R. Prasad, K. Sain, P. Prasad Rao and P. Khare, "Crustal Seismic Studies along Kuppam-Palani Transect in Southern Granulite Terrain," Memoir Geological Society of India, Vol. 50, 2003, pp.79-106.

[22] D. C. Mishra, V. Vijai Kumar and R. P. Rajasekhar, "Analysis of Airborne Magnetic and Gravity Anomalies of Peninsular Shield, India Integrated with Seismic and Magnetotelluric Results and Gravity Anomalies of Madagascar, Sri Lanka and East Antarctica," Gondwana Research, Vol. 10, No. 1-2, 2006, pp. 6-17. doi:10.1016/j.gr.2005.11.014

[23] D. Canil, "Canada's Craton: A Bottoms-Up View," GSA Today, Vol. 18, 2008, pp. 4-10. doi:10.1130/GSAT01806A.1

[24] S. S. Schmidberger, A. Simonetti, L. M. Heaman, R. A. Creaserand and S. Whiteford, "Lu-Hf, in Situ Sr and Pb Isotope and Trace Element Systematics for Mantle Eclogites from the Diavik Diamond Mine: Evidence for Paleo Proterozoic Subduction Beneath the Slave Craton," Earth and Planetary Science Letters, Vol. 254, No. 1-2, 2007, pp. 55-68. doi:10.1016/j.epsl.2006.11.020

[25] M. Santosh, S. Maruyama and K. Sato, "Anatomy of a Cambrian Suture in Gondwana: Pacific Type Orogeny in Southern India," Gondwana Research, Vol. 16, No. 2, 2009, pp.321-341. doi:10.1016/j.gr.2008.12.012

[26] K. Naganjaneyulu and M. Santosh, "The Cambrian Collisional Suture of Gondwana in Southern India: A Geophysical Appraisal," Journal of Geodynamics, Vol. 50, No. 3-4, 2010, pp. 256-267. doi:10.1016/j.jog.2009.12.001

[27] U. Raval and K. Veeraswamy, "Within and beyond the Protocontinents: Some Geophysical Aspects Reflecting Geodynamics of the Indian Continental Lithosphere," Memoir Gondwana Research, Vol. 10, 2007, pp. 263- 285.

[28] GSI, "Geological Map of India on 1: 5 Million Scale," Geological Survey of India, Calcatta, 1993.

[29] D. H. Yedekar, S. C. Jain, K. K. K. Nair and K. K. Dutta, "The Central Indian Collision Suture. In: Precambrian of Central India," Geological Survey of India, Special Publication, Nagpur, Vol. 28, 1990, pp. 1-43.

[30] S. Sinha-Roy, "Proterozoic Wilson Cycle in Rajasthan," Memoir Gological Society of India, Vol. 7, 1988, pp. 95- 108.

[31] D. C. Mishra, B. Singh, V. M. Tiwari S. B. Gupta and M. B. S. V. Rao, "Two Cases of Continental Collisions and Related Tectonics during the Proterozoic Period In India-Insights from Gravity Modelling Constrained by Seismic and Magnetotelluric Studies," Precambrian Research, Vol. 99, No. 3-4, 2000, pp. 149-169. doi:10.1016/S0301-9268(99)00037-6

[32] A. P. Singh, D. C. Mishra, V. V. Kumar and M. B. S. V. Rao, "Gravity-Magnetic Signatures and Crustal Architecture along Kuppam-Palani Geotransect, South India". Memoir Geological Society of India, Vol. 50, 2003, pp. 139-163.

[33] P. R. Reddy, P. R. K. Murthy Rao, I. B. P. D. M. Mall and P. Koteshwar Rao, "Coincident Deep Seismic Reflection and Refraction Profiling of Central India," Research Highlights in Earth System Science, DST Special Volume 1, Indian Geological Congress, 2000, pp. 49-53.

[34] R. P. Rajasekhar and D. C. Mishra, "Crustal Structure of Bengal Basin and Shillong Plateau: Extension of Eastern Ghat and Satpura Mobile Belts to Himalayan Fronts and Seismotectonics," Gondwana Research, Vol. 14, No. 3, 2008, pp. 523-534. doi:10.1016/j.gr.2007.10.009

[35] D. C. Mishra and R. P. Rajasekhar, "Gravity and Magnetic Signatures of Proterozoic Rifted Margins: Bundelkhand Craton and Bijawar and Mahakoshal Group of Rocks and Vindhyan Basin and Their Extension under Ganga Basin," Journal of Geological Society of India, Vol. 71, 2008, pp. 377-387.

[36] K. Sain, N. Bruguier, A. S. N. Murthy and P. R. Reddy, "Shallow Velocity Structure along Hirapur-Mandla Profile Using Travel Time Inversion of Wide Angle Seismic Data and Its Tectonic Implications," Geophysical Journal International, Vol. 142, No. 2, 2000, pp. 505-515. doi:10.1046/j.1365-246x.2000.00176.x

[37] J. S. Ray, J. Veizer, W. J. Davis, "C, O, Sr and Pb Isotope systematics of Carbonate Sequences of the Vindhyan Supergroup, India: Age, Diagenesis, Correlations and Implications for Global Events," Precambrian Research, Vol. 121, No. 1-2, 2003, pp. 103-140. doi:10.1016/S0301-9268(02)00223-1

[38] J. S. Ray, M. W. Martin, J. Veizer and S. A. Bowring, "U-Pb Zircon Dating and Sr Isotope Systematics of the Vindhyan Supergroup, India," Geology, Vol. 30, No. 2, 2002, pp. 131-134. doi:10.1130/0091-7613(2002)030<0131:UPZDAS>2.0.CO;2

[39] D. C. Mishra, "Long hiatus in Proterozoic Sedimentation in India: Vindhyan, Cuddapah and Pakhal Basins—A Plate Tectonics Model," Journal of Geological Society of India, Vol. 77, No. 1, 2011, pp. 17-25. doi:10.1007/s12594-011-0004-9

[40] D. C. Mishra, "Gravity and Magnetic Methods for Geological Studies (Principles Integrated Exploration and Plate Tectonics)," B. S. Publications, Hyderabad & CRC Press, Boca Raton, 2011, pp. 1-938.

[41] A. Roy and M. H. Prasad, "Tectonothermal Events in Central Indian Tectonic Zone (CITZ) and Its Implications in Rodinian Crustal Assembly," Journal of Asian Earth Sciences, Vol. 22, No. 2, 2003, pp. 115-129. doi:10.1016/S1367-9120(02)00180-3

[42] K. Naganjaneyulu and M. Santosh, "The Central India Tectonic Zone: A Geophysical Perspective on Continental Amalgamation along a Meso Proterozoic Suture," Gondwana Research, Vol. 18, No. 4, 2010, pp. 547-564, doi:10.1016/j.gr.2010.02.017

[43] S. Majumder and M. A. Mamtani, "Magnetic Fabric in the Malanjkhand Granite (Central India)—Implications for regional Tectonics and Proterozoic Suturing of the Indian Shield," Physics of the Earth and Planetary Interiors, Vol. 172, No. 3-4, 2009, pp. 310-323. doi:10.1016/j.pepi.2008.10.007

[44] A. R. Sridhar, H. C. Tewari, V. Vijaya Rao, N. Satavani, N. K. Thakur, "Crustal Velocity Structure of the Narmada Son Lineament along the Thuadara-Sendhwa-Sindad profile in the NW Part of Central India and Its Geodynamic Implications," Journal Geological Society of India, Vol. 69, 2007, pp. 1147-1160.

[45] C. K. Rao, S. G. Gokaran and B. P. Singh, "Upper Crustal Structure in the Torni-Purnad Region, Central India Using Magnetotelluric Studies," Journal Geomagnetism and Geoelectricity, Vol. 47, No. 4, 1995, pp. 411- 420. doi:10.5636/jgg.47.411

[46] P. K. Patro and S. V. S. Sarma, "Lithospheric Electrical Imaging of the Deccan Trap Covered Region of Western India," Journal of Geophysical Research, Vol. 114, 2009, pp. B01102-B01118. doi:10.1029/2007JB005572

[47] S. A. Chore and M. Mohanty, "Stratigraphy and Tectonic Setting of the Trans Aravalli, Neoproterozoic Volcano Sedimentary Sequence in Rajasthan," Journal Geological Society of India, Vol. 51, 1998, pp. 57-68.

[48] B. V. Lente, L. D. Ashwal, M. K. Pandit, S. A. Bowring and T. H. Torsvik, "Neoproterozoic Hydrothermally Altered Basaltic Rocks from Rajasthan, Northwest India: Implications for Late Precambrian Tectonic Evolution of the Aravalli Craton," Precambrian Research, Vol. 170, No. 3-4, 2009, pp. 202-222. doi:10.1016/j.precamres.2009.01.007

[49] P. S. R. Raju, "Geology and Hydrocarbon Prospects of Pranhita-Godavari Graben," Journal of Association of Exploration Geophysics, Vol. 7, No. 3, 1986, pp. 131- 146.

[50] T. S. Rao, "The Pakhal Basin; A perspective. In: Purana Basins of Peninsular India, Middle to Late Proterozoic Based on the Proceedings of the Seminar," Memoir Geological Society of India, Vol. 6, 1987, pp. 161-187.

[51] M. Santosh, K. Yokoyama and S. K. Acharyya, "Geochronology and Tectonic Evolution of Karimnagar and Bhopalpatnam Granulite Belts, Central India," Gondwana Research, Vol. 7, No. 2, 2004, pp. 501-518. doi:10.1016/S1342-937X(05)70801-7

[52] J. M. Rao, G. V. S. P Rao and S. K. Patil, "Geochemical and Paleomagnetic Studies on the Middle Proterozoic Karimnagar Mafic Dyke Swarm, India," In: A. P. Parker, P. C. Rock Wood and D. H. Tucker, A. A. Balkema, Eds., Rotterdam Mafic Dykes and Emplacement Mechanism, Balkema, Rotterdam, 1990, pp. 373-382.

[53] K. L. Kaila, P. R. K. Murthy, V. K. Rao and N. Venkates- warlu, "Deep Seismic Sounding in the Godavari Graben and Godavari (Coastal) Basin, India," Tectonophysics, Vol. 173, 1990, pp. 307-317. doi:10.1016/0040-1951(90)90226-X

[54] D. C. Mishra, "Paleomagnetism of variation Rocks of India," Ph.D. Thesis, Banaras Hindu university, Banaras, 1965,

[55] K. Mezger and M. A. Cosca, "The Thermal History of the Eastern Ghats Belts (India) as Revealed by U-Pb and (super 40) Ar/(Super 39) A Dating of Metamorphic and Magmatic Minerals: Implications for the SWEAT Correlation," Precambrian Research, Vol. 94, No. 3-4, 1999, pp. 251-271. doi:10.1016/S0301-9268(98)00118-1

[56] D. K. Paul, T. Barman, N. J. McNaughton, I. R. Flecther, P. J. Potts, M. Ramakrishnan and P. F. Augustine, "Archean-Proterozoic Evolution of Indian Charnockites-Iso- Topes and Geochemical Evidence from Granulites of the Eastern Ghat Belt," Journal of Geology, Vol. 98, No. 2, 1990, pp. 253-263. doi:10.1086/629396

[57] C. J. Dobmeier and M. Raith, "Crustal Architecture and Evolution of the Eastern Ghats Belt and Adjacent Regions of India," In: M. Yoshida, B. F. Windley, S. Dasgupta, Eds., Proterozoic East Gondwana: Super continent Assembly and Break up, Geological Society, Special Publications,