

Preface

Dyke Swarms: Keys for Geodynamic Interpretation

Although research on dyke rocks has been of interest to many geologists since eighteenth century, 25 years ago Henry Halls realized that systematic study of dykes, particularly mafic dyke swarms, may play an important role in understanding many geological problems. Dykes swarms are key elements to understanding geodynamic processes. Their study is particularly important for understanding Precambrian terrains. We know that Earth history is punctuated by events during which large volumes of mafic magmas were generated and emplaced by processes unrelated to “normal” sea-floor spreading and subduction. These are recognized as Large Igneous Provinces (e.g. Coffin and Eldholm, 2005; Bryan and Ernst, 2008). Study of dyke swarms helps to recognize Large Igneous Provinces (LIPs), particularly for the Precambrian period. Many LIPs can be linked to regional-scale uplift, continental rifting and breakup, and climatic shifts (e.g., Ernst et al., 2005 and references therein). In the Paleozoic and Proterozoic, LIPs are typically deeply eroded. They are represented by deep-level plumbing systems consisting of giant dyke swarms, sill provinces and layered intrusions. In the Archean the most promising LIP candidates are greenstone belts containing komatiites. Therefore, such studies are considered to be an important tool for paleocontinental reconstructions. LIPs (and their dyke swarms) may help to solve the reconstruction puzzle for pre-Pangean supercontinents back to 2600 Ma as discussed in recent publications (e.g. Bleeker and Ernst, 2006; Ernst and Srivastava, 2008; Ernst and Bleeker, 2010; Ernst et al., 2010) and showcased in a recent special issue of Precambrian Research on “Precambrian Large Igneous Provinces (LIPs) and their dyke swarms: new insights from high-precision geochronology integrated with paleomagnetism and geochemistry” (Srivastava et al., eds, 2010).

Recognizing the unrealized potential and importance of dyke swarm studies, Henry Halls started a series of International Dyke Conferences in 1985. The first conference was held at the University of Toronto, Mississauga Campus, Canada. It attracted over 120 scientists from 20 countries. A book “Mafic Dyke swarms” (Halls and Fahrig, 1987) was published based on the conference proceedings. Shortly after, an IGCP project, number 257, “Precambrian Dyke Swarms” was launched

by Henry Halls, this kept the momentum going in terms of bringing dykes to the attention of the scientific community. Also important was special session organized by Henry Halls “Giant Radiating Dyke Swarms and Mantle Plumes” at the Geological Association of Canada annual meeting in 1991. During IGCP 257 the idea was borne and finally realized that an International Dyke Conference should be held every 5 years. An important feature of all IDC meetings is the associated field trips. The second IDC meeting (IDC-2) was held in Adelaide, Australia in September 1990 and was organized by Peter Rickwood, Dave Tucker and John Parker. It resulted in a proceedings volume (Parker et al., 1990). The third conference (IDC-3) was held in Jerusalem, Israel, in September 1995, where the principal organizer was Gideon Baer and Ariel Heimann and again an excellent proceedings volume was produced (Baer and Heimann, 1995). The fourth meeting (IDC-4) was held June 2001 in a game reserve in KwaZulu, Natal, South Africa and organized by Mike Watkeys. IDC-5 was held in July–August 2005 in Rovaniemi, in the centre of Finland, and organized by Jouni Vuollo and Lauri Pesonen. A proceedings volume (Hanski et al., 2006) was subsequently published, including contributions from IDC-4. IDC-6 was held at Banaras Hindu University, Varanasi during 4th to 7th February 2010. Considering multifaceted importance of study of dykes, the Organizing Committee chose the overall theme “Dyke Swarms: Keys for Geodynamic Interpretation” with the following 12 sub-themes:

1. Regional maps of dyke swarms and related magmatic units
2. Emplacement mechanism of dykes
3. Petrology, geochemistry and petrogenesis of dykes
4. Geophysics of dykes with special reference to paleomagnetism, new aeromagnetic maps and remote sensing studies
5. Geochronology of dykes
6. Dykes as plumbing system for Large Igneous Provinces
7. Giant dyke swarm and Supercontinents
8. Alkaline dykes (including kimberlites, lamproites, lamprophyres and carbonatites)
9. Synplutonic mafic dykes
10. Dyke swarms and planetary bodies
11. Links to mineralization: e.g. U, PGE & Au, base metals, diamond, Ni-Cr-Co, laterite, etc.
12. Miscellaneous: any other research related to dykes

Out of 175 abstracts submitted for the conference, 168 were included in the Abstract Volume. 52 participants were from abroad, covering 15 countries, 86 participants were from different parts of India and 128 local participants attended the conference (see group photo). In addition to main conference, there were four field trips. These were

1. Mafic dyke swarms and synplutonic dykes emplaced within the Dharwar craton, Southern India (29th January – 4th February 2010)

2. Dyke Swarms of the Deccan Volcanic Province (29th January – 4th February 2010)
3. Wajrakarur Kimberlite Field, Eastern Dharwar Craton, Southern India (7th – 10th February 2010)
4. Mafic Intrusive Rocks from the Western Himalaya (7th – 12th February 2010)



Group photograph of IDC-6 participants

Continuing the tradition of a volume associated with the IDC, we herein offer the IDC6 proceedings volume “Dyke Swarms as Keys for Geodynamic Interpretation”. A total 44 papers were submitted for the IDC-6 volume and after peer review 30 were accepted. All accepted manuscripts were submitted to Springer-Verlag at the end of August 2010. The manuscripts are divided into two parts i.e. “Dykes in Gondwana” and “Dykes in Laurasia” and are arranged in alphabetical order, country-wise.

Dykes in Gondwana

Twenty-five manuscripts fall in this group. **Sushchevskaya and Belyatsky** discuss geochemical and petrological characteristics of Mesozoic dykes from Schirmacher Oasis (East Antarctica) and suggest that plume-related magmatism

within Antarctica shows the distribution of the Karoo-Maud plume, which is associated with splitting of the Gondwana continent and formation of the Indian Ocean. The time and spatial position of the dykes indicate eastward spreading of the plume material from Dronning Maud Land to the Schirmacher Oasis over at least 10 Ma. **Oliveira** studied the Late Archaean Uauá mafic dyke swarm of the São Francisco craton, Brazil. His studies are based on geological mapping and field relations which recognizes two dyke swarms in the Uauá block. Dyke branching suggests magma flow towards NE and this information is used to discuss potential centres of magma propagation in the ancient São Francisco-Congo craton.

There are five papers on the dykes of Dharwar craton, India. The Proterozoic mafic dyke swarms exposed in the Dharwar craton (Southern India) are of special interest because the craton has been a principal constituent of several ancient supercontinents (e.g. Rogers, 1996; Heaman, 2008; Srivastava et al., 2008). A number of reliable age determinations have been reported (e.g. Halls et al., 2007; French et al., 2008; French and Heaman, 2010). An integrated study (paleomagnetic, geochronological and geochemical) of Proterozoic dykes from Dharwar craton, Southern India by **Piispa et al.** supports the presence of at least two different E-W trending dyke swarms (~2370 and ~1890 Ma) in the Dharwar craton. These results are also consistent with the possibility that the Bastar and Dharwar cratons were amalgamated before ~2370 Ma. **Goutham et al.** provide integrated data on the Proterozoic mafic dykes located south of the southern margin of the Cuddapah Basin, India in two papers. In the first paper they provide the geochemistry of the mafic dykes and discuss their petrogenesis. They are interpreted as intraplate basalts with some crustal contamination or involvement of subduction modified lithospheric mantle (probably metasomatised). In the second paper they provide palaeomagnetism and Ar/Ar geochronology. The alternate interpretations are provided: Either the dykes record an Early Neoproterozoic continental rifting event or the magmatism and its magnetism are of Palaeo-Mesoproterozoic age and were overprinted during the Eastern Ghats (Grenville age) orogeny. **Mohanty** examined the palaeomagnetic database and Palaeoproterozoic evolution of the Indian and Western Australian cratons to determine the possible movement patterns for the assembly of Columbia (Nuna). He concluded that between 2500 to 1800 Ma the South Indian craton moved from high latitude to an equatorial position. Mafic dykes of ~2400 Ma age from the Western Australia and the South India provide evidence for the juxtaposition of the Yilgarn craton against the east coast of India and support the existence of a supercontinental block “SIWA” (an acronym for South India and Western Australia). Indian dykes of 2100–1800 Ma were possibly related to the breakup of SIWA at ~2000 Ma. **Sesha Sai** presented petrological and mineral chemical data on a picrite sill from the Peddakudala-Velpula area, in the southwestern part of the Proterozoic Cuddapah basin, Andhra Pradesh, India. This picrite body contains nearly 38% olivine (forestrite) by mode along with an enstatite-phlogophite-plagioclase-magnetite-chrome-spinel association, depleted HREE signature and the presence of mantle xenoliths of garnet-lherzolite composition.

Gold mineralization reported from the Wayanad, Southern Granulite Terrain, India occurs closely associated with probable mantle-derived quartz-carbonate

dykes. **Pruseth** used field criteria, geochemistry of pyrite-hosted fluids and Rb-Sr geochronology of the quartz-carbonate dykes to constrain the source(s) for these auriferous veins.

The next 11 manuscripts cover different aspects of mafic dykes exposed in different cratons of Indian shield. **Lala et al.** presents rock and mineral geochemistry (including isotopes) and paleomagnetic data on the mafic dykes of the Rewa Basin, central India. It is suggested that these dykes are late stage intrusions of Deccan magma along the Narmada lineament and were possibly emplaced along intrabasin faults within the Rewa and other Gondwana basins of eastern India. The tectonic significance and age of doleritic sill near Bandhalimal in the Singhora protobasin of Chhattisgarh Basin, Central India is the subject of **Sinha et al.**'s manuscript. Their observations confirm the existence of igneous/hydrothermal activity in the Chhattisgarh Basin which is consistent with the Rb/Sr age of sill. A concomitant thermal event in the basin at ~ 1100 Ma with related hydrothermal activity is thus proved by this communication. **Mishra et al.** discussed the genesis of the mafic-ultramafic intrusives and extrusives in relation to the basement gneiss of the Central Indian Tectonic Zone and suggested that the basement gneisses has been dissected by numerous mafic dykes, Padhar mafic-ultramafic complex and pillow lavas of Betul supra-crustal belt. They show depleted mantle model ages for the mafic volcanics of between 1951 and 2320 Ma and that for a pyroxenite from the PMUM of 2770 Ma. Based on the available age data they suggest that the basement gneiss and the PMUM rocks appear to have acted together as basement for the younger mafic magmatic dykes and flows. These basement rocks appear to have influenced the evolution of the younger volcanics and dykes through limited contamination.

Different generations of Precambrian mafic dyke swarms are well documented in different parts of the Archaean Bastar craton (Srivastava and Gautam, 2009). In the present communication **Gautam and Srivastava** present petrological and geochemical characteristics of the early Precambrian mafic dyke swarm from central part of Bastar craton. The authors conclude that there is a co-genetic relationship between these dyke samples and probably crystallized from a melt originated by $\sim 25\%$ melting of a depleted mantle source followed by 30–40% fractional crystallization. **Chakraborty et al.** studied mafic dykes that intrude the tremolite-zone siliceous dolomites of Palaeoproterozoic Mahakoshal Group of rocks of Central India which are exposed near Jabalpur, Madhya Pradesh, India. Fluid-rock interactions (in a partially open system) triggered substantial mass and fluid transfer across the contact between mafic dykes and the enclosing dolomitic marble. This mineralogical transformation of the mafic dykes changed the physical properties and allowed strain concentration preferentially along the dyke margins. The next paper by **Bose et al.** also deals with metamorphosed mafic dykes, in this case, exposed around Chilka Lake granulites, in the Eastern Ghats Belt, India. These mafic bodies were metamorphosed and deformed by tectonothermal events at ca. 800–500 Ma. **Ray et al.** have explored the petrological controls on rheological inversion of a suite of deformed mafic dykes from parts of the Chhotanagpur Granite Gneiss Complex of eastern India; they propose a viable mechanism for the development of fish-head boudins. Formation of the dyke swarms in this area is correlated with the ca. 1.5 Ga

extension of their gneissic basement. **Vallinayagam** studied acid dyke rocks from the Malani Igneous Suite (MIS), northern Peninsular India. Petrological and geochemical studies of MIS dyke rocks indicate that they contain rare metals, rare earths and radioactive mineral resources.

Hari and Swarnkar present the petrogenesis of basaltic and doleritic dykes from Kawant in the Chhotaudepur province of Deccan Traps. The results of mass balance calculations for these Deccan units suggest a generalized differentiation scheme from picrite to the most evolved rock that involved removal of olivine, pyroxene and Fe-Ti oxides in the proportion 44:50:6 with ~ 64% of the magma remaining. **Randive** studied xenoliths encountered in the lamprophyre and picrobasalt dykes of Bakhatgarh-Phulmal area, Madhya Pradesh, India. The petrographic and geochemical characteristics of these xenoliths indicate that these are crustal in origin were incorporated into the magma by disaggregation of the country rocks. These xenoliths represent the quartzo-feldspathic residues left in the host magma after to variable degrees of partial melting of basement rocks. **Ghose and Chatterjee** used textural evidence to demonstrate felsic melt emplacement at a microscopic scale in quenched host basalt. The inter-relationship between basalt, plagiogranite and late-granitoids as well as source of sulphide mineralisation were evaluated on the basis of petrography, field relationships, and limited geochemical data. This study indicates that the origin of the late-granitoid intrusives in basalt may be related to hydrothermal metamorphism and partial melting of basalt in the contact aureole of a magma chamber beneath an oceanic spreading center.

Torkian describe magma mingling processes in the Parishan pluton in Qorveh area, southeastern Sanandaj, Iran. He suggested that the mafic enclaves could have been formed by magma mingling process within the host granitoid magma. **Cucciniello et al.** use geochemical data to model the evolution of Cretaceous mafic and silicic dykes and spatially associated lavas in central-eastern coastal Madagascar. They suggest that magmatic evolution of the mafic dykes is dominated by fractional crystallization of plagioclase and clinopyroxene with minor olivine. The Vatomandry silicic rocks are the result of prolonged fractional crystallization from basalt parental magmas coupled with small amounts of crustal contamination. They also report a ^{40}Ar – ^{39}Ar date for rhyolite from the Sakanila massif, southwest of Vatomandr to evaluate the age relationship between basalt and rhyolite in this silicic massif of the east coast.

Mafic dyke swarms are major components of the South Atlantic Large Igneous Province, which originated during the Cretaceous break up of western Gondwana. **Wiegand et al.** present magnetic fabric studies on these mafic dykes at a volcanic rifted margin in the Henties Bay – Outjo Dyke Swarm, NW Namibia. The dykes were emplaced in the NE-SW trending, Neoproterozoic Damara mobile belt. Their results point to magma ascent both far inland and close to the coast. Subhorizontal magma flow directions can be observed in each area. Since there is no lateral continuity in dyke trends because of segmentation, strictly horizontal transport over long distances is not possible. They presume a complex magma flow model, with multiple conduits of magma ascent for the Henties Bay-Outjo dyke swarm. **Python et al.** studied diopsidites and rodingites (which are two specific kinds of altered mafic

dykes) that outcrop in the mantle section of the Oman ophiolite. Both result from alteration in the Ca-rich environment of the mantle or pre-existing gabbroic dykes. **Khan et al.** presented petrogenetic studies on mafic dykes of the Kohistan paleo-island arc-back-arc system, from the Himalayas of North Pakistan. Mafic dykes of the Jaglot Group show enriched MORB-type affinity whereas mafic dykes of the Chilas Complex and the tholeiitic dykes of the Kohistan Batholith give island arc type signatures. The authors suggest that all mafic dykes of the area are derived by the partial melting of depleted, heterogeneous mantle and enriched mantle sources during island arc, continental margin and back-arc tectonic settings. The last paper in this section is on the Monastery Kimberlite, South Africa. **Noyes et al.** investigated for the first time the feasibility of U-Pb ilmenite geochronology as a new tool for determining the age of kimberlite emplacement and formation of kimberlite indicator minerals. The U-Pb results for nine ilmenite fractions prepared from six megacrysts yield a date of 95.0 ± 14.0 Ma, which is less precise but is in good agreement with the 90.1 ± 0.7 Ma composite age determined by other radiometric techniques for the Monastery kimberlite. This study has also demonstrated that the large variations in ilmenite $^{238}\text{U}/^{204}\text{Pb}$ ratios are primary and indicates the feasibility of dating a single ilmenite megacryst. They also suggest that this could have importance for evaluating the provenance of ilmenite from indicator mineral suites during diamond exploration.

Dykes in Laurasia

There are five papers included in this section. **Hamilton and Pearson** provided a precise U-Pb age determination of 297.4 ± 0.4 (2σ) Ma for baddeleyite for the Great Whin Dolerite Complex (GWDC), northeastern England. This new age places the most precise minimum constraint on the absolute age of the Permian-Carboniferous stratigraphic boundary in the UK and provides a maximum age of mineralization in the North Pennine orefield. The precise age determination of this large intrusive complex also permits improved understanding of the timing of structural evolution in the Northumberland basin. The reversed paleomagnetic polarity of the GWDC is in accord with intrusion during the Kiaman reversed superchron and provides firm geochronological support for establishment of this long-lived reversed interval before 297 Ma. **Halls et al.** presented data on the Melville Bugt dyke swarm of Greenland. They obtained paleomagnetic and geochemical data and U-Pb age for this NNW-trending dyke swarm. This study suggests that at 1.6 Ga Greenland lay in such a position to allow the Melville Bugt dyke swarm to trend towards the 1.5–1.6 Ga Fennoscandian rapakivi province, raising the conjecture that the dyke swarm was fed laterally from this magmatic centre. Satellite imagery from southeast Greenland shows several NNW-trending dykes that may represent a southerly continuation of the Melville Bugt swarm, necessary if the dykes are to have a source in Fennoscandia. **Dokukina and Konilov** discuss mafic melt emplacement during the shock deformation in the subvolcanic environment. They have taken Tastau volcanoplutonic ring complex, Eastern Kazakhstan as an example. On the basis

of their study they propose the a synkinematic model of mafic melt fragmentation and mixing between magma and deforming rock at the hypabyssal levels in the crust (i.e. at about 3 km deep). The next two papers discuss chemical zonation in thin dykes. In the first paper **Chistyakova and Latypov** studied a 16 cm thick, fine-grained, dacitic dyke from Southern Urals that reveals a remarkable internal zonation with a systematic inward increase in normative An ($100\text{An}/(\text{An}+\text{Ab})$), normative Opx, and whole-rock MgO and FeO, and a decrease in normative Pl content, whole-rock SiO_2 , Na_2O , Ba and Sr. All these compositional trends indicate that the dyke becomes more primitive in composition inwards from its margin, the opposite to normal in situ fractionation. This suggests that, despite being fine-grained, the dacitic dyke should be interpreted as a cumulate that provides only indirect information on the parental magma composition. In the other paper they (**Latypov and Chistyakova**) present primary and secondary chemical zonation in the Vochelambina dolerite dyke, Kola Peninsula, Russia. This 140 cm thick dolerite dyke has an unexpected internal zonation that combines the features of both reverse and normal differentiation trends. These trends likely reflect increasing alteration caused by the concentration of post-magmatic fluids in the centre of the dyke (secondary zonation).

Future Perspectives

Richard Ernst in his Foreword rightly mention that we are in a golden era of mafic dyke swarm studies and that there is a need to focus on understanding their regional distributions, and relationships to other coeval magmatism, and associated ore-deposits. Most important part of future work would be robust U-Pb geochronology and paleomagnetic studies which certainly help to understand paleocontinental reconstructions, particularly during Precambrian.

During the concluding session of IDC-6 it was also recommended that, in the future, dykes should be studied in the context of global or regional geodynamics and they can be especially useful in deciphering paleo-plumes and related LIPs and as a tool for deciphering supercontinent reconstructions. M. Ramakrishnan emphasized the need to obtain expanded coverage of low altitude (<500 feet) aeromagnetic maps and the need for developing baddeleyite dating techniques through collaborative efforts. Henry Halls suggested, in the context of future Indian research on dykes, that a concerted program of study be carried out on the Godavari rift that separates the Dharwar and Bastar cratons. It was observed that this rift must be of major importance since it separates two Archean cratons with completely different ages and trends of dyke swarms.

The LIP record for a crustal block can be summarized as a barcode and the LIP barcodes of different blocks can be compared to determine which blocks have matching barcodes and were therefore probably nearest neighbors during the interval of matching (Bleeker and Ernst, 2006; Ernst et al., 2008). We need robust U-Pb geochronology of major dyke swarms to achieve this goal. In the context of Indian shield, very limited precise ages for mafic dykes are available (e.g. Halls et al.,

2007; French et al., 2008; French and Heaman, 2010). As high-precision U-Pb geochronology is increasingly applied to the multitude of poorly dated swarms of dolerite dykes and sills of India, it will be expected that barcode comparisons between the Indian Shield and other crustal blocks will become increasingly more robust for testing paleocontinental reconstructions.

References

- Baer G, Heimann A (1995) *Physics and Chemistry of Dykes*. A.A. Balkema, Rotterdam
- Bleeker W, Ernst RE (2006) Short-lived mantle generated magmatic events and their dyke swarms: The key unlocking earth's paleogeographic record back to 2.6 Ga. In: Hanski E, Mertanen S, Rämö T, Vuollo J (eds) *Dyke Swarms -Time Markers of Crustal Evolution*, Taylor & Francis Group, London: 3–26
- Bryan SE, Ernst RE (2008) Revised definition of large igneous provinces (LIPs). *Earth Sci Rev* 86: 175–202
- Coffin MF, Eldholm O (2005) Large igneous provinces. In: Selley RC, Cocks R, Plimer IR (eds) *Encyclopedia of Geology*, Elsevier, Oxford: 315–323
- Ernst RE, Bleeker W (2010) Large igneous provinces (LIPs), giant dyke swarms, and mantle plumes: Significance for breakup events within Canada from 2.5 Ga to the present. *Can J Earth Sci* 47: 695–739
- Ernst RE, Srivastava RK (2008) India's place in the proterozoic world: constraints from the large igneous provinces (LIP) record. In: Srivastava RK, Sivaji C, Chalapathi Rao NV (eds) *Indian Dykes: Geochemistry, Geophysics, and Geochronology*, Narosa Publ House Pvt. Ltd, New Delhi, India: 41–56
- Ernst RE, Buchan KL, Campbell IH (2005) Frontiers in large igneous province research. *Lithos*, 79: 271–297
- Ernst RE, Wingate MTD, Buchan KL, Li ZX (2008) Global record of 1600–700 Ma large igneous provinces (LIPs): Implications for the reconstruction of the proposed Nuna (Columbia) and Rodinia supercontinents *Precamb Res* 160: 159–178
- Ernst RE, Srivastava RK, Bleeker W, Hamilton M (2010) Precambrian large igneous provinces (LIPs) and their dyke swarms: New insights from high-precision geochronology integrated with paleomagnetism and geochemistry. *Precamb Res* 183: vii–xi doi:10.1016/j.precamres.2010.09.001
- French JE, Heaman LM (2010) Precise U–Pb dating of Paleoproterozoic mafic dyke swarms of the Dharwar craton, India: Implications for the existence of the Neoproterozoic supercraton Sclavia. *Precamb Res* 183: 416–441 doi:10.1016/j.precamres.2010.05.003
- French JE, Heaman LM, Chacko T, Srivastava RK (2008) 1891–1883 Ma Southern Bastar–Cuddapah mafic igneous events, India: a newly recognised large igneous province. *Precamb Res* 160: 308–322
- Halls HC, Fahrig WF (1987) Mafic dyke swarms. *Geol Assoc Canada Spl Paper* 34, 503p
- Halls HC, Kumar A, Srinivasan R, Hamilton MA (2007) Paleomagnetism and U-Pb geochronology of eastern trending dykes in the Dharwar craton, India: Feldspar clouding, radiating dyke swarms and the position of India at 2.37 Ga. *Precamb Res* 155: 47–68
- Hanski E, Mertanen S, Ramo T, Vuollo J (2006) *Dyke swarms: Time markers of crustal evolution*. Taylor & Francis, London
- Heaman LM (2008) Precambrian large igneous provinces: an overview of geochronology, origin and impact on earth evolution. *J Geol Soc India* 72: 15–34
- Parker AJ, Rickwood PC, Tucker DH (1990) *Mafic dykes and emplacement mechanism*. A.A. Balkema, Rotterdam
- Rogers JJW (1996) A history of continents in the past three billion years. *J Geol* 104: 91–107

- Srivastava RK, Gautam GC (2009) Precambrian mafic magmatism in the Bastar craton, central India. *J Geol Soc India* 73: 52–72
- Srivastava RK, Sivaji C, Chalapathi Rao NV (2008) Indian dykes: Geochemistry, geophysics and geochronology. Narosa Publ House Pvt. Ltd, New Delhi, India
- Srivastava RK, Ernst RE, Bleeker W, Hamilton M (eds) (2010) Precambrian Large Igneous Provinces (LIPs) and their dyke swarms: new insights from high-precision geochronology integrated with paleomagnetism and geochemistry. *Precamb Res Spl Issue* 183/3, Elsevier, Amsterdam

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