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News & Views

Dyke swarms: keys to paleogeographic reconstructions

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The Seventh International Dyke Conference (IDC7) was hosted by the State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, in Beijing on August 18–20, 2016. Approximately 140 participants from 19 countries of all inhabited continents attended the meeting. 133 selected abstracts published in *Acta Geologica Sinica* (Vol 90, Supp 1) are representative of the range of recent advances in the field. The IDCs are the highest-ranked international conferences on dyke research (including geological, geophysical and geochemical aspects). IDC7 continued the every-5-year tradition started in Mississauga (near Toronto) Canada in 1985, that was inspired by the classic paper of Halls (1982) [1]. Subsequent IDCs were held in Australia (1990), Israel (1995), South Africa (2001), Finland (2005), and India (2010). As a part of the conference, the key founder of the IDC series, Prof. Henry C HALLS, was awarded the "2016 IDC Medal", and four young scientists were issued as Best Oral Awards (A GUMSLEY and N-N NI) or Best Poster Awards (X-P WANG; MHBM de HOLLANDA). Also, Morocco was awarded the opportunity to host the IDC8 in 2020.

The overall theme of the IDC7 was "Dyke swarms: Keys to paleogeographic reconstruction", and included 10 subjects: (1) Regional maps/reviews of dyke swarms and related units (Conveners: R Srivastava and Y-S Wan; Keynote addresses: R Ernst and N Youbi); (2) The role of giant dyke swarms in reconstruction of supercontinents/paleoconti-

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nents: progress, problems and potential (Conveners: R Ernst and S-H Zhang; Keynote addresses: H Halls, MG Zhai, GC Zhao, D Evans and S Pisarevsky); (3) Mapping of dykes using remote sensing techniques such as aeromagnetic data, LANDSAT, drones, radar, etc. (Conveners: S Denyszyn and JH Guo; Keynote address: AR Cruden); (4) Geochronology of dyke swarms (Conveners: X-H Li and M TD Wingate; Keynote address: M Hamilton); (5) Petrology, geochemistry and petrogenesis of dykes (Conveners: Y-G Xu and P Peng; Keynote address: Y-G Xu); (6) Emplacement mechanisms of dykes (Conveners: G-T Hou, EP de Oliveira and W Teixeira; Keynote addresses: E Rivalta and A Bunger); (7) Dyke swarms on planetary bodies (Conveners: D Mege and U Söderlund; Keynote address: Amanda Nahm); (8) Links to mineralization and resources (Conveners: G-C Zhao and R Ernst; Keynote address: S Jowitt); (9) Miscellaneous: syn-plutonic mafic dykes and alkaline dykes (Conveners: CY Wang and S-H Zhang, Keynote address: CY Wang); and (10) Oceanic dyke complexes, and links to sea floor spreading, oceanic plateaus, or juvenile arcs? (Conveners: T Kusky and J Karson; Keynote address: T Kusky).

These subjects reviewed research areas that achieved significant development over the past decade and as well as other areas that are just beginning to generate new insights. In the past decade, the major burgeoning fields have been (1) regional mapping of dyke swarms and related units; and (2) paleogeographic reconstruction of supercontinents/paleocontinents using giant dyke swarms. The four fields that are entering an expansion phase in the following decade will be research focuses in the next few years include (1) emplacement mechanisms of dyke/sill swarms; (2) petrogenesis, tectonic environments and geological implications of dyke swarms; (3) planetary dyke swarms and related units; and (4) links between dykes (and related units) and economic mineralization and resources.

1 Thriving fields in research related to dyke swarms

1. *Regional mapping of dyke swarms and related units* Through regional- or continental-scale mapping, numerous new dyke swarms, some of huge scale, and their related igneous units have been recognized. These achievements have been based on (1) the dramatic improvement of age dating methods such as Secondary Ion Mass Spectrometer (SIMS) or Thermal Ion Mass Spectrometer (TIMS) using accessory minerals such as zircon and particularly baddeleyite (e.g., [2–4]); (2) increased remote mapping of dykes using aeromagnetic data, LANDSAT, Google Earth, radar, drones etc.; and (3) through the use of dyke swarms for Precambrian paleocontinent/supercontinent reconstructions (see below). New dyke swarm maps were presented for a number of regions including northern Canada, India, North China, West Africa, Russia, Egypt, Western Australia, Amazonia, etc. (e.g., [5]).
2. *Paleogeographic reconstruction of supercontinents/continents using giant dyke swarms* Dyke swarms are key tools for continental reconstructions in the following ways: as key paleomagnetic targets (e.g., [6–8]), for their potential to be restored back into a primary giant radiating geometry, and through matching precisely-dated regional dyke swarms and their associated Large Igneous Provinces (LIPs) ("LIP barcode") on formerly adjacent crustal blocks [9, 10]. The project, The Reconstruction of Supercontinents Back to 2.7 Ga Using the Large Igneous Province (LIP) Record, with Implications for Mineral Deposit Targeting, Hydrocarbon Resource Exploration, and Earth System Evolution (www.supercontinent.org; 2010–2015) co-led by R Ernst and W Bleeker, has contributed appreciably to these efforts over the last several years.

2 Emerging fields in research related to dyke swarms

1. *Emplacement mechanisms of dyke/sill swarms* This is a traditional field which focuses on the emplacement mechanisms of dykes, and determining the influence of the regional/local stress field, country rock fabric, and other factors. Recent experimental and numerical modeling on the emplacement of dykes has provided new insights (e.g., [11]). However, progress is still required to explain the formation of radiating and circumferential swarms, their link with feeder chambers, the influence of tectonic environment, and their connection with sills (e.g., [12, 13]).
2. *Petrogenesis, tectonic environments and geological implications of dyke swarms* Other aspects of mafic dyke swarm research include their petrology, geochemistry, magnetic fabric, tectonic environment and geological implications. There is recent research progress on the macro- to micro-scale of petrogenetic processes, mantle source characterization, differentiation mechanisms, interpretation of tectonic settings, and geological implications of dyke swarms, all of which have benefited from the extensive use of modern geochemical (including tracer isotopic studies) and petrological studies (e.g., [14]). However, there are still many outstanding questions, including: what are the controlling factors of magmatic differentiation processes, particularly in the feeder systems (dykes/sills) of LIPs? what are the genetic relationships between coeval mafic and felsic dykes, as well as

between mafic LIPs and felsic (silicic) LIPs (SLIPs)? [10] can specific tectonic environment be identified more reliably based on the chemistries and geometries of dyke swarms? and what are the root causes of "continental lithosphere" or "arc" signatures in many dyke swarms? The characteristics and geological implications of dyke swarms and some specific types (synplutonic mafic dykes, sheeted dyke complexes in ophiolites, alkaline dykes, etc.) need to be considered more fully. Specifically, future studies might place greater scrutiny on dyke swarms in on-land ophiolites and the modern oceanic lithosphere as indicators of extension direction and relative rates of extension/magmatism, leading to a better understanding of sea-floor spreading processes through time.

3. *Planetary dyke swarms and related units* Dyke swarms have been identified on Venus and Mars, and even possibly on the Moon (e.g., [10]). However, there are many questions that remain to be addressed, such as the geometry of the planetary dyke swarms, their crustal context and implications in light of the apparent lack of plate tectonics, their ages, their relationship with other magmatic units, and the identification of non-mafic swarms.
4. *Links between dykes (and related units) and economic mineralization and resources* This new research area concentrates on mineralization (principally, but not limited to, Ni-Cu-PGEs) and other resources (including hydrocarbons and aquifers) which are related to dykes and their LIPs (e.g., [15]). Spatial, geochemical and temporal relationships within LIPs and their dyke swarms (and their associated LIPs) can be used to assess metallogenic prospectivity and their influence on oil/gas resources. An important goal of continued research is to develop strategies for using dykes and their LIPs as an exploration targeting tool [15].

Conflict of interest The authors declare that they have no conflict of interest.

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