Notes

INTERNATIONAL CONFERENCE ON MAFIC DYKE SWARMS

(Toronto, Canada, June 3-7, 1985)

This is the first ever conference on mafic dyke swarms, which are the surface manifestations of activity in the mantle. The Conference took the form of a four-day scientific meet followed by five days field excursions. It was organised by the Geology Department, University of Toronto and sponsored by the Geological Association of Canada, Canadian Geophysical Union, Geological Survey of Canada, IUGS Commission on Tectonics and the International Lithosphere Programme.

The Symposium addressed itself in twelve sessions which included: aspects of dykes in continental lithosphere; global over-view of shield areas; dykes in oceanic lithosphere; mechanics of dyke injection; Mesozoic and Tertiary dykes of Atlantic margin; geochemistry and petrogenesis; geochronology; geomagnetism, and structure and tectonics. The broad objective of the meeting was to bring together an international body of scientists with diverse interests in mafic dyke swarms to discuss problems concerning their genesis and their application to studies of lithosphere evolution. Much information on mafic dykes is no doubt available in literature but this has never been put together to focus much attention. This Conference, paved the way for a compilation of information on the mafic dyke swarms all over the globe and examined them from different tectonic and geological settings. (Maps showing dyke swarms from different continents including India were displayed.)

Reviews on dyke swarms included Arabo-Nubian shield (M. Eyal), Australia (A.J. Parker, D.H. Tacker), Brazil (R.A. Fuck), Canada (J.G. Green), Fennoscandia (R. Gorbatschev), Guiana (A.N. Sial; A.K. Gibbs), Greenland (T.F.N. Neilsen), Eastern Antarctica (J.W. Sheraton and K.D. Collerson), North China (X. Qian), India (N.G.K. Murthy), South Africa (D.R. Hunter), Tanzania (H.C. Halls), Ukrainian Shield, USSR (N.P. Mikhaylova) and Zimbabwe (J.F. Wilson). Discussion on oceanic lithosphere was centered on Iceland (H. Sigurdson; Atlantic island dykes (Stillman, C.J.) and a lone paper on ophiolitic dykes from Troodos (W.R.A. Baragar).

Some of the examples discussed at the Conference were from Tertiary dykes of Eastern Greenland (T.F.N. Neilsen), SE New Brunswick late Precambrian (W.H. Blackburn), Boston platform of Eastern Massachusetts (M.E. Ross), Atlantic Canada (J.D. Greenough) and late Mesozoic dykes of SW India (T. Radhakrishna). These dykes are linked with the rifting and formation of major ocean basins. W.F. Fahrig presented an interesting paper explaining the development and preservation of dyke swarms in three major tectonic stages: (i) dyke intrusion and rifting, (ii) spreading and (iii) collision.

K.C. Condie and John Tarney, among others, suggested mantle source heterogeneities to explain variations in chemistry of the dyke swarms. Condie pointed out that Archaean dykes occupied an intermediate position between Proterozoic dykes and depleted Archaean basalts (They exhibited significant negative Ta and Ti anomalies.) John Tarney described the Scourie dykes (Proterozoic) cutting high grade granulite and amphibolite facies gneisses of Lewisian complex. He compared the compositional characteristics of host rocks and the dykes and suggested the compositions to have been inherited from a heterogeneous sub-crustal source rather than by crustal contamination. Paul Mohr's debate, on the phenomenon that effects changes in mafic magma chemistry and the physical factors that influence the nature and degree of contamination, was of interest. I.H. Cambell proposed that composition of the parent magma for both continental and oceanic tholeiites is essentially the same but the magmas assimilated a part of the lower continental crust *en route* and thereby continental tholeiites were enriched in SiO_2, K_2O and LREE and were more evolved. He suggested that most of the assimilation occurred in dykes which fed magma chambers. J.F. Olmsted demonstrated the correlation between dyke compositions and age, structural province into which dykes were emplaced, dyke thickness and swarm length through statistical methods (1068 samples from 49 swarms were considered.) Enrichment in incompatible elements (Ti, Zr, P, Sr, V) and corresponding depletion in Fe^{+2}, Mg, Si with decreasing age was reported. Coarse-grained dyke centers were enriched in incompatible elements (U, K, Ba, Sr, Zr, Na, Yb, Ti, Si), while refractory elements (Mn, Co, V, Cr, Fe, Cu, Ni, Ca, Mg, Zn) were generally concentrated in chilled margins. I.L. Gibbson, S.A. Goldberg, J.G. Hammond, and P.J. Sylvester described the geochemical and petrological aspects of the Mackenzie and Sudbury dyke swarms (Canada), Bakersville dyke swarms (Appalachains), Proterozoic dyke swarms of Death Valley (California, USA) and dyke swarms of St. Francois mountains of Missourie (USA).

Geochronological data on mafic dyke swarms were very limited. G.A. Hanes reviewed the progress in K/Ar and Rb/Sr techniques of Precambrian mafic dyke geochronology and the advancement of Ar^{40}/Ar^{39} method. He highlighted the advantage of Ar^{40}/Ar^{39} step heating technique over the K/Ar and Rb/Sr dating. A.K. Baksi discussed the usage of Ar^{36} to assess the quality and reliability of the K/Ar ages published in literature. He recommended Ar^{36} analysis being carried out simultaneously with K-Ar dating. Using this approach, he felt that the Rajmahal and Deccan traps (India) and their associated feeder dykes (?) were probably limited to a period of 5-10 Ma each, around 120 and 65 Ma ago respectively.

While discussing the geomagnetic aspects of mafic dyke swarms, M.E. Evans showed the effects of the ambient magnetic field bias on the magnetic remanence of the dykes. Based on the acute angle between dykes and their respective remanence vectors and the updated compilation of the total data up to 1985, he concluded against any large demagnetisation bias. K.L. Buchan demonstrated remanent magnetisation as a measure to calculate the initial magma temperature and ambient temperatures of the host rock at the time of intrusion and also the depth of burial of the present surface. G. Byland, presented palaeomagnetic results from Fennoscandia, on dykes of four different magmatic events between 1250 and 250 Ma and constructed a preliminary APWP for Fennoscandia. L.J. Pesonen, presented the palaeomagnetic results of Sub Jotnian diabase dyke swarm of Aland Archepelago (Finland). Both normal and reverse polarity groups, with contrasting petrological, geochemical, geochronological and rock magnetic properties were described. D.L. Jones' presentation of palaeomagnetic results on mafic dyke swarms of Zimbabwe (Great dyke, Umvimeela and East Dykes, Mashonaland dolerite, Bubi swarm, Crystal Spring swarm, Umkondo sills and on dykes of Karoo age) was of importance because of their relation to Indian and other Gondwanian counterparts and in understanding their pre-rift configuration. Detailed Precambrian palaeomagnetic results of Indian and other fragmented Gondwana land are still awaited.

D.D. Pollard and P. Delany described fracture mechanics and heat transfer theory in relation to mechanics of mafic dyke intrusion. Pollard wanted geologists to use fracture mechanics theory in the study of dyke swarms because of the unique opportunity geologists have for collecting field data which contributes to the understanding of the mechanics of large fractures. Delaney's approach was mainly based on thermal conduction between wall rock and intruded dyke magma. D.L. Turcottee brought out correlation between magma viscosity, length and width of dykes, and the time of their emplacement.

In the section on structure and tectonics, K. Coe pointed out that dykes alone cannot be used as time markers (in Greenland). Y. W. Isachsen demonstrated the use of K-Ar ages to assess changes in the regional palaeostress directions through time. He reported preliminary results obtained at Adirondock dome, New York. F. Podmore presented geological and geophysical (gravity and palaeomagnetic) results of the Great dyke (Zimbabwe). He indicated existence of a feeder dyke (1 km wide) over most of the length of the Great dyke. R. E. Ernst described geochemical and petrological characteristics of Abitibi dyke (Superior province) and suggested it to be related to oblique Grenville-Superior collision. C. Ferand described the dykes of south and southeastern France, Syria and Yeman and related them to the formation of major ocean basins of Atlantic, Tethys and Red Sea. Henry C. Halls discussed the dyke swarms (Ontario State, Canada) with respect to their width, dips, dyke spacing and dyke bifurcation. His main observation was that the per cent crustal dilation by dyke injection was greater at shallower crustal levels based on the higher dyke frequency and widths in the host rock terrains characterised by lower grades of burial metamorphism.

From India, N. G. K. Murthy (Geological Survey of India), Y. G. K. Murthy (National Geophysical Research Institute) and T. Radhakrishna (Centre for Earth Science Studies) participated in the Conference. N. G. K. Murthy exhibited the dyke swarm map of India and described distinctive dyke swarms of several generations varying in age from Archaean to Tertiary. He identified: (1) dolerites of Dharwar craton (E-W), (2) mafic sills and local dolerite dykes within the Cuddapah basin, (3) dykes bordering the Cuddapah basin on the western, SE and SW borders (ENE-WSW), (4) newer dolerite dykes of Singhbhum craton (NNE-SSW; NE-SW), (5) mafic dykes traversing Bundlekhand granite (NW-SE), (6) mafic dykes in Aravalli Super Group (E-W and NE-SW), (7) dolerites, mica peridotites and lamprophyres in Gondwana coal fields of Damodar Valley, (8) dykes traversing flood basalts (NNE-SSW, east of Bombay; ENE-WSW in Narmada, Tapti valley, ENE to NE-SW and NW-SE in Saurashtra and (9) mafic dykes along the west coast of India.

Y. G. K. Murthy presented the geological set up of the dykes around Cuddapah basin along with an aeromagnetic map of the region. Preliminary major element geochemistry and K-Ar age data (by Prof. S. Bhattacharji, co-author) was also presented. K-Ar ages of certain swarms of predominantly E-W trend, near the southern margin were shown to cluster round 1115 ± 20 Ma, although several dykes with different magnetic orientation and polarities showed ages of 1446 ± 60 Ma, Major thick dolerite peridotite dykes trending N-W were the youngest dykes (600-500 Ma) and their age appeared to coincide with the last phase of the Eastern ghat orogeny (500 Ma event of the Indian Shield). The dyke swarms were predominantly dolerite gabbro with minor occurrences of peridotite, syenite and lamprophyre and showed both subalkalic and alkalic characters. The K-Ar age data ranged from 2.2 to 0.5

b.y. The dyke orientations did not show any correlation with age. In the south-western part of the basin, a gravity high (+60 mgals within a broader low of about −23 mgal) was pointed out indicating the presence of denser material (3 to 3.1 gm/cc) in the form of a lopolith.

T. Radhakrishna described the mafic dykes in Kerala. The significant point made out by him was that the mafic dyke intrusion in Kerala was initiated during Early-Mid Proterozoic period contrary to the prevailing notion that the dykes in Kerala are related to the Late Cretaceous rifting of western continental margin of India. Age data suggested four periods of formation 2.1-2.2, 1.4-1.6, 0.4-0.5 and 0.1-0.15 Ga.

The Conference did not address itself to the relationship between dyke swarms and ore deposits. Nor did it attempt at identifying the feeder dyke swarms for the lower mafic flows of Archaean greenstone belts. These aspects too are important to make studies on Lithospheric evolution complete. The Conference discussed in great detail the diversified aspects relating to dyke swarms and helped in synthesising present knowledge on mafic dyke swarms: The staff of the Geology Department, Erindale Campus (Toronto) deserve our sincere thanks for the excellent arrangements made which allowed for a free and frank discussion.

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ISOTOPIC DATING

Geochemists distinguish between *precision,* the measure of how well an analysis can be repeated, and accuracy, the measure of how close the analysis is to the truth. In the Phanerozoic, fossils provide a dating tool of very high precision but little chronometric accuracy. Since precision is all that is needed for correlation and the construction of a column, a stratigraphic column can be set up by the use of fossils alone: all that radiometric methods add is accuracy. Phanerozoic stratigraphy is defined in sedimentary rocks because they are the rocks which contain the best dating tool. In the Precambrian, the best dating tools are isotopic, thus the stratigraphy must be defined in those rocks in which the tools are most precise. Correlation of sedimentary units over wide areas is typically not possible in the Precambrian. The golden spikes should be placed where precision of the dating tool is best, presumably in fresh, high-level igneous rock or in strata which have had well-understood thermal and alteration histories. Any change in isotopic decay constant would simply change the age but not the precision of the stratigraphy and would not disrupt the order of the column.

(F. C. NISBET. *Geol. Mag.* 1985, p. 85)