The LIP Reader

Newsletter of the Commission on Large-Volume Basaltic Provinces
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior

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This Issue...

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Newsletter Production

Judith Haller and Toni Lee Mitchell

The *Origin of Large Igneous Provinces* symposium at the July IUGG Assembly in Boulder, Colorado, USA is the next major event on the Commission's agenda. Twenty-five papers are scheduled to be presented in oral and poster form during the full-day symposium; other symposia will probably also be of interest to Commission members (see below for details).

In this issue, recent research on volcanism associated with opening of the Red Sea, on the crustal structure of the Kerguelen Plateau, and on global mafic dikes is summarized. A final decision on a publisher for the LIP volume is imminent. As always, we welcome your contributions to *The LIP Reader*, and your recruiting of interested scientists to join the Commission.

Commission News

IUGG XXI General Assembly

Several symposia relevant to large-volume basaltic provinces are scheduled for the 1995 IUGG XXI General Assembly in Boulder, Colorado. First and foremost, *Origin of Large Igneous Provinces* will be convened by M Coffin, N Arndt, and J Ludden on 6 July. On 4 July, *Evolution of Large Volcanic Systems*, convened by J Pallister, K Hon, J Cole, and M Mantovani, is scheduled. Pallister and Hon will also lead a field trip the week before IUGG starts to compare the magmatic, structural, and tectonic evolution of large-volume basaltic and rhyolitic volcanic fields through the Columbia River and Yellowstone areas. Other symposia of interest are (in chronological order): 5 July—*Physical and Chemical Evolution of the Earth*, convened by T Ahrens, P Gillet, W McDonough, and E Ohtani; 7 July—*Seafloor Volcanism*, convened by M Perfit; 10 July—*Origin and Evolution of the Continental Lithosphere*, convened by K Burke, S Taylor, J Dewey, V Cermak, H Kahle, and T Jordan; 11 July—*Geochemical and Geophysical Signatures of Mantle Plumes*, convened by W White, L Fleitout, B Hager, and L Kellogg; 12 July—*Mantle Dynamics and the Geological Record*, convened by M Richards, S Cloetingh, G Davies, and M Gurnis. IUGG promises much in store for students of LIPs!

Volume on Large Igneous Provinces

Both the American Geophysical Union Press and Cambridge University Press have responded very favorably to our book proposal for a Large Igneous Provinces volume, and negotiations are entering their final stages. Both publishers produce reasonably priced books, so the volume should be affordable to a wide variety of readers. Authors (you know who you are!) should still plan to submit their papers for review by September. In addition to the papers already pledged, a chapter on the relation of LIPs to climate change and major extinctions would be desirable, and potential authors are invited to contact John Mahoney.

Steering Committee

An updated list of Steering Committee members and their internet addresses follows:

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Full addresses and contact numbers for the above are available over the internet, on diskette, or as hard copy (see below) from Mike Coffin.

Recent Research Summaries

Oligocene Basalt-Rhyolite Flood Volcanism and Opening of the Red Sea

The primary objective of our work on the Yemen margin was to establish relationships among magmatism, uplift/exhumation, and extension. To accomplish this we undertook a detailed study of (a) the contact between the pre-volcanic sediment and the basal flows of the flood basalt-rhyolite province; (b) the volcanostratigraphy and chronostratigraphy (K-Ar and Ar-Ar) along a west-east traverse perpendicular to the Red Sea margin; and (c) the thermal history of the margin using fission track dating techniques. These data were integrated with studies of the extensional history by Davison and others (*Geol. Soc. Am. Bull.*, 1994).

The contact between pre-volcanic sediment and the basal flows shows no evidence for pre-volcanic extension. However radical changes in the paleoenvironment, from one associated with an ample supply of mature arenites from sources in the west to one dominated by sediment starvation and the widespread development of paleosols, may indicate widespread pre-volcanic surface uplift. Ponding of surface water in topographic lows of this uplifted surface gave rise to fossiliferous lacustrine deposits and also provided traps for early volcaniclastic deposits associated with the onset of flood volcanism. The basal flows yield screened K-Ar dates of 25-31 Ma.

Basal volcanostratigraphy is dominated by a thick sequence of monotonous basalt overlain by an equally thick section of more diverse lithologies. The basal basalt series thickens to the south and west (toward the Red Sea). The upper part of the section comprises basaltic flows, rhyolitic fall deposits, and ignimbritic pyroclastic deposits, rare rhyolitic lava flows, and volcaniclastic sedimentary lenses. Although no significant unconformities exist in the main flood basalt pile, laterally discontinuous lenses of sedimentary material do occur in the succession. At the extreme northeastern edge of the province a large trachytic flow unconformably overlies eroded and gently dipping flood basalts. Geochemical analyses indicate that most volcanic rocks have experienced some degree of crustal contamination and that even highly-magnesian flows contain zoned phenocrysts whose core-rim isotopic variations cover the total range observed in many of the volcanic products. Ar-Ar age data precisely establishes the onset and duration of the preserved volcanic stratigraphy as between 30.4-26.2 Ma. This 5 m.y. window for flood volcanism is

much longer than for the Deccan but may compare with that for the Parana-Etendeka. Assuming constant rates of volcanic eruption, it appears that the basalts were erupted as major flows every 5-50 ka and that a major ignimbritic eruption occurred every 200 ka. Interestingly, the onset of rhyolitic volcanism was accompanied by intercalated basaltic volcanism and was associated with a marked decrease in volcanic production rate, consistent with high-level development of magma chambers.

In the southern Red Sea and Gulf of Aden, fission track (FT) modeling has revealed a rapid phase of crustal exhumation which probably began during the mid- to late Oligocene along the zone of active extension adjacent to the proto-Red Sea margin. Significant crustal cooling began immediately after the subaerial emergence of the rift flanks. Furthermore, while exhumation appears to overlap with a major phase of flood volcanism ca 29±2 Ma, denudation and cooling may have waned during this time, only gaining momentum again during the late Oligocene-Miocene when the resistant volcanic cover was actively extended and rifted. Increasing maturity of drainage patterns on the uplifted landscape probably allowed access to the more interior regions of Yemen by breaching the rift escarpment. Field observations, FT data, and thermal modeling suggest relatively shallow burial of present basement highs and long-standing stability as structurally high subsurface features since the early Mesozoic. Sharp contrasts in FT data from (elevated) basement highs to (topographically lower) extended coastal terrain point to differential movement and exhumation along inherited (Proterozoic?) structural lineaments in the Tertiary.

The timing of rift processes in the southern Red Sea illustrates the complex nature of rift formation and, in particular, the difficulty in precisely timing Cloos's (1939) active sequence of events (uplift-rifting-volcanism) preferred by many workers or the passive sequence, rifting-uplift-volcanism. With these data in hand, we can comment on the timing of events associated with the continent rift to oceanic passive margin transition. Although no unequivocal evidence exists within this area for the timing of surface uplift, surface uplift must have occurred prior to 30 Ma because (a) pre-volcanic (i.e. pre-32 Ma) sediment is characterized by the development of thick paleosol (indicative of sediment starvation on a low relief landscape) occurring at the top of a sequence of mature arenites; (b) exhumation (which would presumably postdate surface uplift) overlaps with, and postdates Oligocene volcanism ($^{40}Ar/^{39}Ar$ dates of 32-26 Ma); and (c) extension is largely post-volcanic in age. If these reasons are valid, the sequence of events is (1) SURFACE UPLIFT: uplift and sediment starvation in the pre-volcanic subaerial environment; (2) MAGMATISM: fissure-fed basaltic volcanism (31 Ma) followed by caldera-fed rhyolitic and ignimbritic volcanism (ca 29 Ma); exhumation in response to surface uplift may have been reduced during this intense period of volcanism, hence the lack of interbedded clastic sediments; (3) EXHUMATION of the rift margins gains momentum again during the late Oligocene-Miocene (ca 26 Ma); (4) EXTENSION in a zone less than 100 km across (proto-Red Sea) (ca 26-20 Ma); and (5) MAGMATISM/EXHUMATION: sporadic post-erosional volcanic activity starting ca 19 Ma through to the recent activity.

Ongoing studies include (a) an assessment of the causal link between unroofed magma chambers (syenite-granite-gabbro) and rhyolitic-ignimbritic eruptives; and (b) an evaluation of the geochemical consequences of wet melting of the Arabian lithosphere using naturally melted wet peridotites from the Ataq diatremes.

contributed by Martin Menzies and members of the Arabian Plate Research Project—Andrew Yelland, Joel Baker and Mohamed Al'Kadasi (Royal Holloway, University of London, Egham, Surrey, England)

Deep Structure of the Kerguelen Plateau (Southern Indian Ocean)

Crustal thicknesses inferred from wide-angle seismic data are ~23 km in the northern (NKP) and southern (SKP) domains of the Cretaceous Kerguelen Plateau. High seismic velocities at the base of the crust (up to 7.4 km/s), however, which typify the deep structure of oceanic plateaus, are observed only beneath the NKP. Velocities in the lower crust of the SKP range from 6.6 km/s to 7.0 km/s. Strong anisotropy is observed in the SKP where multiple reflections from a layered, low-velocity reflective zone located immediately above the Moho trend NW-SE, parallel to the strike of the plateau. Along this trend, the upper mantle velocity is 8.6 km/s, whereas it is only 8.0 km/s in an E-W direction. The results confirm the large-scale heterogeneity of the Kerguelen Plateau. The NKP bears most characteristics of a thickened oceanic crust, whereas the SKP exhibits the seismic structure of a thin continental crust. The strong anisotropy of the reflective lower crust and upper mantle is consistent with ~NW-SE extension.

contributed by Philippe Charvis and Stéphane Operto (ORSTOM-GEMCO, Villefranche-sur-mer, France)

The Global Mafic Dike GIS Database Project

We are currently compiling a database of dike swarms of the world. This database contains digitized distributions of swarms as well as tables of properties (geochemical, geochronological, paleomagnetic, etc.). The purpose of our compilation is to enhance correlation of dikes between regions and continents, to test paleocontinental reconstructions and locate mantle paleo-plumes.

More than 300 swarms have been identified worldwide. Seventy of these have lengths >300 km, with the largest approaching 3000 km. Individual dikes have been traced up to 1000 km. However, mapping of lateral flow in the Mackenzie swarm of the Canadian Shield indicates that individual dikes can reach lengths >2000 km. Both linear and radiating swarm types have been identified. The former are generally associated with rift axes. Several of the latter fan over 40°, reaching a maximum of 180°. Furthermore, more complete radiating patterns of up to 250° are observed when coeval swarms are arranged in their primary radiating pattern in a paleocontinental reconstruction.

Giant dike swarms have important geotectonic applications. 1) The convergence point of fanning swarms is thought to locate mantle paleo-plumes and associated LIPs. 2) Away from their focal region swarms commonly swing into the regional stress direction, providing a tool for determining the orientation of ancient plate boundaries. 3) Distorted dike swarms can be used to generate deformation grids for the host terrane. 4) Reassembly of swarms (fragmented by plate tectonics) into their primary geometry can help constrain paleocontinental reconstructions.

Work on the database is continuing and we welcome input and queries (c/o Richard Ernst—rernst@gsc.emr.ca)

contributed by Richard Ernst[1,2], Ken Buchan[1], and Currie Palmer[2] ([1]Geological Survey of Canada; [2]University of Western Ontario)

Summaries of recent research programs are invited—please send your contribution to Mike Coffin or John Mahoney. For the sake of brevity, references are omitted; please contact the contributors directly for more information

LIPs and the Ocean Drilling Program

Each Northern Hemisphere spring, the four thematic panels of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES)—Lithosphere, Tectonics, Ocean History, and Sedimentary & Geochemical Processes—rank all active ODP proposals. These global rankings, plus logistical considerations, form the basis for the JOIDES Planning Committee's choice of ~12 highly-ranked proposals for inclusion in the annual prospectus. Each Northern Hemisphere fall, the four thematic panels rank the proposals in the prospectus. Finally, in December of each year, the Planning Committee looks at the rankings of the proposals in the prospectus and determines a rational scientific program for the JOIDES Resolution one year in advance, i.e., in December 1995, the program for 1997 will be scheduled.

One large igneous province, the Southeast Greenland volcanic margin, is scheduled to be drilled this year during ODP Leg 163 in September and October. This margin was first drilled by ODP in 1993 during Leg 152, and the exciting results from that leg (see "Recent Research Summary" by Andy Saunders and the ODP Leg 152 Scientific Party in *The LIP Reader* #3) contributed strongly to scheduling another drilling leg there. No large-volume basaltic provinces are on the ODP drilling schedule for 1996, but LIPs fared well in the Lithosphere Panel's Spring 1995 global rankings—the Caribbean flood basalt province ranked #2, the Ontong Java Plateau #3, and the Kerguelen Plateau/Broken Ridge #4—suggesting that the Planning Committee may consider scheduling one or more of these LIPs for drilling in 1997. As described in *The LIP Reader* #4, formal links between ODP and our Commission have been established. Mike Coffin represents our Commission within the ODP advisory structure, as a member of the Lithosphere Panel, and welcomes input from Commission members.

The Ocean Drilling Program is proposal-driven, and anyone may submit a drilling proposal. Guidelines for writing and submitting proposals may be obtained from Rob Kidd or Julie Harris, JOIDES Office, Dept. of Earth Sciences, University of Wales, Cardiff, PO Box 914, Cardiff CF1 3YE, UK. Telephone 44.222.874.541. Facsimile 44.222.874.943. Internet: joides@cardiff.ac.uk. Information on ODP's long-range thematic plans can be obtained from the same address.

Upcoming Meetings

Synopses of recent meetings are welcomed—please send your ~200 word review to Mike Coffin or John Mahoney.

2-14 July: **International Union of Geodesy and Geophysics XXI General Assembly,** Boulder, Colorado, USA. Information: IUGG XXI General Assembly, c/o American Geophysical Union, 2000 Florida Ave., NW, Washington, DC 20009, USA.

16-21 July: **PLUME 2 Conference,** Schloß Ringberg, Tegernsee, Germany. Abstract deadline: 1 June 1995. Information: Kerstin Lehnert, Max-Planck-Institut für Chemie, Postfach 3060, D-55020 Mainz, Germany. Telephone 49.6131.305260. Facsimile 49.6131.371051. Internet: kerstin@geobar.mpch-mainz.mpg.de

19 August-1 September: **Petrology and Metallogeny of Volcanic and Intrusive Rocks of the Midcontinent Rift System,** Duluth, Minnesota, USA. Abstract deadline: 15 May 1995. Information: ICGP 336 Conference, Continuing Education & Extension—UMD, 10 University Drive, 316 DAdB, Duluth, MN 55812-2496. Telephone 1.218.726.6819. Facsimile 1.218.726.6336. Internet: vfrench@d.umn.edu

4-8 September: **Third International Dyke Conference,** Jerusalem, Israel. Abstract/pre-registration deadline: 31 May 1995. Information: Organizing Committee IDC-3 (Dr. A. Heimann), Geological Survey of Israel, 30 Malkhe Yisrael St., Jerusalem 95501, Israel. Facsimile 972.2.380688. Internet: dikeconf@vms.gsi.gov.il

10-14 October: **5th International Conference on Paleoceanography,** Halifax, Nova Scotia, Canada. Abstract deadline: 15 June 1995. Information: Larry Mayer, Ocean Mapping Group, Dept. of Geodesy & Geomatics Engineering, University of New Brunswick, Fredericton, NB, Canada E3B 5A3. Telephone 1.605.453.4698. Facsimile 1.506.453.4943. Internet: icpv@predator.ocean.dal.ca

6-9 November: **Geological Society of America Annual Meeting,** New Orleans, Louisiana, USA. Abstract deadline: 12 July 1995. Information: GSA Meetings Department, 3300 Penrose Place, PO Box 9140, Boulder, Colorado 80301-9140, USA. Telephone 1.303.447.2020 ext. 141. Facsimile 1.303.447.0648. Internet: mball@geosociety.org

11-15 December: **American Geophysical Union Fall Meeting,** San Francisco, California, USA. Abstract deadline: September 1995. Information: AGU Meetings Dept., 2000 Florida Ave., Washington, D.C., USA. Telephone 1.202.462.6900. Facsimile: 1.202.238.0566. Internet: meetinginfo@kosmos.agu.org

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13-26 February: **13th Australian Geological Convention and Celebration of Jubilee of BMR/AGSO,** Canberra, Australia. Information: M.J. Rickard, Secretary, 13th AGC, ACTS, GPO Box 2200, Canberra, ACT 2601, Australia. Telephone 61.6.249.2056. Facsimile: 61.6.249.5544

20-22 February: **Tectonic, Magmatic, and Depositional Processes at Passive Continental Margins,** Burlington House, London, United Kingdom. Information: Nick Kusznir, Dept. of Earth Sciences, University of Liverpool, Liverpool L69 3BX, United Kingdom.

11-21 July: **Long Lava Flow Workshop,** Townsville, Australia. Information: P.J. Stephenson, Dept. of Earth Sciences, James Cook University, Townsville 4811, Australia. Telephone: 61.77.81.5061. Facsimile: 61.77.25.1501. Internet: jon.stephenson@jcu.edu.au

Commission Products and Services

LIPs on Internet

The LIPS Gopher server is undergoing several changes. The server has a new address; the new Uniform Resource Locator (URL) is

gopher://gopher.ig.utexas.edu:70/11/res/lips/

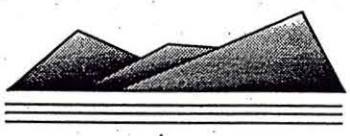
The old URL will continue to work for several more months, but only for Gopher and World Wide Web browsers. The ftp service will be reenabled at the new URL as soon as possible. The LIPS files will be relocated to a machine at the Institute for Geophysics, so we can have better control over the search engine. We apologize to those who have encountered trouble with the existing setup.

The Commission's LIPs bibliography of ~1800 references, the directory of ~200 members, and a digital database of LIP areas (Figure 1 of *Coffin & Eldholm*, Reviews of Geophysics, 1994) are available over the Internet, as well as the calendar of events and text versions of *The LIP Reader*.

As an experiment, *The LIP Reader* will be made available in Portable Document Format (PDF) as well. The PDF format enables anyone with Adobe Acrobat Reader software to view *The LIP Reader* online with all formatting intact. The Adobe Acrobat Reader software is available as freeware for Macintosh, DOS, or UNIX platforms. Many browsing programs can be configured to launch Acrobat Reader when a PDF file is selected. A pointer to the software will be included on the gopher server.

Ideas on how the site could be improved are most welcome. For copies of materials on Macintosh or DOS diskette, please send a blank, formatted 3.5 inch diskette to Mike Coffin.

The LIP Reader



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