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

Janelle L. Berry, Lisa Gahagan and Toni Lee Mitchell

Plans for the 1997 IAVCEI General Assembly in Puerto Vallarta, Mexico, are well underway. Commission on Large-Volume Basaltic Provinces (CLVBP) member Rosaly Lopes-Gautier has spearheaded organizing a special session ***Remote Sensing of Volcanoes on Earth and the Planets***, which promises to be a stimulating fusion of communities working on volcanism throughout the solar system. Timely research results on the Ontong Java Plateau, the Paraná flood basalts, and a global compilation of dyke swarms are summarized in this issue, as are recent meetings focusing on large-volume basaltic provinces. As always, we welcome your contributions to *The LIP Reader*, and your recruiting of interested scientists to join the CLVBP.

IAVCEI News

IAVCEI now has a home page on the World Wide Web (WWW), which includes information on the CLVBP. Check out http://xrfmac.lanl.gov/Heiken/IAVCEI_home_page; comments are welcome. At the site, please note that personal membership has been implemented in IAVCEI. The benefits of membership are listed on the enclosed application form, and personal membership for all Commission members is strongly encouraged.

CLVBP News

Large Igneous Province (LIP) Initiative

LIP studies are by nature interdisciplinary, involving topics in volcanology, petrology, geochemistry, geophysics, geochronology, oceanography, sedimentology, paleontology, paleomagnetism, climatology, geodynamics, and planetary geology. Elucidating linkages among LIPs, mantle dynamics, and environmental consequences presents an exciting set of challenges of widespread interest to the Earth science community. The multidisciplinary nature of LIPs research, with the potential for major breakthroughs in our understanding of linked Earth system processes, requires a concerted initiative to coalesce, focus, and prioritize scientific themes, resources, and facilities. Many CLVBP members have advocated establishing mechanisms to concentrate community efforts via well-coordinated national and international programs to survey, sample, analyze, and model LIPs. Such an effort will involve funding from governmental and industrial sources. For example, CNRS in France is considering a LIP initiative, NSF in the USA is funding individual LIP projects, CNR in Italy has co-funded an Apticore drill hole, AGIP and Statoil are contributing significant resources to basic LIP research, and NASA has a history of funding extensive work in planetary volcanism.

CLVBP members are involved in developing national and international initiatives to study LIPs, and grassroots support of CLVBP members and other interested geoscientists is crucial to the success of focusing resources on LIP problems. The CLVBP solicits your thoughts in developing the strongest possible scientific rationale for focused LIP investigations. Please send comments to any Steering Committee member. Updates will be provided in future issues of *The LIP Reader*.

Volume on Large Igneous Provinces

Papers for the American Geophysical Union (AGU) LIP volume are in various stages of completion, ranging from fully camera-ready, to under revision, to in review. The AGU Press is publishing the book as part of its Geophysical Monograph series, with a planned release date late this year.

FUMAGES Meeting

Marine geological and geophysical community input to the Future of Marine Geosciences (FUMAGES) meeting, to be held in December 1996, has been solicited via Internet by the convenors; a recent letter is available at the LIPs World Wide Web (WWW) site (see "Commission Products and Services"). The scientific planning document that will be forged during the meeting will likely play a key role in guiding marine geological and geophysical funding priorities for the U.S. National Science Foundation over the next five to ten years. Please make your thoughts known to mgfuture@brook.edu.

Steering Committee

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

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Recent Research Summaries

Geological Survey of North-Central Malaita: Implications for the Ontong Java Plateau

Results of a major geological survey of north-central Malaita undertaken between 1990 and 1995 are now publicly available. Nine 1:50,000 scale and one 1:100,000 scale geological maps and two accompanying geological/economic geology memoirs have been produced. Those interested in obtaining copies of these documents should contact the Director of Geology, Ministry of Energy, Water and Mineral Resources, Water and Mineral Resources Division, P.O. Box G37, Honiara, Solomon Islands.

A number of researchers have collaborated with the Solomon Islands Geological Survey in this project (e.g., J. Mahoney, C. Neal, A. Saunders, R. Duncan, M. Tejada, and T. Babbs), and a wealth of field, structural, geochemical, and geochronological data have been produced. The chemical, Nd-Pb-Sr isotopic, and ^{40}Ar-^{39}Ar results demonstrate that Malaitan basement lavas are closely similar in composition and age to basalts from drillholes on the adjacent Ontong Java Plateau (OJP). This summary concentrates on the structural and stratigraphic aspects of the survey.

Building on the work done by Hughes and Turner in southern Malaita in the 1970s, we have produced a more formalized, coherent stratigraphy of the island. The basement exposed on Malaita comprises 2-4 km of basaltic lavas with subordinate dyke and pluton-sized ferrogabbro intrusions; this sequence is termed the Malaita Volcanic Group (MVG). The MVG is remarkable for its uniformity of composition; >97% of the MVG is composed of tholeiitic (cpx-plag-glass-opaques ±olivine) basalt sheets which vary in thickness from 80 cm to 60 m. Very little intra-sheet sediment is present, at most mm to, rarely, 1-3 cm of cherty pelagic sediment. These observations suggest high rates of effusion at water depths below the carbonate compensation depth (CCD). Despite the overall lithological homogeneity, several sub-facies of basalt are present, including a visually distinctive spherulitic variety with coarse anorthitic plagioclase (±cpx) in a fine-grained groundmass. The cover sequence above the MVG is 1-3 km thick; at its base is a sequence of parallel, laminated to bedded radiolarian cherts grading upwards into alternating foraminiferal limestones and cherts (the Kwaraae and Alite formations, respectively). These formations are overlain by a foraminiferal limestone-plus-turbiditic mudstone sequence (the Haruta Formation). The influx of shard-rich, probably arc-derived, turbiditic sediment into the deep-sea pelagic depositional environment occurred only after the Mid-Eocene. The subsequent sedimentary unit (the Suafa Formation) consists of both deep-sea and shallow marine sediments, and records the gradual emergence of Malaita after about 5-6 Ma. The deep-sea pelagic sequence was punctuated by alkalic volcanism during the Mid-Eocene (the Maramasike Volcanic Formation) and by alnoite intrusions in the Oligocene. All of the above units were deformed during the mid-Pliocene (4-2 Ma) and the resulting unconformity now rests beneath a series of localised Plio-Pleistocene limestone and clastic beds, indicating a near-subaerial to subaerial position for Malaita during these times.

The earliest structural history of the island is linked with the emplacement of the OJP, and field observations suggest a simple, stacked plateau-basalt sequence. From the Eocene to the Pliocene, the Malaita region underwent extension, which resulted in graben and basin formation, and the resulting extensional structures have controlled sediment thickness, loci of alkalic basalt and alnoite emplacement, and even mineralisation. Only one period of major compressive-transpressive deformation is recorded on Malaita, and it appears to be bracketed between 4 and 2 Ma. This deformation resulted in: (1) a shortening of the Malaita region of between 24 and 46%; (2) a strong NW-SE (038°-218°) structural grain, with local discordance of ~20° indicating NE-SW compression/transpression with penecontemporaneous, predominantly sinistral strike-slip; and (3) large asymmetrical fold structures and thrusts with predominant early NE vergence and a later stage of SW-directed backthrusting. The basement and cover sequence are deformed coherently; no major decollements are present. We interpret the large asymmetrical fold structures as the tip regions of blind, NE-verging thrusts; line-balanced cross sections suggest possible detachments at depths of between 1 and 4 km beneath the base of the sedimentary cover. The structural data indicate a predominant NE sense of movement between 4 and 2 Ma. Offshore, recent bathymetric results from the SOPACMAPS cruise in 1994 reveal a number of major thrust structures with a SW sense of vergence, consistent with the final SW-directed obduction of Malaita over the Solomon Arc. We believe that structures associated with the late stage of SW-directed backthrusting formed since ~2 Ma.

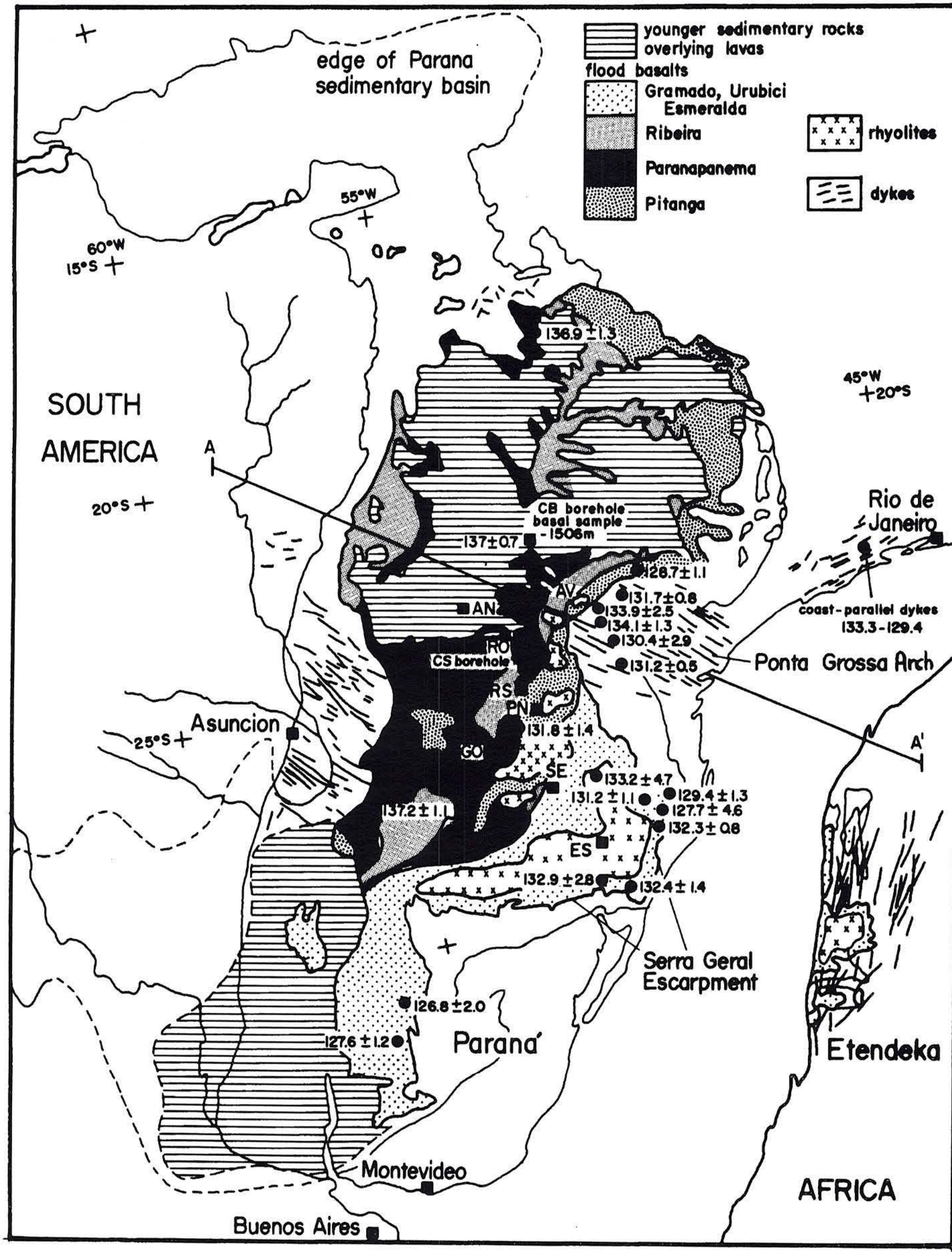
We propose an obduction model for Malaita which involves emergence from abyssal ocean depths at ~5-6 Ma, NE-directed thrusting between 4 and 2 Ma, and final SW-directed obduction over the Solomon Arc after ~2 Ma. Recent SOPACMAPS imagery, together with other seismic and volcano-stratigraphic evidence, implies that the edge of the OJP has been subducting beneath the Vitiaz Trench, at least locally, since ~15 Ma. Evidence from Malaita (and other OJP-related Solomon islands) indicates obduction of the upper parts of the OJP continues to occur. We suggest that the OJP is simultaneously obducting and subducting; that is, it is experiencing "flake tectonics".

contributed by Mike Petterson (British Geological Survey, Edinburgh, UK - mgp@wpo.nerc.ac.uk)

Paraná Flood Basalts

In the Early Cretaceous, the Paraná Basin was the site of one of the larger known continental magmatic events in Earth history. Basic and intermediate lavas, overlain by rhyodacites and rhyolites, form the so-called Serra Geral Formation. The lavas, together with associated dykes and sills intruded into the underlying sediments, form the Paraná continental flood basalt (CFB) province.

This CFB province covers an area of 1,400,000 km^2 (Figure 1), of which ~80% is in SE Brazil; ≤100,000 km^2 in Paraguay; ≤100,000 km^2 in Argentina; and ≤100,000 km^2 in Uruguay. Its present volume, without considering the likely volumes of intrusive and eroded rocks, is ≥800,000 km^3, to which should be added the ≥70,000 km^3 of the African counterpart in the Tafelberg field in Namibia (spread over an area of ≤78,000 km^2). Dykes along and parallel to the Brazilian coast are observed from São Paulo State to Uruguay; NW-SE dyke swarms crop out in Paraguay and in the Ponta Grossa Arch.



younger sedimentary rocks overlying lavas
flood basalts
Gramado, Urubici Esmeralda
Ribeira
Paranapanema
Pitanga
rhyolites
dykes
edge of Parana sedimentary basin
55°W
60°W
15°S
45°W
20°S
SOUTH AMERICA
A
A'
20°S
136.9 ± 1.3
CB borehole basal sample -1506m
137±0.7
128.7±1.1
131.7±0.8
133.9±2.5
134.1±1.3
130.4±2.9
131.2±0.5
AV
AN
RO
CS borehole
RS
PN
GO
SE
ES
Rio de Janeiro
coast-parallel dykes 133.3-129.4
Ponta Grossa Arch
Asuncion
25°S
131.8±1.4
133.2±4.7
131.2±1.1
129.4±1.3
127.7±4.6
132.3±0.8
137.2±1.1
132.9±2.8
132.4±1.4
Serra Geral Escarpment
126.8±2.0
127.6±1.2
Parana'
Etendeka
Montevideo
AFRICA
Buenos Aires

Figure 1

Along the southern continental margin and presumably associated with the Paraná CFB, basaltic sequences covering ≥2,000,000 km^2 may be inferred. To the north of São Paulo, seismic reflectors (>900 km long, Iand between 70 km (N) and 160 km (S) wide) indicate that basalts dip seaward and reveal the presence of extensional faults. SE of the São Paulo Plateau reflectors dip toward the continent, suggesting that they originated on the Angolan margin at the initial stages of rifting, and migrated towards South America during continental breakup. The boundary between the two basaltic sequences along the continental margin coincides with a basement fracture zone.

Although the lavas and sills are thickest (1,900 m) in the central-western part of the Paraná, the best outcrops are found along the escarpment of the Serra Geral in Santa Catarina and Rio Grande do Sul, from which the name of this Formation is derived. Extensive sampling along the escarpment, compared to the rest of the Province, biased descriptions of the general composition of the Paraná CFB until borehole samples became available for analysis. Rhyolites and rhyodacites are abundant on the escarpment and in Namibia, forming to up 40% of the exposed sections in some areas; however, they are not observed in the northern and western portions of the Paraná. A similar bias, with a preponderance of data from the escarpment, also characterised attempts to estimate the age and duration of magmatism by Ar-Ar analyses and sequential palaeomagnetic data, while Rb-Sr mineral isochrons on rhyolites NW of the escarpment yielded older dates. Ar-Ar ages on samples from across the province, and from boreholes subsequently demonstrated that Paraná lavas were erupted from 138-128 Ma, although any changes in eruption rates within this period are still being investigated.

Regional variations in the compositions of the lavas indicate that different sources and mechanisms have been involved in magma production. There is a markedly bimodal distribution in silica along the SE escarpment, but is insignificant to the north and west in São Paulo State, where the high silica rocks are <1% of the effusive component. TiO_2 contents also vary regionally, with the rocks in the north and northwest having relatively high TiO_2 abundances compared with those in the south and southeast. The radiogenic isotope ratios of the low-Ti rocks are "enriched," apparently reflecting both assimilation and contamination within the crust, and old incompatible element-enriched source regions in the upper mantle. The higher-TiO_2 magmas in the north and northwest are less variable and enriched, and they have many of the isotope and trace element features of the older and more enriched rocks from the Walvis Ridge. Most of the basalts have low Nb and Ta abundances relative to La, and to a lesser extent K, compared with most oceanic basalts, suggesting that they were primarily derived from enriched source regions in the sub-continental mantle. The exception is the Esmeralda magma type, which is younger than the SSE rhyolites, and which has a much stronger oceanic compositional affinity.

Geochemical and isotope analysis on samples selected from 10 boreholes, drilled along a N-S trending section, revealed that stratigraphy of the central area differs from that of the escarpment. The central and northern areas, where the sequence is thickest, consist of three main basaltic magma types (Pitanga, Paranapanema and Ribeira), and available data are consistent with these magma types being generated by different degrees of partial melting of similar source regions. However, the main magma type in the southern areas, the Gramado, is very different: it has been affected more by crustal contamination processes, and it appears also to have been derived from an old enriched source region characterised by relatively high Rb/Sr and low U/Pb ratios. The other two southern Paraná magma types are unrelated; the source of the Urubici was similar to that of the high TiO_2 magmas of the northern Paraná, while the Esmeralda, which was probably erupted at the time of breakup, has a predominantly asthenospheric signature.

Mapping of the different magma types, assuming that they represented chronostratigraphic units, has led workers to conclude that magmatism in the Paraná migrated northward with time. However, the increasing number of high precision Ar-Ar ages have demonstrated that different magma types are not chronostratigraphic. Rather, different magma types were erupted in different places at the same time, and some magma types are of different ages in different places. Thus, Pitanga samples from Paraguay and the bottom of the deepest borehole yield ages of 138.4±1.4 Ma and 137.8±0.7 Ma, significantly older than Pitanga samples from dykes in the Ponta Grossa Arch (134.1±1.3 Ma). The Paranapanema (137-132 Ma) overlies the Pitanga in the center and north of the Paraná, whereas the Gramado yields ages of ~132±1 Ma in southern Brazil and 129-127 Ma in Uruguay. These results invalidate an earlier assumption that magma types were chronostratigraphic, and instead suggest that magmatism migrated from the NW to the SE with time. Moreover, the overall duration of magmatism within the Paraná would appear to be 10 m.y., in contrast to the short eruption periods inferred for many other CFBs. The observation that different magma types were generated from different source regions over relatively long periods of time may be consistent with models in which the magmas are largely produced by conductive heating of heterogeneous and volatile-bearing mantle lithosphere.

Although the duration of magmatism is perhaps an order of magnitude longer than those inferred for other CFB provinces, the extrusion rate within the Paraná varies both geographically and with time. On the basis of 55 ^{40}Ar-^{39}Ar laser spot isochrons with MSWD <2, and on the total preserved volume of lavas, eruption rates appear to have reached their climax between 133 and 131 Ma, as exemplified by rocks on the SE escarpment. Although uncertainties in such calculations are still considerable, estimated eruption rates increase from ≥0.03 km/yr between 138 and 135 Ma, to >0.13 km/yr between 135 and 133 Ma, to ≥0.21 km/yr between 133 and 131 Ma. Geographically, in the N and NW, the lower 300-1300 m of basalts were erupted in ~5 m.y., whereas the overlying 600 m were emplaced in ~1 m.y. Intercalation of thick (<10 m) sand dunes between flows is an indication of long periods of quiescence, and therefore consistent with Ar-Ar results.

Available data are consistent with the presence of a thermal anomaly (plume) under South America while W Gondwana was moving NW, and with extensional deformation across the Ponta Grossa dyke swarm. Early magmatism was characterised by small amounts of extension, and hence relatively low eruption rates, whereas later magmatism was accentuated by the onset of extension across the proto-South Atlantic, which resulted in higher eruption rates and large volumes of silicic rocks. The abnormally thick lithosphere, which may have caused long periods of quiescence, lengthened formation of the Paraná CFB province. The uplifted area, highly eroded in the Ponta Grossa Arch, is indicative of magmatic underplating, while the lower but also eroded topography of the Rio Grande Arch suggests more plastic crustal thinning. Furthermore, westward tilting observed for the whole basin appears to be a response to the basaltic load over a major lithospheric weakness (ancient plate boundary?), which is supported by the gravity signature in the area.

Future priorities to refine the general view above include: (1) detailed stratigraphy of the transitional area between northern and southern provinces; (2) E-W transects of deep boreholes with geochemical profiles; (3) more precise estimates of the erosion history; (4) combined marine and continental data analysis; (5) deep seismic E-W transects at different latitudes.

contributed by Marta S.M. Mantovani (IAG-USP, São Paulo, Brazil—marta@iag.usp.br & http://www.usp.br/iag/geofisica)

Diabase (Dolerite) Dyke Swarms of the World: First Edition, 1996

Information from the literature on swarm geometry, geochronology, and key references for more than 500 diabase (dolerite) dykes from around the world is displayed on a 1:35,000,000 scale map and catalogued in a companion report. This compilation has so far facilitated the identification of nearly thirty giant radiating dyke swarms, the focal points of which are interpreted to locate mantle plume centers at the time of dyke emplacement.

The map and report (104 pp.), by R.E. Ernst, K.L. Buchan, T.D. West, and H.C. Palmer, appear in Geological Survey of Canada Open File 3241. Pricing differs within and outside Canada. Both map and report may be obtained from the Geological Survey of Canada Bookstore, 601 Booth St., Ottawa, Ontario K1A 0E8. Telephone 1.613.995.4342. Facsimile 1.613.943.0646. Internet: gsc_bookstore@gsc.emr.ca

contributed by Richard E. Ernst (Geological Survey of Canada—rernst@gsc.emr.ca)

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.

PREVIOUS MEETINGS

DECCAN'96 Workshop, Mahabaleshwar, India, 26-30 January 1996

This workshop was organized by K.V. Subbarao (Indian Institute of Technology [IIT], Powai) and G. Sen (Florida International U., Miami) to 1) assess the current state of knowledge on the Deccan Traps; 2) evaluate priorities in Deccan research; and 3) form informal working groups to collaborate on specific research areas. The workshop was dedicated to the memory of William D. West, who made outstanding contributions to Deccan Trap petrology, first as director of the Geological Survey of India and later as an academic who established the Geology Department at Sagar University. Several Indian organizations (particularly the Geological Society of India [GSI]) and the U.S. National Science Foundation (International Division) sponsored the workshop.

Thirty scientists and students from India, USA, UK, Italy, Russia, and Norway participated, allowing group discussions to be focused, interactive, and lively. The workshop included oral presentations by 29 invited speakers and field trips in the Western Ghats along the Bombay-Mahabaleshwar-Pune transect. Technical sessions took place at IIT-Powai, the Mahabaleshwar State Guest House, and the University of Pune. K.G. Cox (Oxford) delivered the inaugural address, drawing attention to the significance of picritic lavas in the Deccan and West's seminal contributions to understanding these unusual flows. The presentations covered a broad range: geomorphology, geophysics (seismology, gravity, magnetostratigraphy, tectonics), geochemical stratigraphy and petrology, and the atmospheric impact of flood basalt volcanism.

K.M. Storetvedt (Bergen) presented an alternative model for the evolution of the earth. P.R. Hooper (Washington State) argued that extension in the Deccan lithosphere occurred after the main eruptive event. M.R. Rampino (New York U.) presented two papers: in one, he pointed out that a giant radiating dike swarm may have supplied Deccan magmas; in the other, he showed that the dates of several known flood basalt events coincide with mass extinction events. S.A. Kuranko and A.N. Zemtsov (Geological Institute, Moscow) discussed magmatism in the Siberian Traps, and noted that a fundamental difference between the Siberian and Deccan Traps is the presence of a thick pyroclastic layer at the base of the Siberian flows. L. Keszthelyi and S. Self (Hawaii) focused attention on lava flow characteristics and mode of eruption in the Columbia River Basalt. New trace element and isotopic data bearing on Deccan geochemical stratigraphy were presented by S.F.R. Khadri (Vikram U.), K.V. Subbarao, and J.P. Shrivastava (U. Delhi). A. De (Calcutta U.) argued for a near-steady-state behavior of magma chambers beneath the eastern Deccan from phenocryst systematics and phase relationships. The effect of basement structures in controlling eruptions and the subsequent geomorphological evolution of the Deccan landscape was the topic of presentations by V. Kale (U. Pune), R. Shanker and K.S. Misra (GSI), D.A. Sant (U. Baroda), and P.R. Reddy (Nat'l. Geophysical Research Institute, NGRI). T.M. Mahadevan, S.S. Rai, and U. Raval (NGRI) made inferences from seismic tomography and gravity data about how the Deccan plume may have interacted with the lithosphere. Some new insight into the ages and compositions of "post-Deccan" tholeiitic and alkalic dikes from the west coast was provided by L. Melluso (U. Naples), K.V. Subbarao, and A.G. Dessai (U. Goa). There were also new reports of dioritic xenoliths (D. Chandrasekharam, IIT) from the northern Deccan and of garnet pyroxenite xenoliths from an alkalic dike near Bombay (A.G. Dessai). K. Gopalan (NGRI) presented a paper by H.K. Gupta on the origin of the recent Latur earthquake which killed 10,000 people. G. Sen presented a model of plume melting in which the dominant tholeiites are derived from picritic magmas generated over a depth range of 135-85 km, whereas the much rarer carbonatites and other alkaline magmas are generated from the volatile-rich, cooler apron of the plume.

It became clear that very little is known about the physical volcanology of the Deccan, and that a need exists for field measurements to explain structural aspects of the lavas, rate of flow, flow regime, etc. S. Self and L. Keszthelyi are taking the lead on such measurements. A group at NGRI, led by S.S. Rai, is embarking on a detailed tomographic experiment to assess the nature of the sub-Deccan mantle. More dating was considered vital, particularly of the intrusives that occur over large areas of the Deccan; this is being carried out by a group in Physical Research Laboratory (India). Geochemical and petrographic work must be continued as well, so that a comprehensive data base of geochemical and petrographic variations throughout the Deccan may be produced. Sedimentological, paleontological and palynological work on the fossiliferous beds that occur between lavas in some places also was agreed to be important, to ascertain the impact of Deccan eruptions on the local and regional ecosystem.

The perceived importance of having a centralized system where any new information on the Deccan may be made readily available to all interested individuals led to a consensus to create a "Deccan page" as part of the LIPs homepage. Printed or diskette copies would be made available upon request to those who do not have Internet access.

Some of the most enlightening discussions took place during late beer sessions. A senior officer of the Atomic Minerals Division (Govt. of India), whose initials are PK but who will otherwise remain anonymous, managed to sneak in beer every evening for interested participants. Topics in these sessions ranged rather widely—and were not always of geological consequence—but did always have some reference to earthly matters! Only a few foreign and domestic participants had any trouble with the Indian food, but they were adequately equipped (medicine-wise). Perhaps the best part of the workshop was the field trip along the Western Ghats, where the thick sequences of horizontal flows exposed led to comparisons with the Grand Canyon, except that in the Ghats the layers are all lava flows.

Finally, US participation almost did not happen because of the government budget crisis and the shutdown of NSF. M. Lueck (Program Director, INT), with the invaluable assistance of R. Wazir (US Embassy, Delhi), went above and beyond the call of duty to make sure US participants were able to attend.

contributed by Gautam Sen (Florida International University, Miami, USA)

Scientific Konference on Intraplate, Interdisciplinary Themes (SKI-IT), Steamboat Springs, Colorado, USA, 9-11 February 1996

This conference, a prelude to the U.S. National Science Foundation-sponsored Future of Marine Geosciences (FUMAGES) meeting scheduled for December 1996, brought together 15 scientists to define major oceanic intraplate geoscientific problems and to discuss approaches to solving them. The dominant topic of the meeting was transfer of mass and energy from the Earth's interior to its surface, via either plate tectonic or hot spot processes. Four working groups addressed thematic problems associated with these processes in the following categories: large igneous provinces (LIPs)—M. Coffin, R. Larson, J. Mahoney, S. Stein; hot spots—R. Duncan, J. Orcutt, J. Phipps Morgan, P. Wessel, A. Zindler; departures from the age-dependent signal—M. McNutt, D. Sandwell, C. Stein; intraplate deformation and plate boundary evolution—J. Austin, D. Bercovici,

D. Naar. LIP themes discussed included 1) processes of mass and energy transfer among the core, mantle, and crust related to LIP genesis, including the origin and evolution of mantle plumes; 2) emplacement and post-emplacement mechanisms and effects on the lithosphere, including plume-lithosphere-plate motion interactions, emplacement styles, and relation to both early and modern processes of continental growth; 3) consequences of emplacement and evolution for the hydrosphere, atmosphere, and biosphere, especially with respect to the carbon cycle and periods of rapid evolutionary change.

Approaches to addressing the scientific themes that were considered at the conference include declassification of U.S. Navy data; better use of exisiting data; development of an oceanic PASSCAL (Program for the Array Seismic Studies of the Continental Lithosphere)-type capability*; enhanced ocean drilling technologies*; special initiatives*; development of new seismic acquisition systems; implementation of an Ocean Seismic Network (OSN); and thematic foci* (approaches of particular relevance to LIPs are indicated by asterisks).

Conference participants are particularly grateful to M. McNutt for oganizing the program and logisitics, running the conference, and for assembling the final report. Lengthy discussions within and among the working groups were enhanced by the slopeside setting in three self-service condominiums; working, cooking, eating, socializing, bunking, and occasionally skiing together over the three days allowed for much productive interaction. A copy of the SKI-IT report will be made available on the CLVBP World Wide Web site when ready.

contributed by Mike Coffin (University of Texas, USA)

Plumes: What do we know? Workshop, *Leicester, UK, 17 April 1996*

The workshop attracted seventy petrologists and geophysicists to discuss recent advances in our understanding of mantle plumes. Eight oral and ten poster presentations tackled topics ranging from the cause of anisotropy in the D″ layer, to finite element modeling of melting in plumes.

Several important questions emerged from the debate:

(1) Is subducted slab material pooled at the core-mantle boundary, only to rise again in the form of mantle plumes? It is difficult to explain anisotropy in the D″ layer by other mechanisms, such as preferred orientation of lower mantle minerals (M. Kendall).

(2) Are plumes internally heterogeneous? Zonation in temperature, and chemical and isotopic composition appears to be a long-term feature of the Iceland plume (J.G. Fitton, R.S. White). Do other plumes show similar features?

(3) Why do plume models fail to explain many features of extensional volcanism and uplift in East Africa? Geophysical data indicate hot, low density material beneath the Kenya Rift, but the correlation between seismicity and volcanism is poor (C. Birt).

(4) Where isotopic ratios correlate with indices of melt fraction, is it possible to resolve the effects of partial melting from variations in source chemistry (M. Thirlwall)? Do hydrous minerals in the source of oceanic basalts exert a significant control on trace element ratios such as La/Nb?

(5) How much care do we take when interpreting the geological meaning of $^{40}Ar/^{39}Ar$ age-plateau and isochron analyses for partially altered volcanic rocks? A radiometric age should be accepted as an accurate estimate of the crystallisation age only if it passes a set of rigorous statistical tests for internal concordance (M. Pringle).

(6) Were melt production rates in Archaean plumes much greater than those of present-day Hawaii (M. Cheadle)? If so, where are the Archaean oceanic plateaux? Could dehydration melting of underplated basalt be responsible for the tonalite-trondjhemite-granodiorite suites observed in Archaean terranes (H. Rollinson)?

The informal atmosphere of the meeting helped to generate cross-disciplinary discussion of interest to plume student and connoisseur alike. Few issues were resolved completely, but a thorough stir of the melting pot of ideas may have assisted the progress of research.

contributed by Ray Kent & Andrew Kerr (University of Leicester, UK)

Caribbean Plateau Workshop, *Rennes, France, 22-23 April 1996*

A two-day workshop on the Caribbean oceanic plateau attracted participants from five countries (France, England, Netherlands, Italy and USA) and from a range of disciplines (petrology, geochemistry, geophysics, tectonics). The aim of the workshop was to bring together these diverse groups to achieve a better understanding of the composition, tectonic make-up and origin of the Caribbean plateau and of oceanic plateaus in general.

The workshop opened with a presentation by N. Donnelly of the overall geology and history of the region. This was followed by J. Tarney who outlined current ideas on the relationship between mantle plumes and flood volcanism, and the relationship between accretion of oceanic plateaus, subduction and the growth of continental crust.

The first afternoon session was devoted to talks on petrology and geochemistry. There was a strong emphasis on picritic rocks and their possible intrusive equivalents. The unusual abundance of highly magnesian rocks in the Caribbean plateau was discussed, as was their large range of trace-element characteristics, from moderately enriched in incompatible elements in picrites from the Duarte Complex (Hispanola), to essentially unfractionated in examples from Curaçao, to extremely depleted in komatiites and picrites from Gorgona Island. This variation was contrasted with the monotonous character of the plateau basalts, the majority of which have generally flat mantle-normalized trace-element abundances. The problem of deriving such basalts from a source with a long-term depleted character (as indicated by systematically high Nd isotope ratios) was also discussed; it was suggested that the basalts were pooled magmas whose compositions represented the average of melts that formed through a wide range of melting conditions while the picrites were more direct samples of the primary melts. Much discussion also centered on mafic-ultramafic intrusions, such as the Bolivar complex in Colombia, and the possibility that these plutonic rocks might represent cumulate bodies formed by fractionation of primary picritic magmas during their passage to the surface.

The following morning A. Mauffret and S. Le Roy presented results of detailed geophysical surveys of the Caribbean and proposed an interpretation of the crustal structure. Notable features of this interpretation were (1) the wide variations in crustal thickness: ridges and plateaus underlain by thick crust were separated by basins floored by crust with normal to unusually low thicknesses; and (2) the presence beneath the ridges of an unusually thick layer 2, which was thought to composed of intrusive gabbros. This interpretation was confirmed during recent submersible surveys (Nautica cruise, January 1996), which, as described by Mauffret, revealed the presence of substantial thicknesses of gabbro on escarpments flanking the BEATA Ridge. The session then continued with presentations by A. Kerr, who inferred crustal structure on the basis of petrological and chemical data, and by M. Seyler, who described the mafic-ultramafic Tinaquillo complex of Venezuela.

The final afternoon started with presentations by R. Duncan on the possible linkage of global anoxic events to ocean plateaus, C. Ginibre on spinifex textures, and C. Farnetani on petrological and geochemical modeling of the evolution of primary melts and the internal structure of oceanic plateaus.

In the final summing-up session of the workshop we concluded that the Caribbean region provides an outstanding natural laboratory for study of oceanic plateaus, because of:

- the wide diversity of petrology and chemistry of volcanic rocks of the Caribbean plateau, compared with other less well-exposed examples.
- the great advantage in the Caribbean of having access to complementary sources of information, from on-land and marine observations.
- constraints on the deep structure of the oceanic plateau provided by geophysical surveys, studies of intrusive complexes, and petrologic modeling.
- the specific association in the Caribbean of the oceanic plateau and subduction-related sequences, which provide information about plate boundaries and plate movements in the region.

We also recognised that a number of questions and problems remained to be resolved:

- the reason for the abundance of picrite in the Caribbean region—is this a primary feature peculiar to Caribbean magmatism or a consequence of deep exposure of the plateau?
- problems in explaining the diversity of picrite compositions.
- the relatively high $^{87}Sr/^{86}Sr$ at given $^{143}Nd/^{144}Nd$ of picrites from Gorgona and Curaçao: is this a primary or secondary feature?
- the need to obtain better age constraints throughout the province.
- timing of the volcanism: was there only one major pulse at ~88 Ma or were there older and/or younger episodes?
- the fate of the old plate on which the plateau volcanics were deposited.
- the nature of the late volcanoes that ornament the smooth carapace of the plateau.
- the relationship between plateau accretion, subduction, and formation of continental crust and lithospheric mantle.
- the relationship between ridges and basins: is the crust that floors the basins older or younger than the plateau volcanism?
- difficulties in estimating the total size and original geometry of this highly deformed plateau.
- the site of formation of the plateau: near a ridge or in an intraplate setting?

The status of the Caribbean basement drilling proposal was reviewed by R. Duncan, who highlighted the opportunity to continue to improve its objectives and drilling plans with recent on-land and site-survey results. Caribbean community input is also needed in the upcoming workshop, "The Oceanic Lithosphere and Scientific Drilling into the 21st Century," at Woods Hole in May.

contributed by Nick Arndt (Université de Rennes, France)

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

LIPS and the Ocean Drilling Program

Proposals for basement drilling of submarine LIPs fared very well in the ODP Lithosphere Panel's spring meeting (March 6-8, Portland, Oregon, USA). In the yearly global ranking of drilling proposals, the Lithosphere Panel ranked Ontong Java Plateau #1, Caribbean LIP #2, Kerguelen Plateau/Broken Ridge #6, and Shatsky Rise #11. For information on what the rankings may mean for future drilling, and on ODP's panel structure and procedures, see *The LIP Reader* #5 and #6. John Mahoney represents our Commission in the ODP advisory structure, as a member of the Lithosphere Panel, and welcomes input from Commission members.

Commission Products and Services

LIPs on Internet

LIPs have an Internet presence, accessible via standard internet tools. The Commission's LIP bibliography of ~2300 references, directory of ~500 members, and digital database of LIP areas (Figure 1 of *Coffin & Eldholm*, Reviews of Geophysics, 1994) are available, as well as the calendar of events and text versions of *The LIP Reader*. The Internet site is currently set up as a Gopher server, which allows users to log in with anonymous ftp or World Wide Web (WWW) tools, such as Netscape or NCSA Mosaic. As time allows, the site will be enhanced for WWW users. Ideas on how the site could be improved are most welcome. For copies of materials on Macintosh diskette, please send a blank 3.5 inch diskette to Mike.

Anonymous FTP

With ftp, open ftp.cc.utexas.edu, use the login name "anonymous" and your internet address as a password. Then change directory to /pub/lips.

Gopher

Using your Gopher client software, open gopher.utexas.edu. Navigate to UT-Austin, to Colleges and Departments, to Institute for Geophysics, to Research Projects, and then to Commission on Large Igneous Provinces.

World Wide Web

The Universal Resource Locator (URL) is http://www.ig.utexas.edu/research/projects/lips.html.

Upcoming Meetings

11-21 July: **Long Basalt 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

23-27 July: **Western Pacific Geophysics Meeting,** Brisbane, Australia. Special Session: Information: AGU Meetings Dept., 2000 Florida Ave., Washington, D.C., USA. Telephone 1.202.462.6900. Facsimile: 1.202.238.0566. World Wide Web: http://www.agu.org

29 July-2 August: **Pan Pacific Hazards '96,** Vancouver, Canada. Information: Disaster Preparedness Resources Centre, University of British Columbia, 2206 East Mall, 4th Floor, Vancouver, B.C. V6T 1Z3, Canada. Telephone: 1.604.822.5518. Facsimile: 1.604.822.6164. Internet: dprc@unixg.ubc.ca

4-14 August: **30th International Geological Congress,** Beijing, China. Information: Prof. Zhao Xun, Deputy Secretary General, 30th International Geological Congress, PO Box 823, Beijing 100037, PR China. Telephone: 86.1.8327772. Facsimile: 86.1.8328928. Internet: zhaox@bepc2.ihep.ac.cn

23-31 August: **Oceanic Crust and Ophiolites,** Kirkjubaejarklaustur, Iceland. Information: Karl Grönvold, Nordic Volcanological Institute, Reykjavik, Iceland. Facsimile: 354.562.9767. Internet: karl@norvol.hi.is

31 August-6 September: **Origin of Sedimentary Basins**, Faroe Islands. Information: ILP Task Force, Origin of Sedimentary Basins, Institute of Earth Sciences, Vrije Universiteit, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands. Telephone: 31.20.444.7375. Facsimile: 31.20.646.2457. Internet: nsg@geo.vu.nl.

9-14 September: **XXV General Assembly of the European Seismological Commission**, Reykjavik, Iceland. Information: LOC XXV General Assembly ESC, Attn: Mr. Bardi Thorkelsson, The Icelandic Meteorological Office, Bústadavegur 9, 150 Reykjavik, Iceland. Telephone: 354.560.0600. Facsimile: 354.552.8121. Internet: esc96@verdur.is

21-25 October: **International Symposium on Geology and Geophysics of the Indian Ocean - GIO, 1996**, Goa, India. Information: Ch. Madhusudana Rao, National Institute of Oceanography, Dona Paula, Goa 403 004, India. Facsimile: 91.832.223.340. Internet: msrao@bcgoa.ernet.in

6-x December: **Economic Deposits Associated with Carbonatites, Amba Dongar Workshop**, India. Information: Dr. Keith Bell, Dept. of Earth Sciences, Carleton Univ., Ottawa, Ontario K1S 5B6, Canada. Internet: kbell@ccs.carleton.ca; Drs. Tony Simonetti and Shrinivas Viladkar, Max-Planck-Institut für Chemie, Postfach 3060, D-55020 Mainz, Germany. Internet: tsimonet@geobar.mpch.mainz.mpg.de; viladkar@geobar.mpch-mainz.mpg.de

9-13 December: **American Geophysical Union Fall Meeting**, San Francisco, California, USA. Information: AGU Meetings Dept., 2000 Florida Ave., Washington, D.C., USA. Proposed special sessions: ***Tectonic and Geochemical Studies of the Solomon Island Arc and Ontong Java Oceanic Plateau***, convened by P. Mann (paulm@utig.ig.utexas.edu) & K. Suyehiro (suyehiro@ori.u-tokyo.ac.jp); ***Paraná-Etendeka Symposium***, convened by P. Renne (prenne@bgc.org), M. Ernesto, & S. Milner. Telephone 1.202.462.6900. Facsimile: 1.202.238.0566. World Wide Web: http://www.agu.org

1997

19-24 January: **IAVCEI General Assembly**, Puerto Vallarta, México. Special Session: ***Remote Sensing of Volcanoes on Earth and the Planets***, convened by R. Lopes-Gautier (rlopes@jpluvs.jpl.nasa.gov), P. Mouginis-Mark (pmm@kahana.pgd.hawaii.edu), & A. Ocampo (aocampo@jpluvs.jpl.nasa.gov). Information: Instituto de Geofisica, UNAM, Circuito Exterior, Ciudad Universitaria, C.P. 04510, México, D.F. Facsimile: 5.550.24.86. Internet: lourdes@igiris.igeograf.unam.mx

14-19 April: **Plumes, Plates, and Mineralisation '97**, Pretoria, South Africa. Information: PPM'97, c/o Prof. S.A. de Waal, Department of Geology, University of Pretoria, Pretoria 0002, South Africa. Telephone: 27.12.4202454. Facsimile: 27.12.433430. Internet: ppm97@scientia.up.ac.za

19-21 May: **Ottawa '97: Joint Annual Meeting of the Geological Association of Canada and Mineralogical Association of Canada**, Ottawa, Canada. Special Session: ***New Developments in Paleocontinental Reconstruction***, convened by R.E. Ernst (rernst@.gsc.emr.ca), I.W.D. Dalziel (ian@utig.ig.utexas.edu), & K.L. Buchan (kbuchan@gsc.emr.ca). Information: C. Vodden, Geo logical Survey of Canada, Room 757, 601 Booth St., Ottawa, Ontario, K1A 0E8. Telephone 1.613.947.7649. Facsimile 1.613.947.7650. Internet: Ottawa97@emr.ca

1-9 July: **Earth - Ocean - Atmosphere Forces for Change**, Melbourne, Australia. Information: IAMAS/IAPSO Secretariat, Convention Network, 224 Rouse Street, Port Melbourne, Victoria 3207, Australia. Telephone: 61.3.9646.4122. Facsimile: 61.3.9646.7737. Internet: mscarlett@peg.apc.org

The LIP Reader

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