THE GEOCHEMICAL NEWS

Newsletter of The Geochemical Society

NUMBER 94 **JANUARY 1998**

In this issue:

9th V.M. Goldschmidt Conference
Harvard University, Cambridge, MA, U. S. A.
August 22-27, 1999

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Werner F. Giggenbach, Geochemist

1937-1997

"They had brought me back from the depth of Erebus - the twilight of the Occident, where lie Hades and sunless land of the Cimerians, personified as son of Chaos, brother and husband of night, father of Aither and day."

THE GEOCHEMICAL SOCIETY

The **Geochemical Society** is a nonprofit scientific society founded to encourage the application of chemistry to the solution of geological and cosmological problems. Membership is international and diverse in background, encompassing such fields as organic geochemistry, high and low-temperature geochemistry, petrology, meteoritics, fluid-rock interaction, and isotope geochemistry. The Society produces a **Special Publications Series**, ***The Geochemical News*** (this quarterly newsletter), and (jointly with the Meteoritical Society) the journal ***Geochimica et Cosmochimica Acta***; grants the **V.M. Goldschmidt, F.W. Clarke** and **Clair C. Patterson Awards**, and, jointly with the European Association of Geochemistry, the **Geochemistry Fellows** title; sponsors the **V.M. Goldschmidt Conferences**, held in North American in odd years and elsewhere in even years, jointly with the European Association of Geochemistry; and co-sponsors the Geological Society of America annual meeting and the spring meeting of the American Geophysical Union. The Society honors the memory of our first President, F. Earl Ingerson, and our first Goldschmidt Medalist, Paul W. Gast, with the **Ingerson** and **Gast Lectures**. The Geochemical Society is affiliated with the American Association for the Advancement of Science and the International Union of Geological Sciences.

Members of the **Organic Geochemistry Division** are individuals with interests in studies on the origin, nature, geochemical significance, and behavior during diagenesis and catagenesis of naturally occurring organic substances in the Earth, and of extraterrestrial organic matter. GS members may choose to be affiliated with the OGD without any additional dues. The OGD presents the **Alfred E. Treibs Award** for major achievements in organic geochemistry, and **Best Paper** awards (student and professional) in organic geochemistry.

Editor's Corner

Dear Readers:

Please feel free to contact us with contributions for *The Geochemical News*. We want to publish all the geochemical news that's fit to print -- and you are the reporters!

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visit the new Geochemical Society website:

http://www.geochemsoc.org

Letter from Michael J. Drake

New President of the Geochemical Society

Dear Colleagues:

Wow! What an incredible act to follow!! Alex Halliday has completed his term as President, and I have stepped into his rather large shoes. For those of you who were not privy to the firehose of communications and actions originating with Alex, be assured that Alex had a vision for the Geochemical Society that has resulted in a far more vibrant Society at the end of his term than at the beginning. Among the many things accomplished under his Presidency are:

1. The "maturing" of the Goldschmidt Conference, that started so ably at the Pennsylvania State University. We now have a meeting which alternates between various sites in Europe and North America, with the European Association of Geochemistry as our partners. Perhaps one year we will be invited to an non-European/American site. I had the pleasure of co-hosting the 1997 Goldschmidt Meeting with able assistance from my geochemical colleagues in Tucson, and I look forward to seeing all of you in Toulouse this summer.

2. The presentation of the first Gast Lecture by Edouard Bard. Also under Alex, the Patterson Medal in environmental geochemistry was established.

3. The Geochemical Society Business Office, most effectively managed by TinaGayle Osborn, transitioned to new management under Lee Mobley. Sue Viers is the new Business Manager.

4. After the Newsletter was vastly improved by Secretary Dave Wesolowski, Neil Sturchio was appointed Newsletter Editor. This is the first Newsletter under his editorship.

5. In partnership with the Mineralogical Society of America, the Geochemical Society Web Site has been migrated and is now managed by Mark Bloom. In addition to major new membership services, he is initiating substantial new educational outreach activities. Check the Geochemical Society Web Site at http://www.geochemsoc.org.

6. Karl Turekian succeeded Gunter Faure as Editor of *Geochimica et Cosmochimica Acta*. He replaced the associate editor structure with Editorial Advisory Board which, after some initial teething pains, now broadly reflects the diversity of geochemical disciplines in our Society.

Please join me in thanking Alex for an outstanding performance as President of the Geochemical Society!

These accomplishments raise the question of my vision for the Geochemical Society. I see the next two years as a period of consolidation, as we absorb the changes made under Alex's Presidency. Rather than specific new actions, I will work for systemic evolution of the culture of the Geochemical Society. I would like the Geochemical Society to be viewed by all geochemists as their primary home society, and will work hard towards the goal of broadening its appeal to all branches of geochemistry. Geochemistry is also an international field, and a high priority will be building closer ties to the European Association of Geochemistry and other geochemical groups that desire more intimate ties. And to the extent consistent with the role of an international society, the Geochemical Society should attempt to influence national science policies in the countries of its members.

I look forward to working with past-President Alex Halliday, with Vice-President Mike Hochella, with our outstanding Secretary, Dave Wesolowski, and Treasurer, Don Elthon, with a talented Board of Directors, and with all of you in 1998 and 1999. Working together our Society and the field of geochemistry will prosper.

Here's to an outstanding meeting in Toulouse!

With best wishes for the New Year,

Mike

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Free Back Issues of *Geochimica et Cosmochimica Acta*

Free to tax-exempt institution that will make good use of the journal, and will pay postage from Eugene, Oregon, USA. Set includes v. 10-19 (1956-1960) and v. 34-61 (1970-1997).

William T. Holser, Dept. Geological Sciences, University of Oregon, Eugene, Oregon, 97403, USA; phone 541-346-4575; fax 541-346-4692; email wholser@oregon.uoregon.edu

Notes from the Business Manager

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geochsoc@pubcon.com
http://www.geochsoc.org

Happy New Year from the Business Office! The past 4 months since I have taken over the Business office have been very exciting. I am looking forward to the challenges of 1998!

I have had the opportunity to represent the Geochemical Society at two conventions, meet some of the members of the society, and sign up some new members. In October at the GSA convention in Utah we welcomed 43 new members. In December at the AGU meeting in San Francisco we welcomed 18 new members. As of December 22, 1997, we have 94 new members for 1998!

I will be preparing the 1998 membership directory in the next few months, so if you have any changes to your address please send them to me.

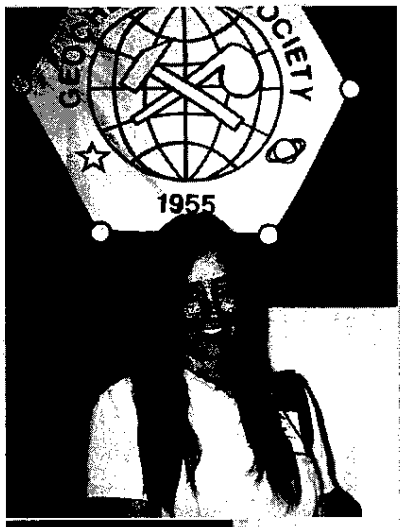
RENEWALS:

For the efficient handling of membership and subscriptions by the business office you will notice the following changes from past years.

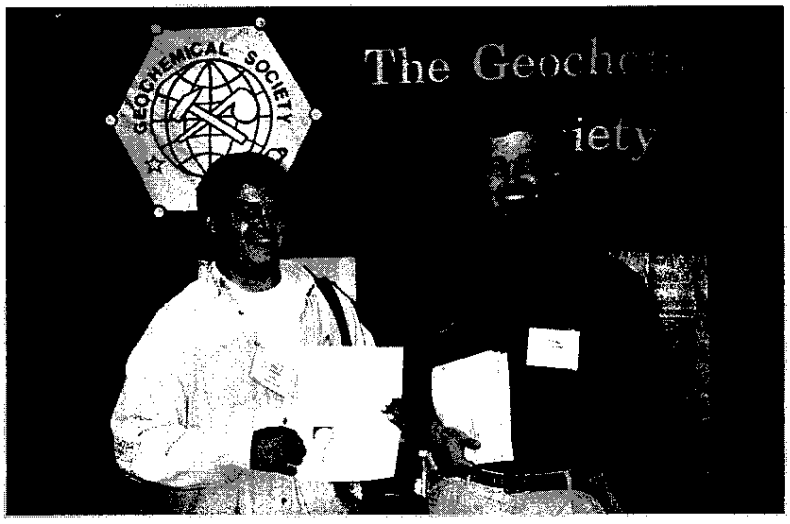
1. Members who have not renewed their membership by January 5th will receive the first newsletter but then will be taken off the list pending payment or payment arrangements for their membership dues. Please contact me if you will have a problem making payment by January 5th.

2. Members who are also subscribers to GCA who have not made payment or payment arrangements for their subscriptions fee for 1998 will not receive any issues of GCA for 1998 until arrangements are made. Back issues will be sent once payment or payment arrangements have been made.

We welcome some of our new student members, who signed up at the Geological Society of America meeting in Salt Lake City, October 1998!



Deb Beryfeld
University of New Mexico



Ted Heath & Brad Terhune, South Dakota School of Mines

Victoria Bruce
University of California, Riverside

DO WE REALLY UNDERSTAND THE MECHANISMS OF NATURAL GAS GENERATION AND MIGRATION?

American Chemical Society
Division of Geochemistry
Spring Meeting, Dallas, TX, March 29th-April 2nd 1998

Contact: K. Anderson, Chemistry Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439
Tel: 630-252-1928; e-mail: kbanderson@anl.gov

PROGRAM

Origins of Gas:

- Gas Precursor and Reaction Mechanism Controls on Isotopic Fractionation During Natural Gas Generation -*C. J. Clayton*
- On-line Pyrolysis-GC/IRMS of Coals: Isotope Fractionation of Thermally Generated Hydrocarbon Gases-*R. Gaschnitz, et al.*
- Modeling Gas Isotopic Fractionation During Thermogenic Gas Generation-*Y. Tang, et al.*
- Information of Timing and Mechanisms of Gas Trapping from Noble Gas Data-*P. Gerling, et al.*
- Improved Models for Isotopic Fractionation During Thermogenic Gas Generation-*B.Gramer,et al.*
- Noble Gas and Stable Isotope Constrains on the Origin of Nitrogen in Sedimentary Basins-*C. J. Ballentine, et al.*

Gas Potential Assessment:

- Gas Geochemistry Applied to the Petroleum System-*M. R. Mello, et al.*
- Generation of Methane from Mature Kerogens: Kinetic and Isotopic Approaches-*F.Lorant, et al.*
- Some Evidence Supporting Catalysis in the Decomposition of Oil to Nature Gas-*F. D. Mango*
- Modeling Gas Generation from Coals and Kerogens-*Y. Tang et al.*
- Carbon Isotope Geochemistry of Devonian Gases from West Canada Foreland Basin-*P. D. Jenden*
- Thermogenic Gases from the Polish Bituminous and Brown Coals: Hydrous Pyrolysis and Isotopic Approach *M. Kotarba, et al.*
- In Situ Generation of Gas in Shales Overlying Steamed Heavy Oil Reservoirs-*D. M. Rowe, et al.*

Gas Migration and Accumulation

- Gas Characterization and Physicochemistry of Geological Processes Affecting Hydrocarbons-*A. Prinzhofer, et al.*
- Compositional and Isotope Data on Hydrocarbon Fluid Inclusions - A Tool for Better Understanding of Light Hydrocarbon Migration and Trapping-*B. Andresen, et al.*
- Isotopically Heavy Natural Gas in Pre-Cambrian Crystalline Rocks - South Greenland. An Example Fractionation Due to Migration-*T. Laier, et al.*
- Gas-Oil Ration Prediction by Modeling the Compositional Kinetics and Migration of Petroleum Fluids in Sedimentary Basins-*J. Wendebourg, et al.*
- Sorption of Methane on Coal: Factors Controlling the Coalbed Methane Potential of Type III Kerogen-*R. Gaschnitz, et al.*
- Criteria of the Prediction of HC Pool Presence and Its Phase State in the Recent Sediments by the Sorbed Gases Information-*S. L. Levesbounova, et al.*

Risk Assessment of Non-hydrocarbon Gases

- High CO2 in Natural Gases as a Later Stage High Temperature Component in the Evolution of Petroleum Systems-*M. Schoell, et al.*
- Mantle Derived Carbon Dioxide in the Pannonian Basin - Integration of Rare Gas and Stable Isotope Signatures-*B. Sherwood Lollar*
- Experimental Investigation of the Release of Hydrocarbon and Non-hydrocarbon Gases from Sedimentary Organic Matter-*B. M. Krooss, et al.*
- Isotope Signature of Late Nitrogen Gas Released from Fossil Fuel Organic Matter-*V. Beaumont, et al.*
- Four Sources of Nitrogen Gas in Rotliegend Reservoirs in Northern Germany - Genetic Differentiation and Spatial Distribution-*P. Gerling, et al.*
- Generation of Nitrogen Gas During Thermal Evolution of Sedimentary basins: An Experimental Investigation of Isotopic Fractionation Processes-*D. Vlassopoulos, et al.*
- The Prediction of Hydrogen Sulfide in Hydrocarbon Accumulations in Deeply Buried Carbonate Reservoirs-*M. V. Dakhnova, et al.*

The Mineralogical Society of America

announces the 1999

Grant for Research in Crystallography

From the Edward H. Kraus Crystallographic Research Fund with contributions from the MSA membership and friends

and

MSA Grant for Student Research in Mineralogy and Petrology

from an endowment created by contributions from the MSA membership

The Grant for Research in Crystallography is a $3500 grant for research in crystallography. There are no restrictions on how the grant funds may be spent, as long as they are used in support of research. The only restrictions on eligibility for the grant are that the applicant must have reached his or her 25th birthday but not yet have reached his or her 36th birthday on the date the grant is awarded, and that the person is not a MSA Counsellor. The award selection will be based on the qualifications of the applicant, the quality, innovativeness, and scientific significance of the proposed research, and the likelihood of success of the project. The next award will be made in January, 1999.

MSA Grant for Student Research in Mineralogy and Petrology is a $3500 grant for research in mineralogy and petrology. Students, including graduate and undergraduate students, are encouraged to apply. There are no restrictions on how the grant funds may be spent, as long as they are used in support of research. The award selection will be based on the qualifications of the applicant, the quality, innovativeness, and scientific significance of the research, and the likelihood of success of the project. The next award will be made in January, 1999.

Application forms for both grants may be obtained from the MSA worldwide web home page, http:/www.minsocam.org, or from Dr. J. Alex Speer, MSA Business Office, 1015 Eighteenth St., NW, Suite 601, Washington, DC, 20036-5274, USA (202-775-4344, fax 202-775-0018, j_a_speer@minsocam.org). Completed applications must be returned to the MSA Business Office by June 1, 1998.

Call for Interest from Students

GEOCHEMICAL MODELING SHORT COURSE

GERM Workshop: La Jolla, CA, 10–13 March 1998

We seek to determine the level of interest for having a short course on geochemical modeling techniques. Given sufficient interest, this short course will be run on the first day of the GERM (Geochemical Earth Reference Model) workshop (10 March 1998) and will emphasize geochemical modeling methods using GERM. Personal computers and workstations will be available at UCSD/IGPP/Scripps for this short course. Francis Albarede will be the principal lecturer.

Since the Tuscon Goldschmidt Conference in June 1997 there have been several new additions to the GERM website (http:// www-ep.es.llnl.gov/germ). We encourage all to visit this site and to subscribe to the GERM newsletter (majordomo@aristo.es.llnl.gov — typing "subscribe GERM" in the message). In this newsletter GERM updates and activities will be announced periodically.

$$$ – Travel support for student participation in GERM and the modeling short course will be available on a competitive basis.

We will not run this short course unless there is sufficient interest. Thus, it is essential that those interested in participating in this short course and the workshop write to us at — germ@igpp.ucsd.edu. Details about the GERM workshop are given on the GERM website (http://www-ep.es.llnl.gov/germ).

Hubert Staudigel (hstaudigel@ucsd.edu)
Bill McDonough (mcdonough@eps.harvard.edu)

Geochemical Society-sponsored sessions at the

1998 Spring Meeting of the American Geophysical Union
May 26 - 29, 1998
Boston, Massachusetts

electronic abstract deadline February 26, 1998 (http://www.agu.org)

Qualitative and Quantitative Approaches to the Characterization and Interpretation of Textures of Igneous and Metamorphic Rocks (jointly sponsored with the Mineralogical Society of America)

This session will provide a forum for discussing recent results and advances in textural studies of igneous and metamorphic rocks. Participants will be from a wide range of disciplines that deal with the textural properties of natural, experimental, or virtual rocks, at scales ranging from individual minerals, to plutons and beyond. Recent advances in textural studies include refinement of traditional techniques of microstructural analysis (e.g., measuring inclusion fabrics preserved in porphyroblasts), better methods for the examination and reconstruction of complex features (e.g., 3-D computer-aided visualization and animation), development of analogue materials for studying crystal growth and deformation (e.g., organic polycrystalline melt mixtures), the application of AMS to rock textures, and the application of techniques traditionally used in other disciplines (e.g., x-ray imaging with computed tomography). Topics to be considered include: qualitative and quantitative approaches to texture characterization, nucleation and crystal growth theory, 3-D analysis of textures, the application of high resolution computed x-ray tomography to imaging natural rocks, application of AMS techniques to infer pluton-scale structure, the use of cathodoluminesence as an indicator of growth history, syn- and post-magmatic textural development in plutons, high-T solid-state deformation, supra- and sub-solidus textures, effects of alteration on primary textures, textures associated with ore-systems, discerning high-T metamorphic from magmatic textures, syneusis, and how the analysis of textures has altered traditional ideas in petrology (e.g., fractionation and cumulate theory, kinematics and folding mechanisms in deformed metamorphic rocks, and the origin and significance of magmatic fabrics). The time is right for an interdisciplinary discussion of the characterization, interpretation and significance of textures within Earth's lithosphere, and we invite you to join us in discussing new approaches and results in Boston. We have tentative plans to publish a special issue of papers from this session. A web site, http://www.geol.umd.edu/~piccoli/agu/textures.htm, has been set up to provide early information on this special session.

Conveners: Phil Piccoli, Department of Geology, University of Maryland, College Park, MD 20742-4211, Phone: +1-301-405-6966, Fax: +1-301-314-9661, E-mail: piccoli@geol.umd.edu; John P. Hogan, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019-0628, Phone: +1-405-325-4428, Fax: +1-405-325-3140, E-mail: jhogan@ou.edu; and Scott E. Johnson, School of Earth Sciences, Macquarie University, Sydney, NSW 2109, Australia, Phone +61-2-9850-7694, Fax: +61-2-9850-8428, E-mail: scott.johnson@mq.edu.au

Siderophile and Highly Siderophile Elements in Earth's Mantle

This session will deal with the application of siderophile and highly siderophile elements to the study of the chemical evolution of the mantle and, by inference, the core. Discussion of siderophile and highly siderophile elements within Earth's mantle, and lunar, Martian and asteroidal mantles is welcome. Topics will include the isotopic evolution of Os in various mantle reservoirs, the absolute and relative abundances of the platinum-group elements within the mantle, and W isotope constraints on core formation on the Earth and other planetary bodies.

Conveners: Richard J. Walker, Department of Geology, University of Maryland, College Park, MD 20742-4211, Phone: +1-301-405 4089, Fax:+1-301-314-9661, E-mail: rjwalker@geol.umd.edu; Gerhard Brugmann, Max-Planck-Institut für Chemie, Abteilung Geochemie, Postfach 3060, 55020 Mainz, Germany, Phone: (01149) 6131 305 362, Fax: (01149) 6131 371 051, E-mail: gerhard@geobar.mpch-mainz.mpg.de

ANNOUNCING A TOPICAL CONFERENCE

The Origin of the Earth and Moon

December 1–3, 1998 ✧ Monterey, California

http://cass.jsc.nasa.gov/meetings/origin98/

SPONSORS

Geochemical Society
Lunar and Planetary Institute
National Aeronautics and Space Administration

The 1988 conference *The Origin of the Earth* was an excellent meeting that produced a classic, frequently cited text on the subject. The 1984 conference *The Origin of the Moon* was arguably the most successful conference ever held in planetary geology, bringing together the key players who then and there formulated, debated, refined, and established the giant impact theory of lunar origin. In recent years there have been major advances in these areas, particularly in the fields of geochemistry and petrology. It has become very apparent that a meeting that focuses on the origin of the Earth and Moon, as coupled problems, would be invaluable. For example, discussions about the development of the Earth's atmosphere or hypotheses concerning magma oceans and core formation are esoteric unless constraints on the nature of the interactions that generated the Moon are incorporated. As such, we believe that this conference should focus on the very earliest histories of these bodies, so that nearly everyone present will share a common interest in all aspects of the discussion.

Therefore, this conference is being planned just prior to the 1998 Fall AGU Meeting in San Francisco to encourage interested scientists worldwide to attend and contribute to what we hope will be the third in a series of highly successful topical conferences on origins of planets.

For further information concerning the conference, and to be added to the mailing list for future announcements, please send your request to:

The Origin of the Earth and Moon Conference
Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX USA
E-mail: simmons@lpi.jsc.nasa.gov

CONVENERS

Alex N. Halliday
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E-mail: anh@umich.edu

Michael Drake
University of Arizona
E-mail: drake@lpl.arizona.edu

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California Institute of Technology

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University of Hawai'i

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Australian National University

Special Session on Fluid and Melt Inclusions

at the 17th General Meeting of the International Mineralogical Association (IMA)
Toronto, Canada, August 9th - 14th, 1998

abstract deadline: March 15, 1998

On behalf of the Working Group on Inclusions in Minerals, we are organizing a special session on fluid and melt inclusions at the 17th General Meeting of the International Mineralogical Association, to be held in Toronto, Canada, August 9th - 14th, 1998. The session will run over 2 days. The format (as dictated by the IMA organizing committee) will have morning oral presentations, most or all of which will be given by invited speakers, and afternoon poster sessions for most of the volunteered contributions. We have decided to focus the first day's oral presentations on the impact of recent fluid inclusion studies in understanding the genesis of mineral deposits and the second day to advances in melt inclusion studies in understanding magmatic processes. Both poster sessions will be open to any inclusion topic.

The circular, along with abstract forms and registration information is available from:

IMA'98, Department of Geology, University of Toronto, Earth Sciences Centre,22 Russell St., Toronto, Ontario Canada, M5S 3B1; Tel: +1 416-946-3306; Fax: +1 416-978-3938; e-mail: ima98@quartz.geology.utoronto.ca

There is also a web site which has the circular along with a form for ordering the circular. The address is: http://www.geology.utoronto.ca/IMA98

Contacts: Maria-Luce Frezzotti, Dipartimento Scienze Terra,Universita' di Siena,Via delle Cerchia n.3, 53100 Siena,Italy; Tel: +39 577 298915; Fax: +39 577 298815; e-mail: frezzotti@dst.unisi.it *or* Iain M. Samson, Department of Earth Sciences, University of Windsor, Windsor, Ontario, Canada, N9B 3P4; Tel: 519-253-4232 x2489; Fax: 519-973-7081; e-mail: ims@uwindsor.ca

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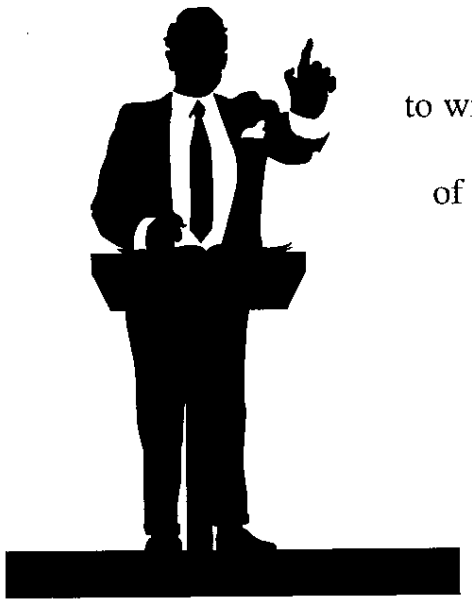
Authors wanted!



to write brief review articles, letters, and other communications of a timely nature for publication in *The Geochemical News.*

Please contact the Editor with your ideas for articles.

(Where else can you get published within 3 months?)

Plan to Attend the Eighth Annual V.M. Goldschmidt Conference

August 30 - September 3, 1998 Toulouse, France

The Eighth Annual V.M. Goldschmidt Conference will be held in Toulouse, France from Sunday August 30 to Friday September 3, 1998. The meeting will be followed by optional field excursions to the neighboring Pyrénées mountains.

This will be the first time that the Goldschmidt will be held in France. The location of the meeting, Toulouse is a university town known for its tradition of culture and 'art de vivre'.

Toulouse, known as 'la ville rose' because of its magnificent brick-based architecture, is the fourth largest city in France. Situated in the south of France, Toulouse is located west of the Mediterranean Sea (90 miles/150 kilometers) and east of the Atlantic Ocean (150 miles/250 kilometers). Summer weather in Toulouse is typically pleasant and sunny, with daytime temperatures ranging from 75° F/24° C to 85° F/30° C.

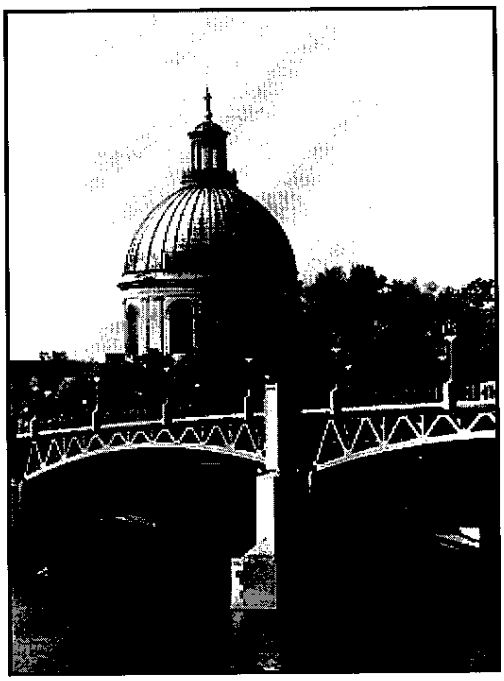
The Goldschmidt 1998 Conference Venue, Université de Toulouse I, is located in the city center, close to hotels, restaurants, outdoor cafés, shopping, and several historical monuments and museums. The University of Toulouse is the second largest in France ; the campus is surrounded by churches, monasteries, and houses dating from the 11th to 17th centuries.

The area surrounding Toulouse is equally interesting. Several exciting touristic destinations are within a very short distance: the medieval city of Carcassone, the Perigord and Dordogne valleys, and the Pyrénées Mountains.

The Conference is organized by the Observatoire de Midi-Pyrénées, an institution dedicated to teaching and research in Earth and Planetary Science, ranging from extra-galactic astronomy to the internal structure of the Earth. If you are interested in obtaining information regarding the conference, send an e-mail message to the organizers(goldconf@lucid.ups-tlse.fr) or visit the web site at http://www.obs-mip.fr/omp/umr5563/goldconf.html.

Hosted by
Observatoire de Midi-Pyrénées
Institut des Sciences de la Terre
CNRS/Université Paul-Sabatier

Sponsored by
European Association of Geochemistry
Geochemical Society
Université Paul-Sabatier
CNRS



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E-mail : goldconf@lucid.ups-tlse.fr

Schedule

April 3, 1998	Abstract deadline
June 1998	Final Announcement/Program
August 30-September 3, 1998	Eigth Annual V. M. Goldschmidt Conference

1998 GORDON RESEARCH CONFERENCE ON ORGANIC GEOCHEMISTRY

HOLDERNESS SCHOOL, NEW HAMPSHIRE, USA, AUGUST 9-14, 1998

Kenneth E. Peters, ***Chairman (214-951-3272, kepeters@dal.mobil.com)***
John I. Hedges, ***Vice Chair (206-543-0744, jihedges@u.washington.edu)***

Send abstracts for posters to:
John I. Hedges
University of Washington, Box 35940
Marine Sciences Building, Room G
Seattle, WA 98195-7940 U.S.A.

How to get GRC information:
GRC@GRCMAIL.GRC.URI.EDU
Phone: 401-783-4011
GRC@GRCMAIL.GRC.URI.EDU
Web: HTTP://www.grc.uri.edu

GEOCHEMICAL EVIDENCE FOR PAST LIFE ON MARS (David DesMarais)
- Everett Gibson, Jr., *Possible relic biogenic activity in meteorite ALH840001*
- Jeffrey Bada, *Organic compounds on Mars*

ORGANIC MATTER PRESERVATION IN SEDIMENTS (Cindy Lee)
- Richard Jahnke, *Marine organic carbon cycling: Production, vertical flux, deposition and preservation*
- Larry Mayer, *Relationships between organic matter and mineral surfaces*
- Elizabeth Canuel, *Application of lipid biomarker techniques to understanding and quantifying early diagenetic processes*

GEOCHEMISTRY OF HYDROTHERMAL ECOSYSTEMS AND DEEP-EARTH MICROBES (Roger Summons)
- John Parkes, *Acetate generation in deeply buried sediments*
- Roger Summons and Linda Jahnke, *Geolipids from cyanobacteria: New studies of mats and cultures from the hydrothermal ecosystems of Yellowstone National Park*

CHEMOSTRATIGRAPHY AND THE GEOCHEMISTRY OF MAJOR TIME BOUNDARIES (Lisa Pratt)
- Albert Holba, *Biomarkers and mass extinctions: Concordance and discordance between biochemistry and major geologic events*
- Evelyn Krull, *Chemostratigraphic identification of the Permian-Triassic boundary on land from the $\delta^{13}C$ of paleosol organic matter*
- Lisa Pratt, *Marine and terrigenous records of perturbations in the carbon cycle during the Mid-Cretaceous greenhouse maximum*

COMPUTATIONAL ORGANIC GEOCHEMISTRY (Yungchun Tang)
- Adri van Duin, *Several applications of computational chemistry in organic geochemical research*
- Yitiam Xiao, *The kinetics and mechanism of oil and gas generation: A first principle approach*

THERMOCHEMICAL SULFATE REDUCTION (Martin Fowler)
- Martin Fowler, *The influence of thermochemical sulfate reduction on hydrocarbon and Pb-Zn deposits in Western Canada*
- Vern Stasiuk, *Petrographic and chemical studies of pyrobitumens associated with thermochemical sulfate reduction*
- Richard Worden, *Thermochemical sulfate reduction: The rock angle*

GENERATION AND PREDICTION OF HYDROCARBON GASES, CO2, AND NITROGEN (Francois Lorant)
- Yungchun Tang, *Modeling thermogenic gas generation and gas isotope ratios for natural gas*
- Francois Lorant, *Methane versus nitrogen generated at high maturity: Potentials, kinetics, and isotopic signatures*

GENERATION AND EXPULSION OF HYDROCARBONS (Dan Jarvie)
- Francois Béhar, *Coal kinetics: Comparison between closed (hydrous and anhydrous) and open systems*
- Wuu-Liang Huang, *Oil generation and cracking kinetics determined by fluorescence spectroscopy*
- Cliff Walters, *Calibration of programmed pyrolysis kinetics to the real world*

RESERVOIR FLUIDS, SEALS, AND DYNAMIC PROCESSES (Peter Meulbroek)
- Steve Franks, *Intramolecular variation of stable carbon isotopes in organic acids from oilfield waters*
- Chris Clayton, *Dynamic seals, pressure dissipation and fluid flow in caprocks*
- Peter Meulbroek, *Estimating gas flux rates, seal leakage, and mudstone permeability from reservoir fluid compositions*

TREIBS MEDAL PRESENTATION
ORGANIC GEOCHEMISTRY DIVISION BEST PAPER AWARD

Formation of the continents — dribble or big bang?

Paul J. Sylvester
Research School of Earth Sciences
The Australian National University
Canberra ACT 0200, Australia

The continents are a thin, light-weight veneer covering 40% of the Earth's surface. They have an average thickness of ~40 km, an average density of ~2.8 g/cm^3, and a tonalitic bulk composition[1,2]. They are sometimes referred to as the scum of the Earth because, although widespread, their total mass is only about a half a percent of that of the mantle. Scum or not, the continents are worthy of our interest. They are a repository for many chemical elements present originally in chondritic proportions in the mantle and thus hold clues to the processes and time-scales of global differentiation. Continent development also modulated oxygenation of the atmosphere and oceans, and the development of life[3].

It is almost certain that the continents were "sweated-out" of the mantle, but exactly when this occurred has proven to be a most intractable problem, even after more than 30 years of intense study. There are two plausible classes of models: (1) progressive growth of the continents to their present volume through an erratic "dribble" of successive additions from the mantle, with little or no loss back again[1,4-9]; and (2) removal of the present volume of the continents in an early "big bang" and recycling of that volume through the mantle in a near steady-state since then[10,11]. Representative growth curves for some dribble[1,9] and big bang[10] models are illustrated in Figure 1.

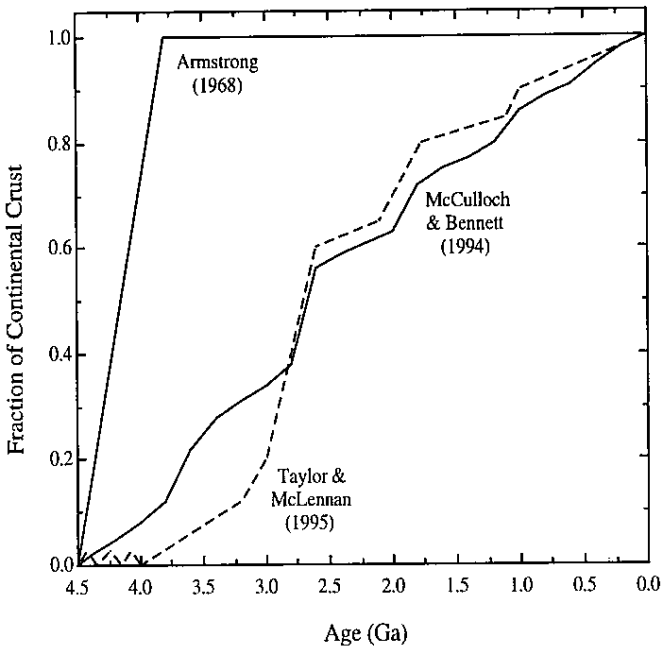

Figure 1. Models for the change in total volume of continental crust with the age of the Earth.

Growth model

The leading model for the origin of the continents has been, until recently, one of progressive, episodic growth. To most geologists, the evidence for a gradual but intermittent increase in continent volume with time has been rather compelling. Rocks now found on the continents, excluding those that formed by remelting of rocks much older than themselves, have ages that cluster around several peaks, most notably at 2.7, 1.9 and 1.1 Ga[9]. The integrated age of all continental rocks, as inferred from Nd isotope measurements of river sediments, is about 2 Ga[12]. Rocks formed before about 3.5 Ga are extremely rare, accounting for only about a half a percent of the total[13], and no rocks older than 4.0 Ga are known at all. The straightforward interpretation of these observations is that the continents were removed from the mantle in stages, starting in earnest only after the Earth had been in existence for more than a billion years and continuing through today. In this way, the volume of continental crust increased through time.

The main criticism of the growth model is that it appears to be at odds with the thermal evolution of the Earth[14]. Heat produced from the radioactive decay of isotopes of K, U and Th has declined progressively with time, so mantle convection in the early Earth was probably much more vigorous than it is today. If the continents were indeed sweated out of the mantle, why was the initiation of large-scale crustal growth delayed until after the Earth had been cooling for more than a billion years?

Steady-state model

The alternative model, first proposed 30 years ago by Armstrong[10], calls on early formation of the continents and steady-state recycling to maintain a constant volume. Magmatic additions from the mantle to the continents are balanced by loss back again. Both addition and subtraction rates slow with time, as the Earth cools, but the balance is maintained. The attractive feature of this model is that it mimics the expected thermal evolution of the Earth in that the most rapid formation and destruction of continents occurs early, when heat production was greatest. It also provides a plausible explanation for the distribution of ages of rocks in the continents: rocks older than 3.5 Ga being rare not because they formed in small volumes but because they failed to survive the recycling "engine" of the early Earth. The few very old rocks preserved today escaped recycling by being either "lucky" or in some way predisposed to avoid destruction. Indeed, some have suggested that the preservation of old crust requires thick roots of mantle lithosphere of a distinct composition[15]. It is entirely possible that such roots did not form everywhere and a highly biased record of Archean crust has been preserved[16]. Thus, the "spikiness" of ages in the surviving rock record could have more to do with selective preservation than to episodic growth. Intense meteorite bombardment during the Earth's first 600 Ma may also have contributed to the destruction of the early crust[17].

Present recycling balance

One might think that the easiest way to begin evaluating whether the continents have grown through time is to deter-

mine whether they are growing today. However, there have been two detailed estimates of "modern" recycling fluxes and, unfortunately, they arrive at opposite conclusions. Reymer and Schubert[6] deduced that the magmatic addition rate to the continents in the Mesozoic-Cenozoic has been 1.65 km^3/yr, based on data from 17 island-arcs and 3 ocean-island "hot-spots". Using earlier estimates for the flux of continental detritus returned to the mantle at island-arcs by sediment subduction (0.40 km^3/yr) and mechanical erosion (decretion) of the overriding plate (0.18 km^3/yr), they concluded that the continents have been growing at a net rate of ~1 km^3/yr since the Mesozoic. In contrast, from a study of 37 trenches at active convergent plate margins, von Huene and Scholl[18] estimated that 0.7 and 0.6-1.1 km^3/yr of continental material is lost by sediment subduction and decretion, respectively. They concluded that there has been little net continental growth over the past 200 Ma, assuming Reymer and Schubert's[6] magmatic addition rate is accurate.

Since these estimates were made, the difficulty of making an accurate assessment of the present recycling balance has become even more apparent. In addition to island-arc and hot-spot volcanism, it is now thought that large flood basalt provinces, erupted both on continents and in ocean basins[19], as well as being ponded at their bases[20], represent a significant magmatic flux to the continents. Ocean plateaus in particular may have served as the seeds for continent nucleation and growth by subsequent convergent plate margin processes[21]. However, the flux of flood basalt volcanism has not been constant during the past 200 Ma, having been particularly great during the Cretaceous[22]. Thus, it is difficult to know whether the average flood-basalt-flux for the last 200 Ma would be representative of any other 200 Ma interval of Earth history. Also, most of the ocean plateau basalt erupted during the Cretaceous has yet to be incorporated or "transformed" into continents, so quantitative estimates of its contribution depend on models of how this occurs[23].

With regard to recycling of continental material back into the mantle, there is circumstantial evidence that crustal delamination following continental collision may be as important as sediment subduction and erosion at island arcs[24]. Collision-related plateaus such as in Tibet are characterized by rapid crustal uplift and extension, high heat flow, high-temperature metamorphism, and granite genesis. These features have been attributed to delamination of the mantle lithosphere and its replacement by comparatively hot asthenosphere[25,26]. Some models predict that, during collision, portions of the middle and lower continental crust may be delaminated as well[27,28]. This would be facilitated by the conversion of gabbro to eclogite facies rocks in the deep crust, the latter being denser than mantle peridotite[24]. Removal of lower crustal eclogites provides a plausible explanation for why the continental crust has the bulk composition of a tonalite even though partial melts of the mantle are overwhelmingly basaltic[29].

Archean crustal thickness and composition

Estimates of the thickness and composition of continental crust in the Archean have been discussed extensively in the debate between proponents of the growth and steady-state models of continent formation[1]. The idea is that, in modern settings, continental crust thickens as it develops, progressively growing above sea level, and "matures" in composition, first being formed from basalts and andesites, and later undergoing intracrustal differentiation to form potassic granites. Island-arcs in the Pacific, for example, range from those built on thin, largely submerged crust dominated by basalt and andesite, such as the Marianas, to those on thick subaerially-exposed crust which contains potassic granitoid, such as Japan. Thus, assuming analogous continent-forming processes, the character of the Archean crust may provide some guide to its total volume: thin, immature crust dominating in the Archean according to the growth model; a mixture of mature and immature crust expected in the steady-state model.

Early work on the character of Archean continental crust suggested that its composition was decidedly more immature than post-Archean crust, containing mostly basalts and tonalites and few potassic granites[30,31]. Taylor and McLennan[1,31], in particular, have argued that post-Archean sedimentary rocks have chondrite-normalized rare-earth-element patterns with large negative Eu anomalies, reflecting large-scale intracrustal differentiation, whereas the patterns for Archean sedimentary rocks have small or no Eu anomalies. They saw this as evidence for progressive growth of the continents. It is now recognized however that Archean potassic granites are widespread, being major components of most cratons including those formed in the middle and early Archean[32]. Supposed differences in the sizes of Eu anomalies in sedimentary rocks are largely a function of tectonic setting rather than of age[33,34]. Cratonic shales of both Archean and post-Archean age, for example, possess large negative anomalies[1,34].

It seems likely that large proportions of both mature and immature crust were present in the Archean, as they are today. Archean cratons preserve high-pressure rocks[35], mineral assemblages reflecting modern-like geothermal gradients[36] and unconformities indicating sea level emergence[37]. This suggests that at least portions of Archean continents were as thick as modern continents. Whether this is evidence for the steady-state model of continent formation is, however, debatable. Archean continents may have been just as differentiated and thick as modern continents but this does not require them to have had the same total volume.

Freeboard

It was once thought that the record of freeboard (sea level) on the continents through time could provide a straightforward measure of the extent of continental growth. Assuming constant ocean volume, constant sea level on the continents would indicate no growth, whereas a decline in sea level would favor growth[6,10]. This method has not proved to be useful for two reasons: (1) the Archean sedimentary record is not sufficiently well-preserved for reliable estimates of freeboard to be made[38]; and (2) freeboard variations are critically dependent on a number of poorly constrained factors including subsidence of the continents with time[14] and secular evolution of asthenospheric mantle temperature[39].

Zircons in Archean sediments

In the search for some record of a now lost, extensive early Archean continental crust, some have turned to zircons in

Continued on page 23

THE GEOCHEMICAL SOCIETY

Call for Nominations for 1999 Joint EAG-GS Geochemistry Fellows

The European Association of Geochemistry (EAG) and the Geochemical Society (GS) established in 1996 the honorary title of Geochemistry Fellow, to be bestowed upon outstanding scientists who have, over some years, made a major contribution to the field of geochemistry. Existing and new Urey, Goldschmidt and Treibs Medal winners become Fellows automatically. In addition, up to 0.5% of the total combined membership of the two societies should be elected as Fellows each year. This corresponds to approximately 15 honorees per year at current enrollment levels, and allows for growth in the societies. Nominations will be sought and recommendations for election made by a committee (Fellows Selection Committee) of 8 persons, 4 from GS, and 4 from EAG.

Any member of either society may nominate Fellows by right. No individual may be elected a Fellow, except as a result of having previously won the Urey, Goldschmidt or Treibs Medal, while serving either on the Fellows Selection Committee or as a Council / Board member of EAG / GS. The Selection Committee may not nominate individuals, but may actively solicit nominations from others. Members of the Selection Committee and Council / Board may not vote on any nomination where there is a clear conflict of interest. Final approval of all nominees will be made by the EAG Council and the GS Board of Directors. In the event that the EAG Council and the GS Board differ over the ratification of a nomination, the Executive Committee of the Goldschmidt Forum (the Presidents and Vice Presidents of EAG and GS) will resolve the issue. Fellows will be inaugurated at the 9th V.M. Goldschmidt Conference in Cambridge, MA in 1999.

Nominations should include the name, address, and telephone number of the nominee, a citation of no more than two pages describing the contributions the individual has made to geochemistry, and up to three letters of support from members of either society. The nomination should also include the nominator's name, address, phone number, and signature.

Nominations should be sent no later than November 1, 1998 to:

Dr. John M. Hayes (Chair, Fellows Selection Committee)
WHOI, MS8
Woods Hole, MA 02543 USA

T: 508-289-2585
F: 508-457-2183
E: jhayes@whoi.edu

Geochemistry Fellows (excluding Urey, Goldschmidt and Treibs Medalists)

1996: William Compston, Willi Dansgaard, John Edmond, John M. Hayes, Marc Javoy, Ho-Kwang Mao, Stephen Moorbath, John Reynolds, Jean-Guy Schilling, Nick Shackleton, Mitsunobu Tatsumoto, Werner Stumm, George Tilton, Grenville Turner, Heinrich Wänke, William White

1997: Donald J. DePaolo, Jan Bottinga, Philip Abelson, Gunter W. Lugmair, Tom Krogh, Michael O'Hara, Ikuo Kushiro, Fred T. Mackenzie, Denis M. Shaw, Bruno J. Giletti, George W. Wetherill, Keith O'Nions, Ian Carmichael, Edward M. Stolper, Derek York, Alex Navrotsky

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Call for Papers for the Symposium on

New Developments in the Geochronology of Clays, Zeolites, and Oxides

1998 Clay Minerals Society Annual Meeting
Case Western Reserve University, Cleveland, Ohio, USA, June 6-10, 1998

The 1998 Annual Meeting of the Clay Minerals Society will be held at Case Western Reserve University in Cleveland, Ohio, on June 6-10, 1998. At this meeting, there will be a symposium on *"New Developments in the Geochronology of Clays, Zeolites, and Oxides"*. This symposium will focus on recent progress in methodology and new applications in the geochronology of these minerals. The symposium will provide a great opportunity for sharing and learning new technology and knowledge in this exciting field.

Deadline for submitting abstracts is March 1, 1998. If you are interested in submitting an abstract for the symposium, please contact me. I would appreciate to receive titles by February 10, preferably by e-mail or by fax (see below). I will send you information pertaining to the meeting and the instruction on submitting the final abstract.

Mingchou Lee, Symposium Chairperson; Mobil E&P Technical Center, 3033 Irving Blvd., Dallas, TX 75247 U.S.A.
Tel: (214)-951-3058; Fax: (214)-905-7058; E-mail: Mingchou_Lee@email.mobil.com

The Patterson Medal in Environmental Geochemistry

The Geochemical Society is establishing the new honorary award of the Patterson Medal, named after the late Clair C. Patterson, to be given for innovative and exciting research in environmental geochemistry. Environmental geochemistry is an important expanding field in which major discoveries are likely to play a societal as well as scientific role. There are few awards in this area. Clair Patterson was a key player in understanding the environment and developing environmental geochemistry. It was clearly the major portion of his life's work and this award will be a fitting tribute to him as well as a way of recognizing creative science and scientists.

The Patterson Medal will be bestowed upon scientists who have recently made a particularly important and innovative breakthrough in environmental geochemistry, considered to be of fundamental significance. The research must be highly original and contribute in a significant fashion to our understanding of the natural behavior of the Earth's environment. Such a contribution must be in the form of a widely recognized important piece of innovative scientific research published in a peer reviewed journal. There is no age limit associated with this honor. The award will be bestowed biennially and is to be distinguished from the Goldschmidt and Treibs Medals and the Geochemistry Fellows. Such awards reflect a longer term of achievement and are generally bestowed upon senior individuals, whereas the Patterson Medal is for a single accomplishment, irrespective of age or career stage. The closest parallel is with the Clarke Medal but this is reserved for early-career scientists. A Clarke Medal awardee cannot receive the Patterson Medal for the same accomplishment (and vice versa). The awardee does not have to be a member of the Geochemical Society. If the scientific discovery is clearly a joint effort then the award may be shared in a given year.

Nominations will be sought, and a recommendation for the awardee plus an alternate, made by a committee (Patterson Medal Committee) of 6 persons. The first Patterson Medal Committee will comprise Joel Blum (Dartmouth College), Ed Boyle (M.I.T.), Alex Halliday (University of Michigan), Malcolm McCulloch (A.N.U.), Judy McKenzie (ETH Zürich) and Lee Silver (CalTech). Any member of the Geochemical Society can nominate an individual, with the exception that the Patterson Medal Committee cannot nominate any individual themselves, unless no suitable nomination is received from the membership. Nobody is permitted to be selected for this award while serving on the Patterson Medal Committee or on the Board of Directors of the Geochemical Society. Members of the Patterson Medal Committee and Board of Directors cannot vote on a nomination where there is an obvious conflict of interest. If none of the nominees is judged to have made a sufficiently distinctive contribution, the award will not be made in that particular year.

Nominations will only be considered if accompanied by the same critical mass of supporting material as follows:

1 A citation of no more than two pages describing the contribution the individual has made to geochemistry.

2 A two-page condensed resume that includes education and employment history together with details of service to national and international scientific and educational organizations. Personal details and funding record are not required.

3 A list of no more than 10 peer-reviewed publications relevant to the accomplishment being recognized, with full references.

4 Up to three letters of support.

Nominations for the first Patterson Medal should be sent to Alex Halliday, Department of Geological Sciences, The University of Michigan, 2534 C.C. Little Building, Ann Arbor, MI 48109-1063, by May 1, 1998.

Notes from the OGD Chair:

Mike Lewan

As the new Chairperson of the Organic Geochemistry Division (OGD) of the Geochemical Society (GS), I would like to give the membership a brief summary of my charge for the next two years and recent activities within OGD. First, the membership extends its thanks to John Hedges for serving as the OGD Chair for the last two years. John's leadership produced two excellent symposia at the Annual Meeting of the Geological Society of America (GSA). The first of these symposia that John sanctioned (1996, *Organic Geochemistry-Linking the Biosphere and Geosphere*) brought together a wide spectrum of organic geochemists dealing with research issues in essentially every major discipline within organic geochemistry. The second symposium (1997, *Organic Perspectives on Geochemical Processes*), in which John was an organizer with Cindy Lee and Stuart Wakeham, dealt with a wide range of geochemical processes extending from early diagenesis in soils and water columns through late catagenesis deep within sedimentary basins. From my own experiences, I have always found that meetings with this breadth of expertise are helpful in providing new insights and methods for resolving issues and controversies within our scientific community. These symposia also gave the geological community at the GSA meetings an opportunity to learn about the interplay between geology and organic geochemistry. Continuing in this vein, Barbara Sherwood-Lollar and I will be organizing the 1998 symposium on *Research Issues in Petroleum and Environmental Organic Geochemistry*. With employment opportunities continuing to open up in both these areas, Barbara and I felt that it would be helpful for the membership to get a summary of key research issues confronting these two industries. The speakers will be invited, and we are open to suggestions from the membership on specific topics or speakers.

In addition to making sure OGD remains representative of all the disciplines in organic geochemistry, I feel it is also my charge to foster a collaborative relationship with other related associations and societies. As we are all aware, the number of meetings and publications within organic geochemistry continue to grow and tax our ability to provide lucid presentations, meaningful publications, and thorough reviews. While this trend is not likely to diminish, we can work more collaboratively among the related organizations to avoid duplication of efforts and help facilitate the science in a more time efficient manner. I encourage our members who are also members of related organizations, such as the European Association of Organic Geochemists, Geochemistry Division of the American Chemical Society, Association of Petroleum Geologists, Society of Organic Petrology, International Humic Substances Society, and Gordon Research Conferences, to use *The Geochemical News* to announce meetings and awards, highlight new discoveries and methods presented in the literature, present editorial comments on societal issues or government policies that affect our science, and feature notable accomplishments by members. To facilitate this collaborative effort, I feel it is important that the officers of these related organizations receive copies of *The Geochemical News* regularly and feel free to use it for communicating information to the geochemistry community at large. Similarly, the OGD Executive Committee and members are expected and encouraged to use *The Geochemical News* to communicate activities within the organization and the geochemistry community. We are fortunate to have a dedicated and enthusiastic editor like Neil Sturchio to facilitate the newsletter, and I hope we all take advantage of this opportunity to its full capacity.

In the spirit of working more closely with the Geochemical Society, the members of the OGD Executive Committee will take office on January 1 instead of after our annual meeting. Since the OGD Chair and Secretary serve on the Board of Directors of the Geochemical Society, this will make the changing of officers in both parts of the organization concurrent. OGD members should also be aware of the opportunity to organize sessions for the V. M. Goldschmidt Conferences. Jun Abrajano is currently soliciting suggestions on topics and speakers for a tentative session at the 9th Goldschmidt Conference in 1999 (Boston) on the interaction of metals and organic matter. I encourage any GS members interested in such a session to contact Jun (email: abrajano@anl.gov) at their earliest convenience.

On a final note, I would like to thank the members of the Treibs Medal and Best Paper committees for their diligence in selecting the recent recipients of these awards. I am pleased to announce that John Hayes is the 1998 recipient of the Treibs Medal for his pioneering and innovative contributions in stable isotope organic geochemistry. And recipients of the 1996 Best Paper Award are Elizabeth Canuel and Christopher Martens for their paper in *Geochimica et Cosmochimica Acta* entitled "Reactivity of recently deposited organic matter: Degradation of lipid compounds near the sediment-water interface". Both awards will be formally presented at the Gordon Research Conference on Organic Geochemistry at Holderness School, NH this summer, and the award citations will be published in GCA later this year.

I look forward to the next two years as the OGD Chair, and I trust a collaborative spirit within the geochemistry community will continue to grow.

Michael D. Lewan

email: mlewan@usgs.gov
tel: 303/236-9391
FAX: 303/236-3202

Direct Observation and Measurement of Hydrothermal Reactions

Symposium to be held at the 8th V.M. Goldschmidt Conference
Toulouse, France, August 30 – September 3, 1998

The goal of this symposium is to bring together experimentalists and field geochemists who are using innovative methods to directly observe and characterize hydrothermal processes and species in the laboratory, monitor hydrothermal reaction progress parameters, and obtain real-time chemical data in active hydrothermal systems. Methodologies might include *in situ* measurements of pH, gas fugacities and species activities; spectroscopic determinations of reactant or product concentrations and/or species and solvent structures; solution conductance; scattering of X-rays and neutrons at elevated temperatures and pressures to elucidate solvent or solute structure; direct observation of mineral dissolution and precipitation, atomic scale processes, and fluid phase equilibria under hydrothermal conditions; and field-deployed monitoring or observation systems to obtain similar data from active hydrothermal systems, such as seafloor hot springs, volcanic vents, and bore hole studies in geothermal and hydrocarbon reservoirs. We are planning a full day oral session, to include 3 to 4 keynote addresses, and an associated poster session. A special issue of *Chemical Geology* will be published from the symposium proceedings. Those interested in participating should contact one of the convenors by **March 1, 1998.**

Convenors:
David J. Wesolowski, Chemical and Analytical Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee, 37831-6110, USA; **dqw@ornl.gov**

Terry M. Seward, Institut für Mineralogie und Petrographie, ETH-Zentrum, CH-8092 Zürich, Switzerland; **tseward@erdw.ethz.ch**

Eric H. Oelkers, Goldschmidt Organizing Committee Representative, Université Paul-Sabatier, 3100 Toulouse, France; **oelkers@cict.fr**

2nd European Conference on the Geochemistry of Crustal Fluids: Characterization of Reactive Transport in Natural Systems

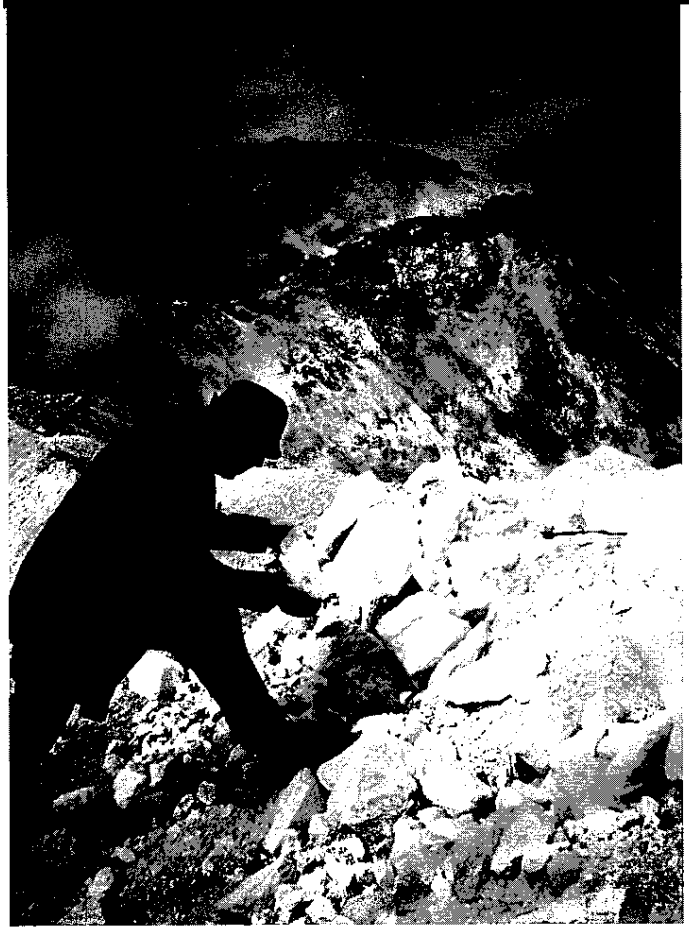
22-27 May 1998, Aghia Pelaghia, near Heraklion Crete, Greece

Abstract deadline: February 28, 1998

Chairman: Eric H. Oelkers (Toulouse)
Vice Chairman: Sigurdur R. Gislason (Reykjavik)

Concerns about the environment and the future availability of mineral resources have provoked an explosion of new research in the field of reactive chemical transport in natural systems. The goal of this second European Research Conference on the Geochemistry of Crustal Fluids is to present, review, and discuss recent advances in the understanding of reactive chemical transport, from the surface of Earth into subduction zones. Invited lectures will cover experimental, field, and computational approaches towards quantifying the rate, extent and consequences of chemical transport due to fluid flow and fluid/rock interaction in natural systems on the surface and in the crust of the Earth. Emphasis will be placed on thermodynamics of natural fluids, mineral surface chemistry, and the effect of fluid phase chemical transport in surficial, environmental, sedimentary, volcanic, and metamorphic systems. The meeting will comprise 6 sessions of lectures given by invited speakers and a half-day field trip. Poster sessions will be organised; all participants are encouraged to contribute posters.

Further information from Eric Oelkers: oelkers@cix.cict.fr *or* Siggi Gislason: sigrg@raunvis.hi.is
Abstract deadline is February 28, 1998. Abstracts should be sent to the European Science Foundation, 1 quai Lezay-Marnesia, F-67080 Strasbourg CEDEX, France. Abstract forms are available from the ESF web site: http://www.esf.org/euresco/Lc96.htm



A rare photograph of W. F. Giggenbach looking at a rock, atop Satsuma Iwojima. The rock he is holding was originally a rhyolite but is now 99.9% silica. It was isochemically leached by hyperacidic condensates of volcanic vapor seen discharging in the background. (Photo by J.W. Hedenquist, October, 1991).

Werner F. Giggenbach, Geochemist

1937 - 1997

"They had brought me back from the depth of Erebus - the twilight of the Occident, where lie Hades and sunless land of the Cimerians, personified as son of Chaos, brother and husband of night, father of Aither and day."

So wrote Werner Giggenbach following his attempt in 1978 to collect the first samples of volcanic gas from the Mt. Erebus lava lake in Antarctica. Unfortunately, the volcano chose to erupt as he was dangling on the end of a 100-m long rope near the crater floor. As described below, he was hauled out just in time [see p. 28-29]. Two decades later, after sampling volcanic gases in over 20 countries on all continents, Werner died at Rabaul, Papua New Guinea in early November last year. He was on a sampling trip with his colleague and wife, Agnes Reyes, to collect gases from this tectonically complex region; he thought such samples would provide insight on recycling of subducted material. The trip was a present to himself. He was two days short of his 60th birthday.

Werner was born in the Bavarian city of Augsburg in 1937, and at the age of four he knew that he would be a scientist. Some of his early childhood experiments confirmed that he was destined for chemistry, such as the making of bromine gas in his bathroom, or the firing of saltpeter rockets with his brother. As all good scientists do, he learned from experience. He was sick for two days after the bromine escaped his retort and filled the tub; he "shovelled" the heavy gas out the window, alternately sticking his head outside to breath, concerned what would happen if he opened the door. He also found out how wetting the saltpeter increased its explosiveness, losing control of the rocket and having it land in the neighbor's living room (through the roof and ceiling).

During a term of military service Werner developed a dislike for bureaucracies and illogical, "silly" decision makers. He crossed swords with the System on many occasions; more often than not Werner prevailed, either through force of argument or sheer stubbornness. Once he argued with a Japanese matron looking after the trail head of a steep climb to a remote shrine. She maintained that he could not go in his wooden soled Birkenstock sandals, and he argued that he had climbed Mt. Etna in them; never mind that neither understood the other's language. Finally she threw up her arms and let Werner pass. Only on descent, grasping roots to ease his plummet, did he admit that other footwear might be more appropriate. At other times he took his arguments to a higher level, such as when he convinced a Prime Minister to overrule a Navy decision, and thus allow a Soviet research vessel into New Zealand waters.

Werner graduated as Diplom Chemiker from the University of Munich in 1964, and two years later was awarded a Dr. rer. nat. (summa cum laude) from the Technical University of Munich for his thesis on the blue sulfur. Student visits to volcanic and geothermal areas in Italy and Iceland stimulated his interest in natural hydrothermal systems. Following a two-year post-doc at Michigan State University, where he worked on Ti(III) complexes, he accepted an offer from Jim Ellis to join the DSIR Chemistry Division in New Zealand in 1968. This move completed his transition to geochemistry, although he remained a chemist through and through. Early laboratory work in New Zealand focussed on the behavior of sulfur in hydrothermal solutions, leading to studies on topics such as the second dissociation constant of hydrogen sulfide, and the behavior of polysulfide species at elevated temperatures. These were the heydays of hydrothermal geochemistry in New Zealand, with a host of geochemists assembled by Ellis blending observation and sampling of natural systems with rigorous laboratory analysis and experiments.

During the 1970s Werner was instrumental in developing techniques for the representative sampling of volcanic and geothermal fluids, techniques that are now standard the world over. At the same time, he started to formulate his framework to interpret the evolution of crustal fluids and the processes of water-rock interaction. He was seconded to the International Atomic Energy Agency in Vienna from 1980 to 1982, during which time he worked on geothermal exploration around the globe. The

1980s saw Werner expand his horizons to consider the link of tectonic setting to fluid composition, including the contribution from mantle sources. New Zealand science was restructured in 1992, and with it Werner accompanied the geochemistry program in its shift to the Institute of Geological and Nuclear Sciences, although more appropriately, New Zealand geochemistry followed Werner's move to this new institute. He was synonymous with geochemistry in New Zealand, and to many of his colleagues around the world his work on crustal fluids defined the direction in which many of us followed.

Werner published many of his evolving ideas in short papers in proceedings volumes, and careful reading of these illustrates the development of his thinking on the sources of hydrothermal components, and the hierarchy of crustal processes. Examples include his N2-Ar-He plots that highlighted the magmatic (subduction recycled)-meteoric-mantle endmember sources, respectively, of these relatively unreactive species. He used N2/Ar corrections to subtract the meteoric component, and coupled the results with He isotope constraints to identify subduction recycling versus mantle input to hydrothermal fluids, arguing that relatively constant N2/CO2 ratios in the corrected gas compositions of the subduction component indicate fundamental controls on recycling. This was the topic he was pursuing with his recent sampling efforts of volcanic and geothermal fluids from hotspots, spreading centers and backarc regions around the globe.

Recent collaboration with colleagues from a variety of backgrounds extended his approach to the study of high-heat flow basins and petroleum accumulations, ore deposits, metamorphic degassing and seafloor systems; to Werner, these environments were all variations on a theme. Indeed, he had just won a three-year fundamental research grant from the Royal Society of New Zealand to finish the compilation and interpretation of his own huge data base on the composition of crustal fluids, filling in with sampling of critical systems in various tectonic settings as required. The aim was to produce a book on crustal fluids that would integrate and extend the thinking that was recorded in his 75 first-authored publications, plus his peripheral work that was covered in papers with his colleagues.

Werner's wide range of research topics, coupled with the geographic diversity of his field areas and his extensive involvement in a variety of overseas assistance programs (he authored over 100 project reports on geothermal assessments and volcanic hazard mitigation) resulted in a breadth of colleagues the world over. No single person could adequately discuss his contributions, or more importantly, provide a memorium that gives the flavor of who he was as a scientist and as a person. He was always logical, even though we could not at times keep up with his logic. He liked to dilute his wine, much to the chagrin of French and Italian colleagues. As a good German, he liked potatoes ('All the vitamins you need.'). He did not like to dance, since he was made to dance in elementary school. He was conservative in finances, and liberal in social causes. He got by in a variety of languages, no doubt due to his firm grasp of Latin, and his chemistry provided him with insight to a multitude of topics. To give an idea of who Giggenbach was, the following anecdotes and memories have been provided by a variety of his colleagues and friends.

"One well known anecdote about Werner originated from his one-year sojourn at the Wairakei field lab during the 1970s, a posting that Ellis insisted upon. Werner was working in the lab when the secretary came in to chat and pass the time of day. Somehow, a flask of silver nitrate got spilled over Werner and the secretary's lovely new dress. Werner and the lady were next observed in the lab standing in their underclothes as Werner rinsed his trousers and the lady's dress in dilute cyanide solution in order to try to complex and remove the silver. The dress was saved from silver staining but otherwise quite ruined. But as a chemist, he had at least to try!

For many years, Werner and I shared a ride to work. Real excitement came when there was a strong southerly storm. At such times, huge waves rolled over the eastern bays coast road, making the drive to and from the lab rather tricky. I recall one stormy morning when the road at high tide was impassable with white water and flotsam. Werner had a commanding view of the coast road and ocean from his balcony and phoned me and said, 'OK, let's go, the road is quite clear now.' I drove around the point into his bay and Werner jumped in the car. The sea was wild and the road quite impossible. But we decided to try it and sat timing the periodicity of the big swells as they tumbled over the road. At one point, Werner said 'Go for it' and I rev'd up the motor and off we went, getting past the worst parts unscathed. There were even fish flipping around on the road which had become merely an extension of the beach. Werner was exhilarated. He knew the road was effectively blocked but he just could not resist 'having a go'. This exemplified his modus operandi in science - careful, cautious and clever but every now and then, trying something outlandish, which ranged from hanging on rope in the inner crater of Mt. Erebus when the lava lake unexpectedly erupted, to throwing a manuscript in the rubbish and rethinking the whole thing. His science was his life in an almost monastic way - but nothing was sacred - everything was to be challenged. He started his career as an inorganic chemist and became a geochemist. Field work became a tonic. He was one of the best."

"Werner got off the bus, wearing his sandals as usual, chatting and joking with the other participants in the post-conference field trip to Lakes Nyos and Monoun, Cameroon, held after the August 1986 Lake Nyos gas disaster. The conference in March 1987 was organized by the Cameroonian Government and sponsored by UNESCO to discuss the medical, geological, geophysical, geochemical, limnological, and socio-cultural data collected after the disaster. Emphasis was put on understanding what happened, to look for the causes of the gas bursts from Lake Monoun in 1984 and Lake Nyos in 1986, and to mitigate future disasters of a similar kind.

At the conference Werner presented an hypothesis that intrusion of cold meteoric water to a depth of neutral buoyancy pushed CO2-containing lake water upward, thus triggering the lake explosion (Giggenbach, 1989, Journal of Volcanology and Geothermal Research). In the discussion he integrated direct and indirect information, cooked data and drew diagrams in his characteristic manner. As is well known, there was hot debate between supporters of 'limnic eruption' versus 'volcanic (phreatic)

eruption' for the ultimate cause of the gas burst. He supported the limnic eruption hypothesis. His idea provided a possible trigger mechanism for the limnic eruption, although what induced the gas burst is still unclear. Journalists at that time described blisters found on some survivors as resulting from a 'burn'. This expression was then connected literally to the thought that the victims were exposed to gases which were chemically corrosive to human skin, such as H2S or SO2, thus supporting the volcanic eruption hypothesis.

Back in New Zealand Werner exposed his arm to H2S gas from a cylinder in a fume hood to test what would happen to human skin. No blistering resulted. In fact, nothing happened except that his skin darkened and smelled badly for a time. When I heard this story, I was impressed by his attitude and approach to clarify a point that was scientifically uncertain. Everybody knows that Werner was good in experiments, theory and field observations. The above story places him in another category, as an 'experientialist'."

"The first time I met Werner was in Paris University, soon after he had returned from a trip to Erta Ale lava lake in January 1974. I was starting my PhD on the isotopic composition of water, carbon and sulfur in high-temperature volcanic gases, including samples from Erta Ale collected by a colleague. Werner came to our lab to try to obtain these samples because he wanted to perform the same isotopic measurements in New Zealand. Fortunately I was able to keep our samples for my own research, but I thought how this guy, speaking English with a terrific German accent, is voracious!

Later I had the opportunity to become a friend, and I realized that Werner was truly voracious, but in the good sense; he was permanently attracted by new ideas and new samples. He put so much energy in tracking both that, within only two decades he become the very best of us. His multitude of chemical and isotopic analyses of volcanic gases and geothermal fluids from all over the world now fill reams of tables, and these data plus his innovative interpretations are his legacy to science.

To me, the outstanding scientific contribution of Werner Giggenbach results from the rare combination of complementary qualities. Not only did Werner have a very good theoretical background, but he was also a good analyst and a true field man, collecting by himself in craters and other uncomfortable sites the samples he studied, thereby keeping a critical eye upon their quality and real meaning. In addition, he was a strong unconformist, which allowed him to promote new ideas and not simply follow well established rules. This also left him out of the honors.

Werner will be missed in particular by all volcanologists and geochemists involved in the activities of the IAVCEI Commission on the Chemistry of Volcanic Gases (CCVG). Since 1988 he was the editor of the Newsletter of this Commission, a role through which he could manifest all his abilities at synthesis; he was the glue that held this group together. He also played a leading part in the CCVG field workshops organized every three years. We shall miss his impetuous and often irascible character, and his caustic humor."

"The second time we met was in Hawaii in 1985, my last year of graduate school. After a conference we attended a field excursion together. At that time, Kilauea was active, and on our last day I found out that it was erupting. It was already late and raining hard. Werner was in bed, and I thought it would have no meaning to go to an observation point; it was far from our hotel and probably the rain and fog were hiding the volcano. I knocked on his door. He did not wait. 'You should go!' I was still thinking. 'Why do you think? You are a scientist. You should not lose such a chance.' Werner dressed, found a car and got directions to an observation point. We rushed in darkness and driving rain for more than one hour. During this time, he talked about an impressive eruption of Mt. Etna, the first time he saw a volcanic eruption. He was a student at the time, and the experience was part of the motivation for him to eventually study volcanoes. After a while, we gave up and returned to Hilo. Werner left the next morning. I saw Kilauea erupt the next evening, which was my last day in Hawaii. It was beautiful, and I was sorry he was not there."

"Werner's reputation as a field geochemist was equally matched by his reputation as a rigorous analytical chemist, and his gas chromatography system has been copied many times by other volcanic gas geochemists all over the world. Or at least they tried. One day it was my turn, and my advisor showed me two blue boxes and told me that those are GCs and that it was now part of my Master's project to turn those two blue, innocent boxes into Werner's GC system. With it came a hand sketch by the master himself, revealing all the details about the setup which at the time meant nothing to me. This was followed by endless faxes (he did not use e-mail at that time because if you use 'blooming' e-mail you never get anything done), asking Werner how to put things together. Then we exchanged peeks and peaks of each other's system. Finally things worked out, I got my Master's degree and I met the master for the first time in Java.

A few years later, Werner invited me to come to New Zealand to work in his lab because you are not a real geochemist unless you have worked in New Zealand. Of course his office was very small and completely covered with large piles of papers (because if you have filing cabinets, they fill up within a few years, he has tried that). Next door is an equally small space which is his lab. On one side are three GCs, on the other side bench space of about 2m x 1m, and the third side is a window with a beautiful view over Wellington bay. I arrived with about 50 gas samples which I had collected over the course of about one year. He said 'Blooming heck, you brought half of your PhD here, I have no way of analyzing them, you have to do that yourself.' So he turned on his system, which is only remotely similar to what I put together and we fiddled for a few hours to get the ink flowing on the chart recorder pens. This was one of the most difficult tasks of the whole analysis procedure and a crucial test for one's patience and endurance as a geochemist. During that time you must never laugh because he will not tolerate that and make you leave the room. We finally got the pens going and it was time to run the first sample. The detector of that machine is extremely sensitive so that you need to attenuate the signal significantly; if you don't attenuate it, the peak would be about 3 km high. So we injected the first sample and I was on the attenuation nob (the driver's seat). Seconds later, the peak went wild and I had no chance of getting it sufficiently attenu-

W. F. Giggenbach at Kitabira fumarole, taking care to place his sampling tube correctly amidst the yellow sulfur incrustations. (Photo by J. W. Hedenquist, October, 1991).

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ated. He just said 'See, I told you, you can not run this system, you need more practice, it is too difficult and I am not going to modify it for you.' The thing with Werner was that he loved the challange so he ran the same sample himself. The same thing happened, the peak went way off the chart recorder. 'You have to anticipate the peak height before the peak, you need to have enough experience about the composition of this particular sample, where you collected it, the pressure in the bottle, in order to already know that the hydrogen peak will be high and adjust for it before the peak is there, otherwise it is too late. If you over-adjust you lose valuable sensitivity.'

Werner was a fabulous teacher, he knew everything and he explained it all, in the field or in the lab. Sampling or analyzing samples, I will always miss him, and his voice will always be there. 'You nink. I hate it when geologists pretend that they are geochemists, they should never touch a GC, ever. They just muck things up, there is no use for it. Blooming heck.'"

"The only thing that others have not mentioned that I have always enjoyed is *what does the F in WFG really stand for?*, because it is such a good example of how unpretentious a person Werner really was, despite his being essentially the guru of volcanic/hydrothermal gases. On our first meeting, in 1988 in Colombia, we spent a 13 hour-long day driving to Machin volcano, so we got to know one another. About half way through that trip, we passed a single room school with the official title *Escuela Mixta Flabio Rodriguez* printed nicely on the front. I proclaimed 'Oh that is what that funny F in your name stands for!'. Ever since, he signed all his letters with Flabio, in a flourish. He did not like authority and enjoyed irreverence. Five years later, we would have died together in another volcano [Galeras] except that the authorities did not manage to get him his plane ticket and I did not die, by a fluke. Two weeks after that fatal eruption, in the hospital, I received a nice, warm letter - 'I guess that I am glad that they screwed up my ticket. Good luck! Flabio.' It meant a lot to me and he always will."

Werner's approach to interpretation methods became legendary, although his debunking of various targets, some less obvious than others, was even more well known. You either agreed with him (i.e., if you understood what he was getting at), or you did not (if you did not understand); the latter group did not think much of him, and they are the worse for it, not for the disagreement, but for not seeking to understand his approach. Fundamentally, he saw no reason, thermodynamically or otherwise, to do anything other than to plot what was measured; of course, this is easier for someone working on fluid samples compared to rocks and minerals.

"He was a very strict chemist who was always conscious of the significance of each analytical result, plot of data, and theoretical evaluation. For example, he criticized the unconscious thinking when oxygen fugacity is commonly used during discussion of redox processes of hydrothermal fluids or volcanic gases. The oxygen content in these fluids is too low to measure, and therefore is an unlikely actual reaction participant. Although there are several reports of oxygen fugacities measured with oxygen fugacity sensors, what actually reacts with sensors is not oxygen but more likely hydrogen/water, sulfur species or other redox pairs. Therefore, the application of the oxygen fugacity evaluation should be restricted to high-temperature conditions where reaction equilibrium can be justified. We are likely, however, to forget his criticism and to spend time playing number games with thermodynamic modeling, statistical analyses, etc. We may sometimes need to go back to his articles, not only for their scientific results but also to remind us how he tried to clarify the framework of discussion."

"'For creatures like ourselves, who evolved in an evidently three-dimensional world, the four-dimensional cosmos can take some getting used to!' (Timothy Ferris, in The Whole Shebang, Weidenfeld & Nicholson, 1997, London).

That's how most of us knew Giggenbach! And the more I think, the more I see how those uniquely constructed GCA 'Giggegrams' of four variables and everything plotted reflected the personality, the simplicity and elegance, the love of excellence and the hidden humor that was, and is, Werner."

"Werner was instrumental in creating the applied geochemistry of geothermal systems. Many of use now use his precise geochemical language: isotopic, gas, and ionic Giggegrams. And nearly single-handedly he created the applied geochemistry of volcanic gases. For more than 20 years many of us have collected volcanic gases into Giggenbach bottles, analysed gases by Giggenbach's method, and interpreted the results using his framework. All his life he was generating ideas, ideas that could be checked, and applied usefully. He was a leader in his own unassuming way, the center and pivot of a community of strange and a little bit crazy people working on active volcanoes; passionate wanderers with love of the smell of sulfur. And he was and is a great teacher. Not in terms of a university professor. But every second of his papers is a handbook, a manual for anyone who is going to be a volcano-hydrothermal geochemist. He was a good man, very clever, sarcastic at times but kind. His death is a huge loss."

"He lit candles at various dark corners to help those of us following to see the path. There are candles yet remaining that he placed in front of us, but it is now up to others to light them."

[Contributed by P. Allard, B.W. Christenson, T. Fischer, J.W. Hedenquist, R.W. Henley, H. Keys, Kusakabe M., Masuda H., Ono A., T.M. Seward, Shinohara H.. Y. Taran, & S. N. Williams]

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Continued from page 13

Archean sedimentary rocks. Zircon is ubiquitous in the continents, resistant to weathering, and amenable to precise geochronology via the U-Pb and Lu-Hf isotope methods. If extensive early Archean continents existed, then it is possible that zircons from those continents survived, even if much of the rest did not. In effect, the ancient zircons would have to have been eroded from the now-lost early sial and transported to preserved Archean cratons for deposition.

With this rationale, the zircon populations of several Archean sedimentary sequences have been dated by ion microprobe (SHRIMP) and thermal ionization mass spectrometric (TIMS) methods. In the most broad study, Stevenson and Patchett[40], using TIMS techniques, found that the bulk of zircons in Archean sediments have the same ages as those of the craton on which the sediments were deposited. Only a minor proportion of zircons had older ages. Studies using SHRIMP have found similar results, albeit with identification of some very old zircons[41] including the oldest known terrestrial materials, ~4.3 Ga zircons from Western Australia[42].

The sedimentary zircon record thus preserves only marginally more evidence for early Archean continental crust than does the existing rock record itself. This could indicate that an extensive early continental crust never existed. Alternatively, it could indicate that early Archean zircons were destroyed almost as efficiently as the continental crust which hosted them, before they could be transported for deposition on preserved Archean cratons. Perhaps the early continental crust was more fragmented than the continents of today and surviving Archean cratons were isolated from older, now-destroyed continental crust.

Nd isotope evolution

Among geochemists, most discussion about the extent of continental growth and recycling has been concerned with isotopic data, in particular for Nd isotopes[7-9,43-45]. Archean rocks have ε_{Nd} values, a measure of the deviation of the $^{143}Nd/^{144}Nd$ ratio of a magmatic rock from the chondritic value (CHUR) at the time the rock crystallized, that span a large range from about +7 to -8 (Figure 2). Positive ε_{Nd} values indicate sources of rocks that have had a long-lived depletion in Nd relative to Sm, whereas negative ε_{Nd} values reflect "enriched" sources with long-lived, low Sm/Nd ratios. Based on the expected partitioning of Sm and Nd between melts and residues, extraction of the continental crust from the mantle is expected, over time, to produce negative ε_{Nd} values in the continents and to leave a residual mantle with positive ε_{Nd} values.

The large range of ε_{Nd} values, both positive and negative, seen in even the oldest of the Archean rocks suggests that significant volumes of both residual mantle and continental crust sources had formed within the first few hundred million years of Earth's history[43]. Moreover, the most positive of the ε_{Nd} values (+4 to +7) seem to have remained relatively constant throughout the Archean, suggesting that the Nd isotopic composition of residual mantle was buffered by continuous reintroduction of continental material with negative ε_{Nd} values[43]. Without these additions from the continents, the most positive ε_{Nd} values from the residual mantle would be expected to have increased steadily

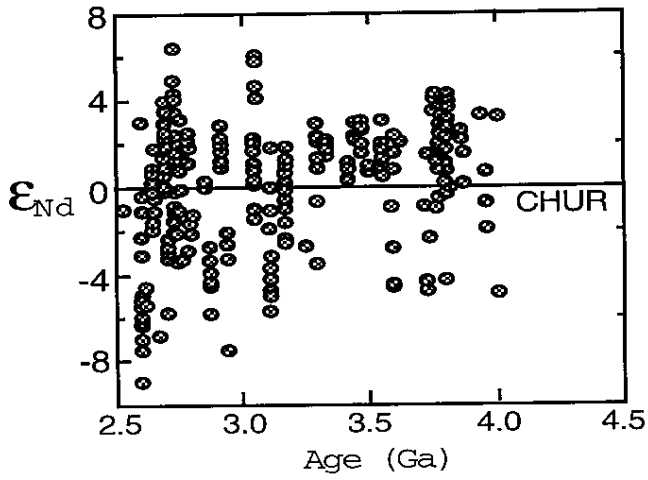

Figure 2. Compilation of ε_{Nd} values for Archean rocks[43].

during the Archean. If the volume of mantle feeding the continents remained constant through the Archean and thereafter, the Nd data are consistent with an early big bang of continent formation, followed by large scale recycling.

The Nd data are not universally interpreted in this way however. Questions have been raised about the integrity of the Sm-Nd system during polymetamorphic events that affected many Archean rocks[44]. In particular, some of the high, positive ε_{Nd} values measured in early Archean samples may be the result of secondary alteration, not intrinsic magmatic diversity. This allows the possibility that the residual mantle was only mildly depleted in the early Archean but became much more so by the late Archean. In some old gneisses, for example, Hf isotopes record a much smaller degree of incompatible element depletion than do Nd isotopes[44]. Thus, in contrast to the impression given in Fig. 2, positive ε_{Nd} values in the depleted mantle may have in fact increased from, say, +1 at 3.8 Ga to +4 at 2.7 Ga. In this case, early continent formation and steady-state recycling are neither required nor excluded by the Nd data[14,45].

Even if the Nd isotopic ratios have not been seriously degraded by alteration, and the most positive ε_{Nd} values in the depleted mantle did indeed remain constant through the Archean, a low-ε_{Nd} source other than the continental crust may have been the buffering agent involved. One possibility is that the depleted mantle was buffered by a recycled and now-lost, early basalt crust which had negative ε_{Nd} values[46]. In this case, it would be very difficult to distinguish the timing of continent formation using Nd isotope data. Another possibility is that the depleted mantle was buffered by primitive mantle, which by definition has an ε_{Nd} value of zero. This scenario implies that the volume of depleted mantle has increased progressively with time at the expense of primitive mantle, first being much smaller than the upper mantle and eventually becoming somewhat larger[9]. The buffered, positive ε_{Nd} values of Archean rocks could thus reflect progressive growth of the volumes of both the depleted mantle and continental crust. The main problem with this model is the lack of a mechanism for progressively changing the scale of mantle convection to accommodate growth of the volume of

depleted mantle. Numerical modelling[47] suggests that large-scale convective stirring of the mantle may have changed from two layers separated by the phase transition at 660 km in the Archean to whole mantle convection thereafter, but there is no evidence for progressive changes in the sizes of the two layers over Earth history.

Nb/U approach

Given the uncertainties surrounding the Nd isotope evidence, some geochemists have begun to focus on trace element evidence addressing the issue of continent formation and on two elements in particular, niobium and uranium. The value of these elements in addressing the origin of the continents lies in their possessing an unusual characteristic: During "normal" melting of the mantle, to produce basalts, the elements are extracted into the melt to the just about same degree so that the ratio of Nb/U in the basalts is, for practical purposes, the same as that in their mantle sources[48]. However, during melting of basalts to form tonalites, the major component of the continental crust, U is extracted into the melt much more readily than is Nb, resulting in the continents having much lower Nb/U ratios than their basalt sources.

Modern ocean basalts have Nb/U ratios of 47 +/- 10 so this is thought to be the value of the "sampled" part of the mantle today[48]. The continental crust[1,2], in contrast, has a Nb/U ratio of only about 10. Because the Nb/U ratio of chondritic meteorites (taken to be representative of the primitive mantle) is 30, a value between those of the sampled mantle and continental crust, it seems very likely that the two components are complementary[48]. Formation of the continental crust with its low Nb/U ratio would have thus resulted in a net increase in the Nb/U ratio of the sampled mantle from 30 to 47. In practice, this has required a four-step process (Figure 3) in which, first, basalt is extracted from the primitive mantle, leaving the Nb/U ratio unchanged at the chondritic value of 30; second, the basalt is partially melted to form a low Nb/U reservoir (~10), the major tonalite component of continental crust; and third, the eclogitic residues of basalt melting, a high Nb/U reservoir (>60), are mixed back into the mantle resulting in a net increase in its Nb/U ratio from 30 to 47. Once the continents reach their present volume, a fourth step of recycling of continental crust back into the mantle is necessary to compensate for the continued formation of tonalite and mantle recycling of high Nb/U eclogitic residues.

If this model is correct, then we have a splendid way of determining when the continents achieved their present volume: it should be the age at which ancient basalts first started forming with Nb/U ratios of about 47 rather than ratios closer to 30, assuming a mantle source reservoir of constant volume. There are however two potential pitfalls in this approach: mobility of U in basalt samples due to alteration or metamorphism, and addition of U to basalt magmas that have passed through continental crust before eruption. Uranium, unlike Nb, is well-known to be susceptible to mobilization by hydrothermal fluids, and is much enriched in the continental crust compared to basalts. Thus, the Nb/U ratio of an ancient basalt may not reflect the value of its mantle source.

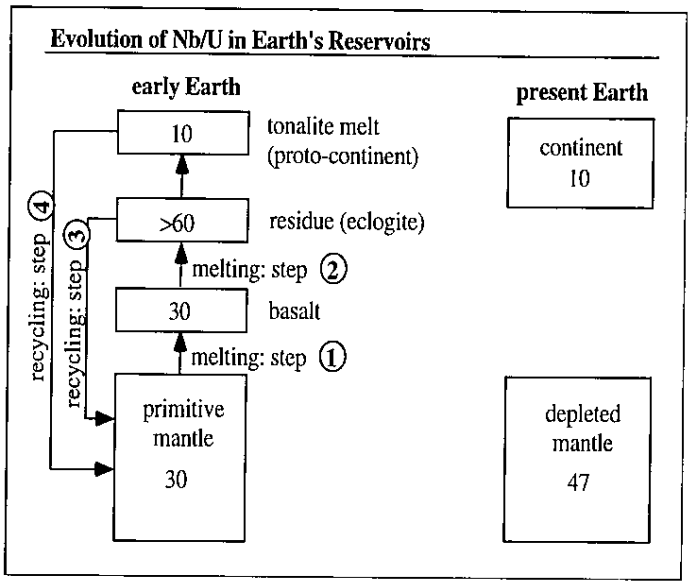

Figure 3. Evolution of Nb/U in the Earth during the four-step process of making continental crust.

So far, there have been two attempts to apply the Nb/U approach to ancient basalts. Jochum et al.[49] used samples from various Precambrian localities and found Nb/U ratios ranging from about 10 to 50. They attributed the variability to mobility of U during secondary alteration and did not draw any firm conclusions about the timing of continent formation. Sylvester et al.[50] adopted a somewhat different approach, measuring the Nb/U ratios of many basalts from a single thick formation, the 2.7 Ga Lunnon Basalt of Western Australia. Nb/U ratios range from 47, the value in the present-day mantle, to about 30. The lower values are probably the result of minute amounts (<1%) of crustal contamination in some Lunnon magmas but the high values reflect a mantle source which had suffered just as much continental crust extraction as the modern mantle. If the volume of mantle sampled by the Lunnon basalt is representative of the late Archean mantle, and the volume of mantle feeding the continents has remained fixed through time, these results provide the first clear evidence that the continents reached their present volume by 2.7 Ga.

Outlook

We have made significant progress in understanding many aspects of the complicated processes involved in continent formation but we cannot yet say that we have solved the problem of the rate of continent growth. In recent years however the pendulum of evidence has swung away from models for an erratic dribble of continent formation throughout Earth history towards those appealing to a big bang and large-scale recycling. To finally decide the issue, we must achieve better constraints on the present recycling balance, a firmer understanding of how preserved ancient crust has survived, and a more complete knowledge of the processing of zircons in sedimentary environments. Uncertainties surrounding the isotopic evolution of Nd in the

depleted mantle during the Archean must be resolved and the analogous data base for less well-studied isotopic systems, Lu-Hf and Re-Os in particular, needs to be enhanced. Nb/U studies should be extended to more Archean basalt sequences in order to define a mantle evolution curve for this element pair.

We must also take note of discoveries made about the nature and composition of the crusts of Venus and Mars, which may provide clues to the formation of the Earth's continents. As indicated by the recent discovery of rocks of andesitic composition on the surface of Mars[51], the Earth may not be the only planet which has formed a differentiated crust.

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Meetings Calendar

Dec. 16-18, 1997: Minerals Management Service 17th Information Transfer Meeting, New Orleans, LA USA. Contact: Office of Conference Services, University of New Orleans, Metropolitan College, ED 122, New Orleans, LA 70148; Tel: 504-280-6680; Fax: 504-280-7317; Email: confmc@uno.edu; WWW: http://www.mms.gov

1998: Canadian Institute of Mining, Metallurgy and Petroleum, 100th Annual General Meeting, Quebec, Canada. Contact: John Gaydos, Meetings Manager, Canadian Institute of Mining and Metallurgy, 1 Place Alexis Nihon, 1210-3400 de Maisonneuve Boulevard West, Montreal, Quebec H3S 3B8, Canada; Tel. 514-939-2710; Fax 514-939-2714.

1998: 10th IAGOD Symposium, Australia. Contact: Professor I. R. Pliner, University of Melbourne, Parkville, VIC 3052, Australia; Tel. 613 3446520; Fax 613 3447761.

Jan. 19-21, 1998: Minerals Colloquium, Ottawa, Ontario, Canada. Contact: Geological Survey of Canada; Tel. 613-992-1600; Fax: 613-996-9820; Email: colloq98@gsc.nrcan.gc.ca; WWW: http://www.nrcan.gc.ca/gsc/mrd/colloq98.htm

Jan. 26-29, 1998: Tailings and Mine Waste '98, Fort Collins, CO USA. Contact: L. Hinshaw, Dept. Of Civil Engineering, Colorado State University, Fort Collins, CO 80523-6081 USA; Tel: 970-491-6081; Fax: 970-491-3584; Email: lhinshaw@vines.colostate.edu

Feb. 12-15, 1998: Tucson Gem and Mineral Show, Tucson. AZ USA. Contact: Tucson Gem and Mineral Society Show Committee, P. O. Box 42543, Tucson, AZ 85733 USA; Tel: 520-322-5773; Fax: 520-322-6031

Feb. 17-20, 1998: 6th International Zonenshain Conference on Plate Tectonics, Moscow, Russia. Contact: E. Pristavakina, Institute of Oceanology, Nakhimosky prosp. 36, Moscow 117851, Russia; Tel: 007-095-124 7396; Fax 007-095-124 5983; Email: prist@sbg.geol.msu.su

Mar. 10-13, 1998: Geochemical Earth Reference Model (GERM) Workshop, Institute for Geophysics and Planetary Physics, Scripps Institution for Oceanography, University of California, San Diego, La Jolla, CA 92093-0225 USA. Contact: Hubert Staudigel, UCSD-IGPP, UCSD-0225, La Jolla, CA 92093-0225; Tel. 619-534-8764; Fax: 619-483-7708; Email: hstaudigel@igpp.ucsd.edu; WWW: http://www-ep.es.llnl.gov/germ/lajolla.html

Mar. 10-13, 1998: Oceanology International '98, Brighton, United Kingdom. Contact: Spearhead Exhibitions Ltd., Ocean House, 50 Kingston Road, New Malden, Surrey KT3 3LZ, UK; Tel: + 44 (0) 181-949-9222; Fax: + 44 (0) 181-949-8186/93; Email: oi98@spearhead.co.uk

Mar. 16-20, 1998: Lunar and Planetary Science Conference, Houston, TX USA. Contact: LeBecca Simmons, Conference Administrator, LPI Publications and Program Services Dept., 3600 Bay Area Blvd., Houston, TX 77058-1113 USA; Tel: 281-486-2158; Fax: 281-486-2160; Email: simmons@lpi.jsc.nasa.gov

Mar. 30-Apr. 3, 1998: 18th Annual Hydrology Days, Fort Collins, CO USA. Contact: J. Montera, Dept. Of Civil Engineering, Colorado State University, Fort Collins, CO 80523-1372; Tel: 970-491-7425; Email: jmontera@engr.colostate.edu

Mar. 30-Apr. 4, 1998: International Association of Geochemistry and Cosmochemistry, Water Rock Interaction-9, Taupo, New Zealand. Contact: B. W. Robinson; Tel. 64-7-374-8211; Fax: 64-7-374-8199; Email: wri-9@gns.cri.nz, WWW: http://www.ruamoko.gns.cri.nz/wri-9.html

Apr. 13-16, 1998: Experimental Mineralogy, Petrology & Geochemistry, Orleans, Cedex, France. Contact: EMPG-VII Organising Committee, CNRS-CRSCM, 1A Rue de la Ferollerie, 45071 Orleans Cedex 2, France; Tel: + 33 02 38 25 53 96; Fax: + 33 02 38 63 64 88; Email: empg@cnrs-orleans.fr

Apr. 13-17, 1998: Seventh International Kimberlite Conference, University of Cape Town, Rondebosch, South Africa. Field trips between April 6-12 and 19-24, 1998. Contact: James Gurney, Secretary/Treasurer, 7IKC, Dept. Of Geological Sciences, University of Cape Town, Private Bag, Rondebosch, 7700, South Africa; Tel: + 27 21 531 3162 or + 27 82 550 2004; Fax: +27 21 650 3783; WWW: http://www.uct.ac.za/depts/geolsci/7ikc/

Apr. 14-18, 1998: Geoscience '98, Keele University, Staffordshire, UK. Contact: Conference Dept., Tel: 44-171-4349944; Fax: 44-171-4398975; Email: conf@geolsoc.cityscape.co.uk

Apr. 20-23, 1998: Eighth Symposium on Environmental Toxicology and Risk Assessment, Atlanta, GA USA. Contact: D. S. Henshel, Indiana University, SPEA 340, Bloomington, IN USA; Tel: 812-855-4556; Fax: 812-855-7802; Email: dhenshel@indiana.edu

April 20-24, 1998: European Geophysical Society, Nice, France. Contact: EGS Office, Max-Planck-Str. 13, 37191 Katlenburg-Lindau, GERMANY. Phone: +49-5556-1440; Fax: +49-5556-4709; Email: EGS@COPERNICUS.ORG; http://www.copernicus.org/EGS/EGS.html

Apr. 27-30, 1998: International Conference on Modern Preparation and Response Systems for Earthquake, Tsunami, and Volcanic Hazards, Santiago, Chile. Contact: B. Bolt, Dept. Of Geology and Geophysics, University of California, Berkeley, CA USA; Fax: 510-845-4816; Email: boltuc@socrates.berkeley.edu

May 3-7, 1998: 34th Forum on the Geology of Industrial Minerals, Norman, OK USA. Contact: Kenneth S. Johnson, Oklahoma Geological Survey, University of Oklahoma, 100 E. Boyd St., Room N-131, Norman, OK 73019 USA; Tel. 405-325-3031 or 800-330-3996; Fax: 405-325-7069

May 5-8, 1998: Fractal Scaling, Non-Linear Dynamics, and Chaos in Hydrologic Systems, Anderson, SC USA (Clemson University). (Abstract deadline: Jan. 8, 1998) Contact: AGU Meetings Dept., 2000 Florida Avenue, NW, Washington, DC 20009 USA ; Tel: 202-462-6900 or 800-966-2481 (North America only) ; Fax: 202-328-0566; Email: meetinginfo@kosmos.agu.org; WWW: http://www.agu.org

May 13-15, 1998: Advances in Fluid Mechanics (AFM 98), Udine, Italy. Contact: P. Doughty-Young, AFM 98, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, 2040 7AA UK; Tel: 44-1703-293-223; Fax: 44-703-292-853; Email: paula@wessex.ac.uk; WWW: http://www.wessex.ac.uk/

May 14-18, 1998: Linking Spatial and Temporal Scales in Paleoecology and Ecology, Annapolis, MD USA. Contact: A. Cohen, Dept. Of Geosciences, University of Arizona, Tucson, AZ 85721 USA; Tel: 520-621-4691; Fax: 520-621-2672; Email: acohen@geo.arizona.edu

May 18-20, 1998: Quebec Canada Joint Meeting Geological Association of Canada, Mineralogical Association of Canada, and Association Professionnelle des Geologues et des Geophysiciens du Quebec. Contact: Agathe Morin, Dept. Of Geology, Universite Laval, Pavillon Adrien-Pouliot, Sainte-Foy Quebec G1K 7P4, Canada; Tel: 418-656-2193; Fax: 418-656-7339; Email: quebec1998@ggl.ulaval.ca; WWW: http://www.ggl.ulaval.ca/quebec1998.html

May 18-21, 1998: First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, USA. Contact: J. Purvis, The Conference Group, Inc., 1989 West Fifth Ave., Suite 5, Columbus, OH 43212-1912 USA; Tel. 800-783-6338 or 614-424-5461; Fax 614-488-5747

May 22-27, 1998: European Research Conference on the Geochemistry of Crustal Fluids: Reactive Transport in Natural Systems, Aghia Pelaghia, Crete, GREECE. Contact: Eric H. Oelkers, Laboratoire de Geochimie, Universite Paul Sabatier, 31000 Toulouse FRANCE; Tel: 33 5.61.55.87.85; Fax: 33 5.61.52.05.44; Email: oelkers@cict.fr

May 26-29, 1998: Spring AGU Meeting, Boston, MA USA. Abstract Deadline: Feb. 19, 1998 (by mail) or Feb. 26, 1998 (via WWW). Contact: AGU Meetings Dept., 2000 Florida Ave. NW, Washington, DC 20009; Tel: 800-966-2481 or 202-462-6910, ext. 215; Fax: 202-328-0566; Email: meetinginfo@kosmos.agu.org (subject: 1998 Spring Meeting); WWW: http://earth.agu.org/meetings/sm98top.html

June 1-4, 1998: Pan American Current Research on Fluid Inclusions (PACROFI) VII; Las Vegas, NV USA. Contact: Jean S. Cline; Dept. of Geosciences; University of Nevada-Las Vegas; Las Vegas, Nev. 89154-4010 USA; Fax: +1-702-895-4064; E-mail: jcline@nevada.edu

June 4-12, 1998: Evolution of Ocean Island Volcanoes, Galapagos Islands, Ecuador. (Abstract deadline: Jan. 15, 1998) Contact: Dennis Geist, Dept. Of Geology, University of Idaho, Moscow, ID 83844; Tel: 208-885-6491; Fax: 208-885-5724; Email: dgeist@uidaho.edu

June 16-20, 1998: 8th Pacific Congress on Marine Science and Technology, Seoul, Korea. (Abstract deadline: Jan. 15, 1998) Contact: PACON International, P. O. Box 11568, Honolulu, HI 96828; Tel: 808-956-6163; Fax: 808-956-2580.

June 23-27, 1998: 7th International Conference on Permafrost, Yellowknife, Canada. Contact: J. A. Heginbottom, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario, Canada K1A 0E8; Tel. 613-992-7813, Fax 613-992-2468; http://www.ncrcan.gc.ca/gsc/permaf_e.html

June 29-July 15, 1998: 8th International Platinum Symposium (IAGOD/CODMUR), Johannesburg, South Africa. Contact: Dr. C. A. Lee, P.O. Box 68108, Bryanstown, SOUTH AFRICA; Tel: + 27 1127 373 2580; Fax: + 27 1127 836 0371; Email: clee@amplats.co.za

July 6-10, 1998: Australian Geological Convention, Townsville, Australia. Contact: Debbie Buckley, School of Earth Sciences, James Cook University, Townsville QLD 4811 ;, Australia; Tel: +61 077 81 5047; Fax: +61 077 25 1501; E-mail: jcu.edu.au; WWW: http://www.jcu.au/dept/Earth/l/AGC14.html

July 4-11, 1998: Processes of Crustal Differentiation (Geological Society of America), Verbania, Italy. Contact: Tracy Rushmer, Dept. Of Geology, University of Vermont, Burlington, VT 05405 USA; Tel: 802-656-8136; Fax: 802-656-0045; Email: trushmer@zoo.uvm.edu

July 7-14, 1998: Coupled Ocean-Atmosphere Response Experiment '98 (COARE98), Boulder, CO USA. Contact: B. Jackson, University Corporation for Atmospheric Research/ Joint Office for Science Support Program Support Group, P.O. Box 3000, Boulder, CO 80307-3000 USA; Tel: 303-497-8663; Fax: 303-497-8633; Email: bjackson@ucar.edu; WWW: http://www.joss.ucar.edu/joss_psg/project/coare98/

July 11-17, 1998: IAVCEI International Volcanological Congress '98, Rondebosch, South Africa. Contact: Secretariat, IAVCEI 1998, Dept. Of Geological Sciences, University of Cape Town, Rondebosch, South Africa; Fax: + 27 21 650 3783; Email: ivc98@geology.uct.ac.za; WWW: http://www.uct.ac.za/depts/geolsci/ivc98/

July 21-24, 1998: 1998 Western Pacific Geophysics Meeting, Taipei, Taiwan. Contact: Tel: 800-966-2481 or 202-462-6900; WWW: http://www.agu.org (Click on Meetings, Click on 1998 Western Pacific Geophysics Meeting)

Aug. 5-8, 1998: Eighth International Symposium on Solubility Phenomena, Niigata, Japan. Contact: Kiyoshi Sawada, General Secretary of the 8th ISSP, Dept. Of Chemistry, Faculty of Science, Niigata University, Niigata 950-21, Japan; Tel: + 81 25 262 6265; Fax: + 81 25 262 6116; Email: issp@sc.niigata-u.ac.jp

Aug. 9-12, 1998: 4th International Symposium on Environmental Geotechnology and Global Sustainable Development, Boston, MA USA. (Abstract deadline: Nov. 15, 1997) Contact: H. I. Inyang, Center for Environmental Engineering and Science Technologies, James B. Francis College of Engineering, University of Massachusetts-Lowell, One University Avenue, Lowell, MA 01854 USA; Tel: 508-934-2285; Fax: 508-934-3092; Email: inyangh@woods.uml.edu

Aug. 9-14, 1998: International Mineralogical Association: IMA '98, 17th General Meeting, Toronto, Canada. Contact: Professor A. J. Naldrett, Dept. Of Geology, University of Toronto, Canada M5S 3B1; Tel: 461-978-3030; Fax: 416-978-3938; Email: ima98@quartz.geology.utoronto.ca

Aug. 10-16, 1998: International Ophiolite Symposium and Field Excursion; Generation and Emplacement of Ophiolites Through Time, Oulu, Finland. Contact: Jouni Vuollo, Dept. Of Geology, University of Oulu, FIN-90570 Oulu, Finland; Fax: + 358-81-5531484; Email: vuollo@sveka.oulu.fi or Eero Hanski, Geological Survey of Finland, P.O. Box 77, FIN-96101 Rovaniemi, Finland; Fax: + 358-60-3297289; Email: eero.hanski@gsf.fi

Aug. 15-20, 1998: Sixth International Congress on History of Oceanography, Qingdao, China. (Abstract deadline: Nov. 30, 1997) Contact: G.-K. Tan, First Institute of Oceanography, SOA, 3A Hongdao Branch Road, Qingdao 266003. P. R. China; Tel: + 86-532-2883127; Fax: + 86-532-2879562; Email: fiokjc@ns.qd.sd.cn

Aug. 17-20, 1998: The Second International Conference on Climate and Water, Espoo, Finland. Contact: N. Helenius, Helsinki University of Technology, Water Res. Eng., Tietotie 1, FIN-02150 Espoo, Finland; Tel: + 358 9 275 3835; Fax: + 358 9 451 3827; Email: nheleniu@ahti.hut.fi; WWW: http://ahti.hut.fi/wr/caw2

Aug. 19-25, 1998: Global Atmospheric Chemistry and Climte, Seattle, WA USA. Contact: Patricia Quinn, CACGP/ICAG Meeting - 1998, NOAA/PMEL OCRD, Bldg. 3, 7600 Sand Point Wa NE, Seattle, WA 98115 USA; Fax: 206-526-6744; Email: quinn@pmel.noaa.gov

August 20-26, 1998: 9th International Conf. on Geochronology, Cosmochronology & Isotope Chemistry (ICOG-9), Beijing, China. Abstract Deadline: Mar. 1, 1998; Contact: ICOG-9 Secretariat, Chinese Academy of Geological Sciences, Baiwanzhuang Road 26 , Beijing 100037 P.R. China; Tel: +86-(10)-6831-1545 and +86-(10)-6832-6456 ; Fax: 86-(10)-6831-1545; e-mail: liudunyi@public.bta.net.cn; WWW: http://www.cags.net.cn

Aug. 30-Sep. 3, 1998: 8th Annual V.M. Goldschmidt Conference, Toulouse, France. WWW: http://www.obs-mip.fr/omp/umr5563/goldconf98.html *[see p. 10, this issue]*

Aug. 30-Sep. 4, 1998: Clay Mineralogy and Petrology Conference and Workshop, Brno, Czech Republic, by International Geological Correlation Programme Project No. 405. Contact: Petr Sulovsky, Dept. Of Mineralogy, Petrology, and Geochemistry, Faculty of Science, Masaryk University, Kotlarska 2, CZ 611 37 Brno, Czech Republic: Fax: + 420 541211214; Email: clays@sci.muni.cz

September 12-18, 1998: European Union, Università di Siena -Vrije Universiteit Amsterdam - Universitetet i Oslo, SOCRATES - Intensive Programme, Modern Trends in Fluid-Phase Petrology. Contact: Maria-Luce Frezzotti, Dipartimento Scienze Terra, Via delle Cerchia n.3, 53100 Siena ITALY. Phone: +39 577 298915; Fax: +39 577 298815; Email: frezzotti@dst.unisi.it

Sep. 21-25, 1998: GQ '98: International Conference and Special Workshops on Groundwater Quality: Remediation and Protection, Tubingen, Germany. Contact: Conference Secretariat GQ '98, c/o Lehrstuhl fur Angewandte Geologie, Sigwartstrasse 10, D-72076 Tubingen, Germany; Tel: + 49-7071-2974692; Fax: + 49-7071-5059; Email: mike.herbert@uni-tuebingen.de

Oct. 26-29, 1998: 1998 GSA Annual Meeting, Toronto, Canada. Contact: GSA, 3300 Penrose Place, Boulder, CO 80301 USA; Tel: 303-447-2020; Fax: 303-447-1133; WWW: http://www.geosociety.org/meetings/index.htm

Dec. 1-3, 1998: The Origin of the Earth and Moon, Geochemical Society Topical Conference, Monterey, CA USA.; Contact: LPI; 3600 Bay Area Blvd.; Houston, TX USA; e-mail: simmons@lpi.jsc.nasa.gov*[see p. 8, this issue]*

Dec. 6-10, 1998: Fall AGU Meeting, San Francisco, CA USA. Contact: AGU Meetings Dept., 2000 Florida Ave. NW, Washington, DC 20009; Tel: 800-966-2481 or 202-462-6910, ext. 215; Fax: 202-328-0566; Email: meetinginfo@kosmos.agu.org (Subject: 1998 Fall Meeting)

EREBUS - ALMOST

by Werner F. Giggenbach (1979)

"I had actually no intentions to go there this season. After three visits and having spent almost fifty nights up there, the novelty of camping in Antarctica, even 3600 m up on a volcano, had worn off a bit; all I wanted were those gas samples. Anyway, it would be the same again, after days of storm and steam and one demoralising eruption following another we would have to pack up, time and effort wasted, at least, as far as my project was concerned.

Wasted? - Not quite. After all, a rare phenomenon such as a permanent lava lake deserves some attention, it is almost a cultural obligation and we had, as a team, carried out a series of quite valuable observations. We had seen the lava lake growing from a few small pools in 1972 to the 'lava river' in 1974 and the present lake covering half of the Inner Crater. We had kept a record of explosions, collected fresh, often still hot lava samples for petrological examinations. Ray Dibble was able to locate volcanic earthquake epicenters and to correlate seismic and barometric shock waves associated with eruptions. We had explored one of the mysterious ice caves and a map of the summit area was prepared. From my point of view the most important achievement, however, was that we had steadily inched our way closer and closer to those steam vents at the bottom of the Inner Crater, our ultimate aim. After coming thousands of kilometers to Antarctica, the last forty to the summit camp by helicopter, the last kilometer to the edge of the Inner Crater by climbing and struggling, the last hundred meters down the pit had evaded us.

Of the probably 300 to 500 active volcanoes around the globe, only a handful are likely to be at any time in a state conducive to high-temperature gas sampling. Of these the majority are probably inaccessible due to logistic or political difficulties and looked at in that way, Erebus is probably one of the most easily accessible ones. Most volcanoes are situated in tropic to temperate climatic zones with abundant precipitation in the form of liquid water, with an isotopic composition close to that of any proposed juvenile water; thus, the presence of the juvenile water even in considerable amounts would be difficult to detect in any of these discharges. The absence of liquid water in the vicinity of Erebus, with the isotopic composition of precipitation far removed from that of any possible juvenile water, should allow even small amounts of such primordial water to be observed. The majority of the few acceptable gas analyses reported for high-temperature discharges are based on samples collected from basaltic magmas; samples from Erebus would allow the study of gases released from more acidic magmas.

In 1972 we had considered it quite an achievement to have reached the Main Crater floor, in 1974 the descent in the Main Crater became a routine operation. From there it is just another 100 meters down to the Inner Crater floor, with its lava lake and high-temperature gas vents. The problem was how to get there without getting caught in one of the eruptions which then sent twirling domas of molten rock to heights above the Main Crater floor, or bombs as far as our camp site. Our only hope was that some day the volcano may grow tired of its fireworks and settle down to a more relaxed state of activity.

That long awaited moment appeared to have arrived in 1978 when Phil Kyle rang me at the end of October from McMurdo. He, Hairy Keys and Colin Monteath had been up there for a few hours and hadn't seen any signs of recent eruptions, no new, black bombs on the crater rims or floors. And the Active Vent, the main cause of our previous troubles, was filled with snow and the lava lake itself was slowly convecting, gently blowing bubbles every now and then.

Of course, that changed the whole picture; for the first time, it looked like we stood a real chance. Phil, Hairy, Kathy Cashman and Bill MacIntosh would be off to Northern Victoria Land all November; we, the New Zealand team, Ray Dibble, Colin Monteath, a surveyor, a field assistant, and I, plus the French party would meet them up on the mountain sometime during the first half of December.

On December 8 we left Christchurch for Antarctica. Haroun Tazieff had come alone; all his gas sampling and telemetric gas measuring equipment had been held up at an airport in Indonesia and had been damaged by unsuitable storage. After two days at Scott Base we were airlifted by U.S. Navy helicopter to the intermediate altitude acclimatisation camp near The Fang on December 10. This procedure is necessary to prevent the recurrence of attacks of acute mountain sickness which during earlier visits to the summit area of Erebus had required the evacuation by helicopter of around half a dozen people, often under hazardous conditions.

We stayed at The Fang until December 13. The weather was perfect, days with 360 degree, 24-hour sunshine with views over the breaking ice of the Ross Sea along the coast of Victoria Land to Mt. Melbourne around 350 km away; some claimed they could see Cape Hallett at a distance of over 600 km. Low humidity and no wind caused the plume rising from the crater to dissolve quickly, leaving only a thin veil of 'smoke' trailing toward the horizon. Such days are quite rare and acclimatised or not, we had to go to the top, a climb of around 1100 m. Colin Monteath and Carl Thompson, the field assistant, took their skis up to the edge of the summit plateau, and the rest of us reached the Main Crater rim at around 15:00. The crater floor didn't look quite as Phil had said - the Active Vent was dark and here and there were a few black specks in the snow. Oh - yes, there might have been an eruption or two, no really big ones, maybe only an occasional burp - nothing serious, we thought.

The next day, airlifted up to the summit camp, put up tents, cleaned up hut, got oil-heater going. Next day, the weather still beautiful, the first eruption, a short sharp bang, a small one, but definitely an eruption; in the evening another one, a bigger one, two a day, almost back to the old pattern. On December 15 Phil, Hairy, Kathy and Bill arrived back at Scott Base, we start to transport material from camp to Main Crater floor. Haroun is busy to shoot material for another film. Eruptions continue, weather slowly deteriorates. December 18, first attempt to enter Inner Crater, had to give up because of steam and gas obscuring descent route. The next day Hairy and Bill walk up from Fang camp, bomb hits coil of rope on Main Crater floor and burns it through in many places; have our first hangi, leg of lamb tender cooked in steaming ground of Side Crater. December 20, Karen Williams, information officer from Scott Base, arrives for short visit, remains storm bound until 22 when she and Haroun return

to Scott Base. Ray Dibble is busy to establish and maintain seismograph, microphone and induction coil eruption monitoring network, while the surveyor, Colin Fink, puts aerial photo marker crosses all over the summit plateau.

December 23, the weather clears, little wind. We, Colin, Carl, Phil, Kathy, Hairy, Bill and I make our way up and down into the Main Crater. We all know this could be the day. No further bombs had hit our ropes and the Z-pulley system is quickly laid out; the Active Vent is very quiet, too quiet perhaps.

At around 16:00 Colin Monteath is ready to descend. He cautiously abseils down the first 20 m of steeply sloping layers of more or less consolidated volcanic ejecta. At the edge of the overhang he pauses a while; I am busy filming him with Haroun's camera, so I can't hear what he is saying over the little radio he carries. Then he is off, down over the 30 m high overhang, over a wall of solid, almost unfractured kenyte. He soon reaches what we thought were ash benches below, but he obviously has problems finding a good foothold; as it turned out, the ash benches consist of ash and debris fallen from the crater wall, but cemented by ice. The unexpected hardness and steepness of this material would require the cutting of steps to provide a base to descend past steep permafrost slopes that drop another 30 m, to another vertical-to-overhanging cliff 10-15 m high right above the most active gas vents.

Colin reached the end of the descent rope at the bottom of the ash benches during this first attempt. The Z-pulley system on the Main Crater floor required three or four people to retrieve a person from the Inner Crater; with one person belaying and one attending to the radio, we were all occupied during Colin's return, and therefore didn't note that residual torque in the new rope used had caused Colin to spin while being pulled up over the last overhang. His belay rope became slowly entangled around the Z-pulley rope, making it difficult for him to find his feet when reaching the top of the overhang. He was dragged for quite a distance up the steep debris slope. When he finally reached the Main Crater floor, he was exhausted and bleeding from scratches on both forearms.

In preparation for the second descent by me, we shifted the belay point some 15 m to the east, and another length of rope was tied to the descent rope. I encountered no problems during this second descent, and after my ride down the overhang, I soon reached the knot tying the two descent ropes together. The extra length of rope was draped below me over projections close to the edge of the ash bench. It was quite a problem to disentangle it all; the stretch in the 80 m of rope holding me caused it to behave like a rubber band - leaning back would force me to make a step back, then in the new position leaning forward the rope would pull me forward straight on my face. Anyway, I was just about to re-attach the descender below the knot, when - B-ROOM, the thing went off.

I thought - that's it - what else could one think - and looked back. I was at about the same level as the Active Vent at the foot of the crater wall over there; from where I was most of the material appeared to be ejected in the form of a shallow inverted cone centered on the crater. Looking up I saw about a dozen larger pieces cruising towards the Main Crater floor. One smaller piece the size of a handbag appeared to be headed to a point just above me and threatened to hit the rope. While hopping a few steps sideways to prevent this from happening another bomb the size of a large cucumber hit me above the right knee. Because of the highly vesicular nature of the material ejected it didn't cause any injuries. However, the temperature of the still-incandescent piece was sufficient to ignite my woolen trousers; I quickly patted out the sparks eating along the edges of the burnt hole and looked up to avoid some of the up-to-football-sized pieces of incandescent debris raining down the crater wall. Looking up along the rope I was dangling on, I saw a piece of smouldering material lodged very close the the point where the rope passed over the overhang. I tugged on the rope to check if it was still safe and decided it was time to look for a somewhat more secure position in case the rope burned through. I traversed some 15 m to the left where a small fumarole had eaten its way through the permafrost. At last I had a proper foothold and things looked quite a bit brighter. Then the radio crackled - 'Werner how are you, are you alright?' - It took me a while to find the mouthpiece - 'Yes, that was a good one, I am alright, how are you?'

For the first time since I got down here I had some time to look around. I was almost level with the surface of the lava lake. It was quite surprising to see that the lava lake was actually perched, quite elevated above the bottom of the crater; generally the topography of the Inner Crater floor was much more rugged than it appeared from the top. The ice-rimmed steam vents to the right were two gaping clefts in what appeared to be some older cone; the crater of the Active Vent had closed up again, steaming lumps of lava draped over its rim. The intermittent fumarole at the foot of the descent route was up to its best, with a hissing roar that made it almost impossible to understand the radio - 'Werner, we decided you should come up, two bombs up here have almost landed on your ropes, they could be damaged further down.' It took me a while to think it over. I was so close, another 10-20 m and I would be there; the smoldering piece, did it touch the rope? Besides that, I got lousy cold. Hoping to be warmed by radiation from the lava lake I had left my down jacket up there. The surface of the lava lake was almost hidden by its elevated rim, no way it could warm me. Besides - there is always a tomorrow, and enough is enough - 'Yes, I think I come up, give me a little pull to check if everything is alright. - - Stop, you strangle me!' Almost all my weight was hanging on the jumar connected to my chest harness, another pull and I would have fainted, that's how my lungs got squashed. I attached another sling and jumar to my right foot and shortened the sling attached to my seat harness and off it went, like a chairlift. I was a bit apprehensive about the two-meter sampling tube sticking out of my pack; if it got wedged underneath the overhang I may end upside-down on the rope. But the belay rope meeting me at an angle allowed me to turn face to rock and without any further hitches I reached the rim.

They had brought me back from the depth of Erebus - the twilight of the Occident, where lie Hades and sunless land of the Cimerians, personified as son of Chaos, brother and husband of night, father of Aither and day.

There was no other attempt. From Christmas on we had only storms and white outs; on January 3 the last of our team left the mountain to return to wherever we had come from."

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