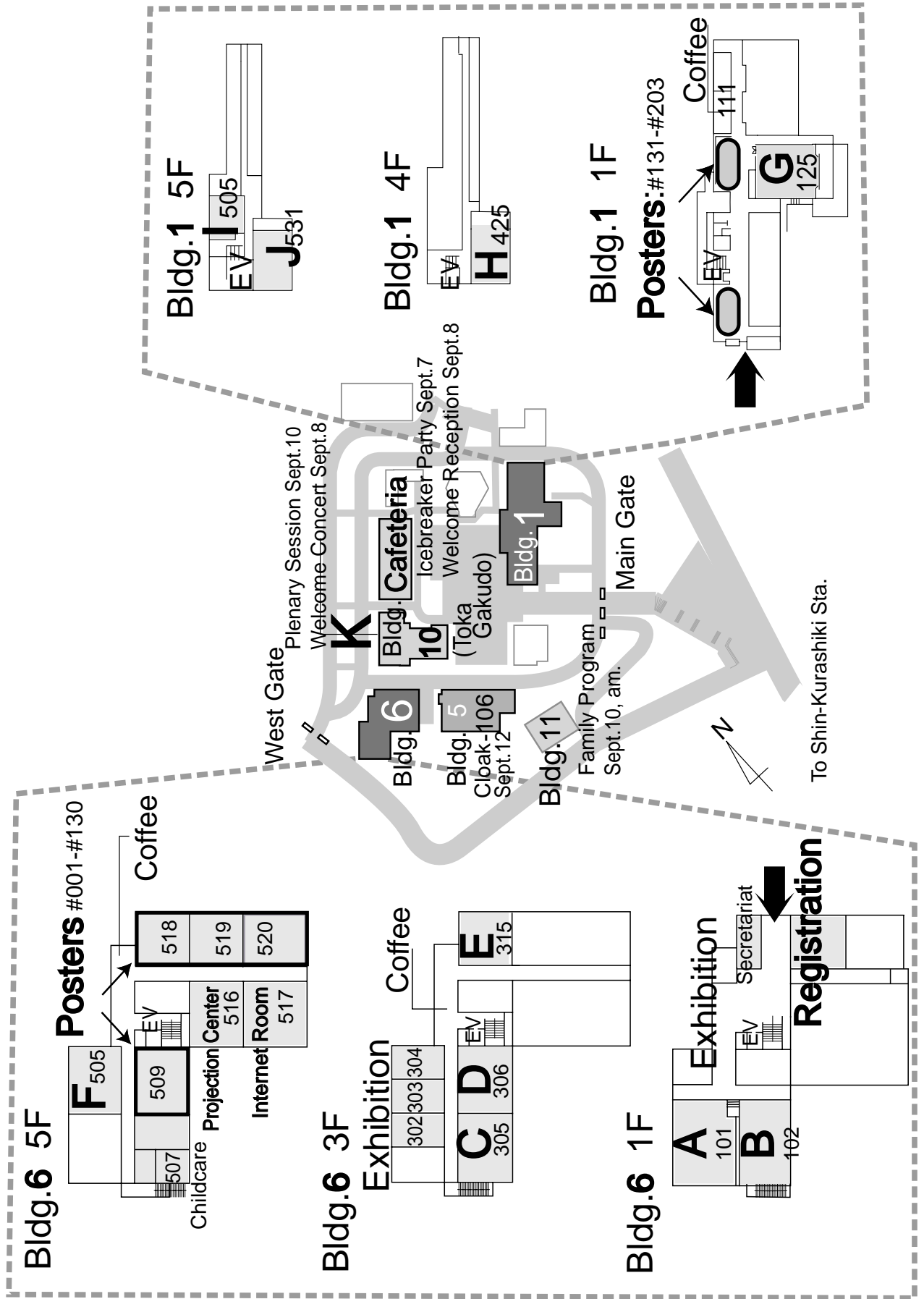


Goldschmidt 2003

PROGRAMME VOLUME

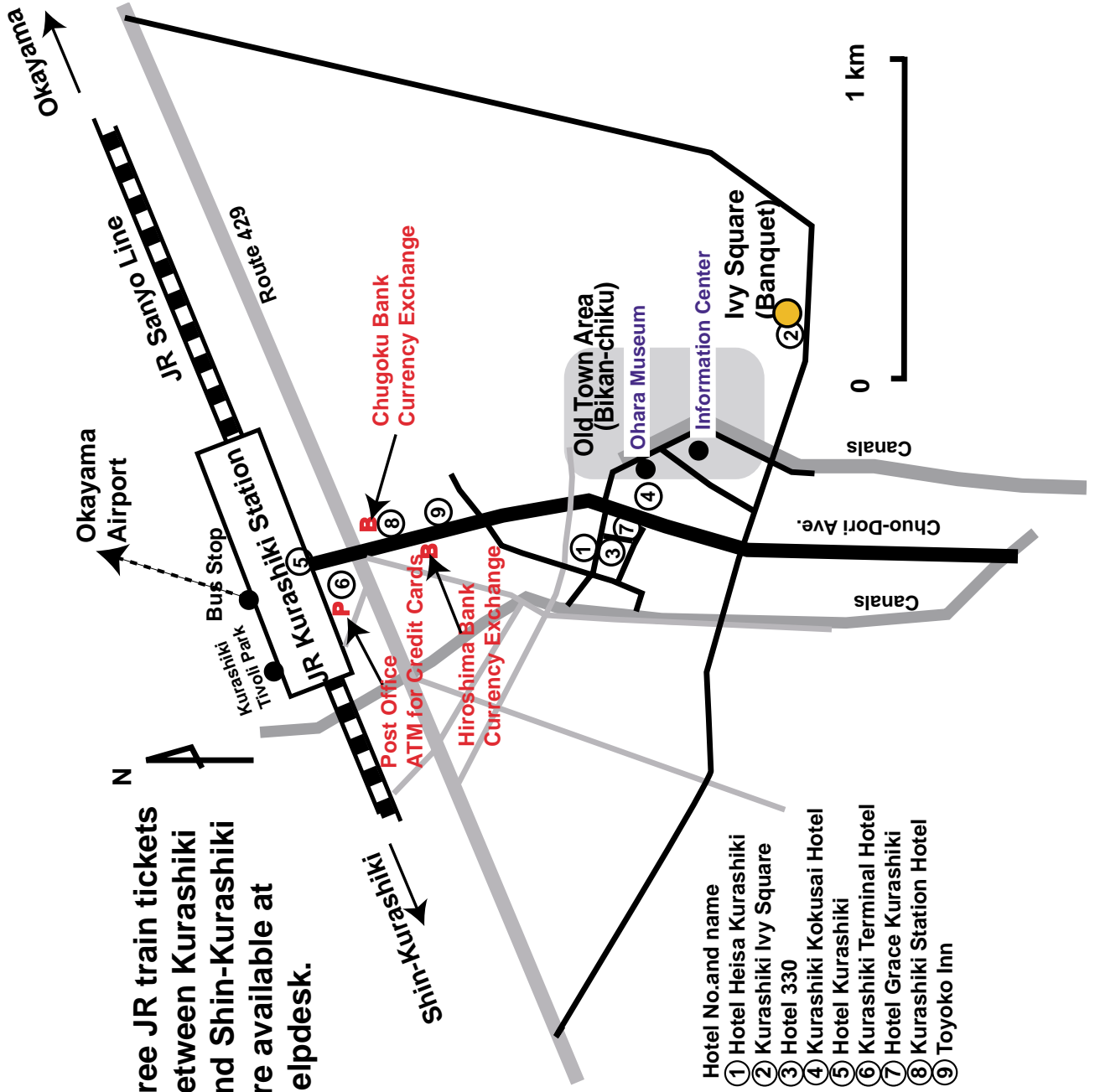
7th – 12th September 2003
Kurashiki, Japan

Map of Conference Venue Kurashiki Sakuyo University



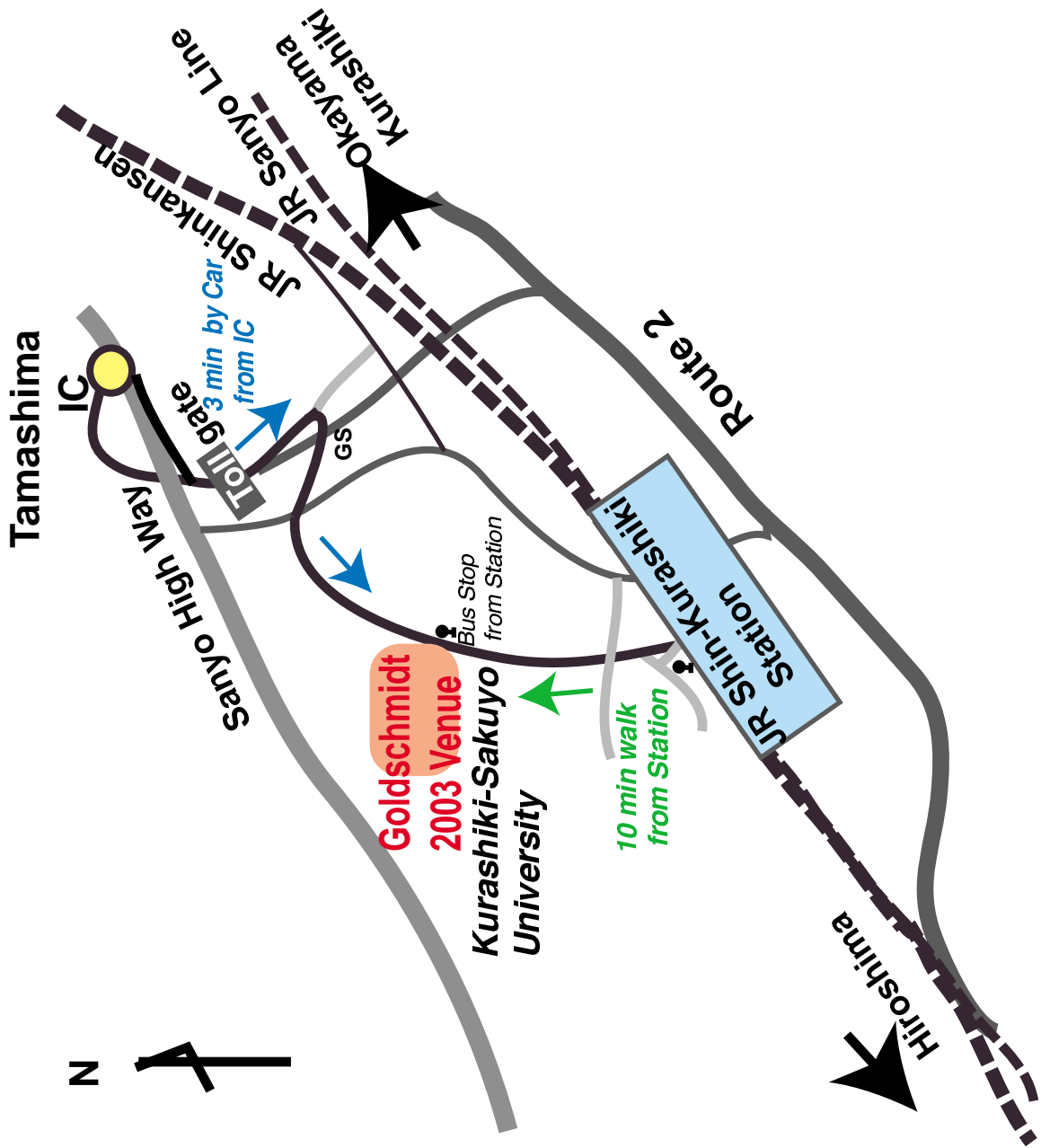
Hotel Map (Kurashiki)

Free JR train tickets between Kurashiki and Shin-Kurashiki are available at Helpdesk.

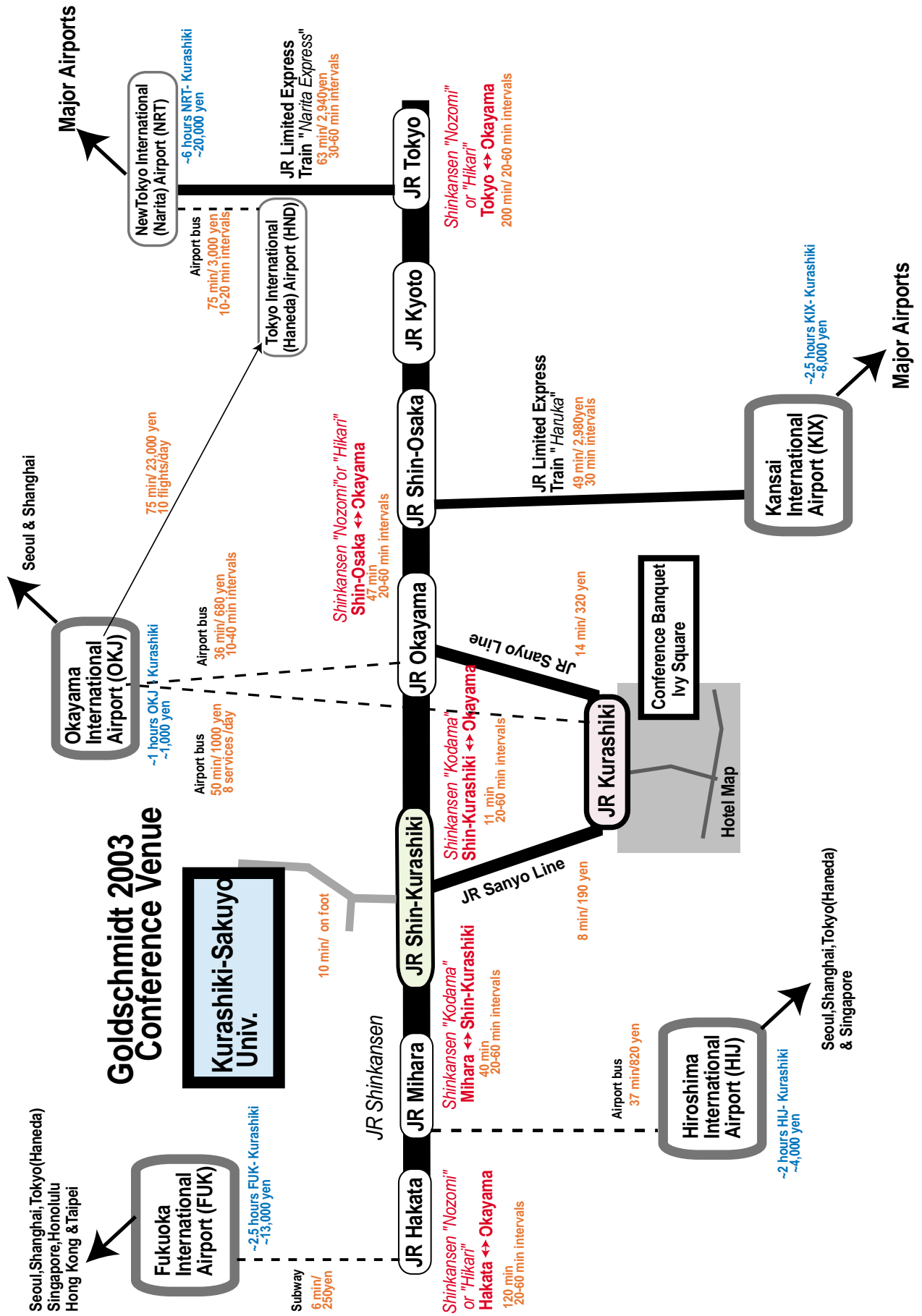


- Hotel No. and name
- ① Hotel Heisa Kurashiki
 - ② Kurashiki Ivy Square
 - ③ Hotel 330
 - ④ Kurashiki Kokusai Hotel
 - ⑤ Hotel Kurashiki
 - ⑥ Kurashiki Terminal Hotel
 - ⑦ Hotel Grace Kurashiki
 - ⑧ Kurashiki Station Hotel
 - ⑨ Toyoko Inn

Access Map to Goldschmidt 2003 Conference Venue



Travel Map to Kurashiki



Goldschmidt 2003

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Welcome to Goldschmidt 2003

On behalf of the Organizing Committee, I would like to welcome you to the 13th Annual V. M. Goldschmidt Conference (Goldschmidt 2003). The Goldschmidt Conference is now the premier annual meeting for geochemistry and cosmochemistry. Goldschmidt 2003 has a special significance, as it is the first time that the meeting is to be held in the western Pacific region. This will provide a great opportunity to broaden research activities and increase awareness of geochemistry and cosmochemistry worldwide. The past Goldschmidt Conferences have been organized through the collaboration of the Geochemical Society and European Association for Geochemistry. Recently, the Mineralogical Society of America have taken part in the sponsorship. This year, the Geochemical Society of Japan joined their collaboration. These collaborations promise a wider scope and basis for future Goldschmidt Conferences.

A comprehensive meeting, the Goldschmidt Conference is the place to integrate different disciplines where geochemists from all over the world come together to discuss the Earth, solar system, and the universe from both subdisciplinary and interdisciplinary points of view. We are coming into an exciting new era to explore unknown areas of the natural world, particularly at the interfaces between disciplines, which have been previously seldom considered. This was made possible through the development of new experimental techniques and progress in our understanding of nature. Geochemistry is also becoming an important tool to help understand and solve problems of social interests. We hope Goldschmidt 2003 will create new frontiers in geochemistry and cosmochemistry.

With the increasing size of the Goldschmidt Conference, it is becoming increasingly difficult for local organizers to fit all aspects of geochemistry together into the science program. Last year, Alex Halliday, whilst organising the Davos meeting, established the International Program Committee (IPC) with experts from a broader cross section of scientists to help plan the special symposia. This idea worked well. Therefore, we followed this idea for Goldschmidt 2003 and established an IPC chaired by Jun-ichi Matsuda for 13 specific areas of geochemistry. We received as many as 65 proposals of special symposia covering all the current topics in geochemistry, which eventually became 53 symposia after some necessary rearrangements. Conveners of the special symposia have invited excellent keynote and invited speakers to highlight topics in their symposia. Without their efforts, this meeting would not have been such a success. In addition to these special symposia, we have planned nine general symposia with the assistance of the Japan Program Committee (JPC) to cover the broader scope of geochemistry. The members of IPC and JPC are mentioned elsewhere in this volume.

One of the special features of Goldschmidt 2003 is travelling in Japan. We have established a plan of field trips after the meeting to visit sites of geologic and cultural interest around Kyushu. In the trip to Kyushu, you will visit several active volcanoes including Aso, one of the world's largest calderas, and Beppu, the Japan's largest hot spring resort. Pottery lovers cannot miss this trip, which includes a visit to Arita, a world-famous pottery producer. We also have plans to take you to Okayama and Himeji as mid-conference tours, where you will enjoy Japanese gardens and castles from medieval times. Guided tours to the old town area of Kurashiki and family programs during the conference would also help you enjoy and understand Japanese culture.

Goldschmidt 2003

Goldschmidt 2003 was realized with the effort and support of many people and organizations. We appreciate Jun-ichi Matsuda, who devoted himself as the chairs of both IPC and JPC to promote proposals of symposia topics and arrange them into the science program. The team of Cambridge Publications lead by Paul Beattie again provided us with excellent systems for receiving and handling abstracts, and helping JPC to arrange the scientific program. The abstracts are published by Elsevier in a supplement issue of *Geochimica et Cosmochimica Acta* as was done last year. International Communications Specialists, Inc. (ICS) helped us as the secretariat for Goldschmidt 2003 in the web page preparation, registration procedures, conference operation and other essential works of management. JTB, the official travel agent of Goldschmidt 2003, managed accommodation arrangements, field trips and mid-conference tours for delegates. Special thanks should be given to the city of Kurashiki for its support on various occasions to hold the conference in this historical town as well as for financial support.

Kurashiki Sakuyo University generously offered their facilities and hospitalities to the conference. As a supporting organization, the Geological Survey of Japan, AIST, authorized its staff to work in part for Goldschmidt 2003. I would like to mention the great efforts and contributions made by the members of the Organizing Committee and many part-time and volunteer workers, without which the conference would not have been realized. Finally, we acknowledge the Commemorative Association for the Japan World Exposition (1970), Japan National Tourist Organization, Tokyo Geographical Society, Electric Technology Research Foundation of Chugoku and many other organizations and companies for their financial support to Goldschmidt 2003. This conference was partially supported by a Grant-in Aid for Publication of Scientific Research Results (#1562002), Grant-in-Aid for Scientific Research, the Ministry of Education, Culture, Sports, Science and Technology, Japan.

Enjoy the meeting and your stay in Japan.

Yukihiro Matsuhisa

For the Organizing Committee,
Goldschmidt 2003

CONFERENCE INFORMATION

Conference Location

Goldschmidt 2003 is held in the Kurashiki Sakuyo University at Kurashiki, Japan. The conference venue layout can be found in the maps on page ii. We use three buildings (Buildings 1, 6 and 10) and the cafeteria. The doors open at 08:30 am each day except for Monday morning (08:15 am). The conference badge (included in each delegate's registration pack) is required to ensure entry.

The registration desk is located on the ground floor of Building 6. All oral and poster presentations are held in Building 1 or 6. The Exhibition is located in Building 6. The Plenary Session on Wednesday morning is held in Building 10 (Toka-Gakudo Hall).

The Icebreaker Party on Sunday evening and Welcome Reception on Monday evening take place in the University cafeteria. Traditional Japanese music (free admission) is offered in Building 10 (Toka-Gakudo Hall from 17:30) prior to the welcome reception. The banquet on Thursday evening (19:00-21:30) is held at the Ivy Square in downtown Kurashiki City (see the map on page iii).

Registration Desk

The Registration Desk is located in the Entrance Hall of Building 6. It is open as follows:

Sunday, September 7th14:00 - 19:30
Monday, September 8th08:15 - 17:30
Tuesday, September 9th08:30 - 17:30
Wednesday, September 10th.....08:30 - 12:30
Thursday, September 11th08:30 - 17:30
Friday, September 12th.....08:30 - 15:00

Pre-Registration and On-site Registration

Delegates who have pre-registered and fully paid their fees can pick up their conference materials upon arrival at the Pre-Registration Desk. On-site registration is available during the hours indicated above.

Publications

Each delegate will receive a copy of the programme volume containing abstracts and programme CD-ROM. Each delegate will also receive a printed copy of the abstract volume, which has been edited by the Goldschmidt 2003 Program Committee and Cambridge Publications, and published by Elsevier Science as a supplement to *Geochimica et Cosmochimica Acta*.

Computing and Internet Access

The Internet Room is Room 517 on the fifth floor of Building 6. The Room will be equipped with more than 20 PCs and spaces for delegates to use their laptops. These computers will run Windows XP. The facility which enables delegates to revise PowerPoint presentations will be prepared in the next room (Projection Center, Room 516).

Refreshments

Coffee and tea will be served during the coffee breaks in morning and afternoon sessions as well as during the poster sessions.

Messages

There will be a message board adjacent to the Helpdesk. Any program changes or urgent announcement from the Organizing Committee will be posted on the message board.

Personal messages can be left and retrieved at the Helpdesk. Messages can also be sent to the following fax number +81-86-522-0210, or, in emergency, +81-86-522-0216. These numbers will be available only during the conference. Otherwise, please contact gold2003@ics-inc.co.jp.

The postal address of Kurashiki Sakuyo University is 3515 Nagao, Tamashima, Kurashiki, Okayama 710-0292 Japan.

CONFERENCE INFORMATION

Helpdesk

The Helpdesk is located at the Entrance Hall of Building 6 during the Registration Desk hours indicated above.

Emergency Call

You will find the emergency call number for out of office hours in your registration pack. The number can be used for medical and other emergencies. This number will be available only during the conference.

Certificate of Attendance

Please contact the Registration Desk if you require a certificate of attendance at Goldschmidt 2003.

Travel Information Desk

The Travel Information Desk will be open on the ground floor of Building 6 throughout the Conference period. For hotel accommodation and train reservation queries, please contact the Travel Information Desk.

Currency Exchange

Only Japanese yen (JPY) is acceptable at local shops and restaurants. Delegates may use the currency exchange service at Hiroshima Bank, Kurashiki Branch and Chugoku Bank, Kurashiki Branch. The business hours are 09:00-15:00, Monday through Friday. Both banks are located along Chuo-Dori Street near JR Kurashiki Station (see the map on page iii).

Delegates may use their Credit Cards (Visa, MasterCard, American Express, JCB etc.) to obtain JPY at Automatic Teller Machines located at the Post Office in front of the south exit of JR Kurashiki Station (for exact location, please contact Helpdesk). The business hours are 09:00-19:00, Monday through Friday, and 09:00-17:00 on weekends.

Traveller's Checks and Credit Cards

Traveller's checks are accepted only at leading banks and major hotels in principal cities. Visa, MasterCard, and American Express are widely accepted. Some local shops and restaurants may accept only JPY cash.

CONFERENCE EVENTS

SCIENTIFIC EVENTS

Oral Presentations

The oral sessions will take place during 09:00-12:00 and 14:00-17:00 on Monday, Tuesday, Thursday and Friday. Tea breaks are 10:30-10:45 and 15:30-15:45. There are nine general and 53 special symposia. Originally there were 55 special symposia, but two of them (S19 and S50) have been merged with other symposia. The titles of these symposia are listed on page xiii. The rooms and times allocated for the oral presentations of each symposium can be found in the charts on page xvii. The list of the first authors is also given on page 69.

Poster Sessions

There are two groups of poster sessions. The first group of posters (session 08/09PO) will be displayed on Monday and Tuesday. The second group (session 11/12PO) will be displayed on Thursday and Friday. The groups and the numbers of poster sessions in each symposium can be found on the charts on page xvii.

The posters will be displayed in the two poster halls. Posters 001-130 will be displayed in the poster hall on the fifth floor of Building 6, while posters 131-203 will be displayed in the poster hall on the first floor of Building 1. Both these venues are shown on the map on page ii.

Authors will be present to discuss their posters between 13:00 and 14:00 on Monday and Tuesday for the first group, and Thursday and Friday for the second group.

The Plenary Session

The Plenary Session will take place at the Toka-gakudo Hall (Building 10) on Wednesday morning from 09:00. This session will include the awarding of the medals of the Geochemical Society, European Association for Geochemistry, and the Geochemical Society of Japan, and the plenary lectures. The timetable for the Plenary Session can be found on page 23.

SOCIAL EVENTS

The Icebreaker Party

Sunday September 7th, 17:00-20:00

Welcome Reception

Monday September 8th, 17:30-20:00

Sponsored by Kurashiki Sakuyo University.

This will take place at the university cafeteria. All delegates to the conference are cordially invited. A concert of Japanese traditional music (admission free) is planned at Toka-gakudo Hall Building 10) prior to the welcome reception. The concert will start at 17:30.

The Conference Banquet

Thursday September 11th, 19:00-21:30

This will take place at the Ivy Square in the downtown of Kurashiki City, about 15-minute walk from the Kurashiki Station (see the map on page iii). Those who have booked places will find their tickets in their registration envelope. Further tickets may be purchased from the Helpdesk while places remain.

Family Programs

The following family programs are planned. Those who are interested in the programs will find detailed information of each program and can make reservations at the Family Program Registration Desk in the Entrance Hall of Building 6.

Guided tour to the old town area of Kurashiki

Tuesday September 9th 10:00-12:00

Tuesday September 9th 14:00-16:00

Tea ceremony

Wednesday September 10th 10:00-12:00

(20 people, at Kurashiki Sakuyo University)

Flower arrangements with Japanese Taste

Thursday September 11th 10:00-12:00

(14 people, at the Ivy Square, Kurashiki)

"Yukata" dressing

Thursday September 11th 13:00-15:00

(10 people, at the Ivy Square, Kurashiki)

CONFERENCE SYMPOSIA

General Symposia

- G01: Chemical Oceanography (*Toshitaka Gamo, Yoshiki Sohrin*)
G02: Climate Change (*Yutaka Abe, Kimitaka Kawamura, Yutaka Kondo*)
G03: Biogeochemistry and Organic Geochemistry (*Masao Minagawa, Hideshige Takada*)
G04: Environmental Geochemistry (*Naohiro Yoshida*)
G05: Sedimentary Geochemistry (*Iwao Kawabe*)
G06: Igneous/Metamorphic Geochemistry (*Yoshiyuki Tatsumi, Takashi Nakajima*)
G07: Planets and Meteorites (*Noriko Kita, Tomoki Nakamura*)
G08: Physics and Chemistry of Minerals (*Eiji Ohtani, Masaki Akaogi*)
G09: Volcanic Gases, Fluids and Ore Deposits (*Hiroyuki Kagi, Shun'ichi Nakai*)

Special Symposia

Marine and Atmosphere Geochemistry, and Climate Change

- S01: High-resolutional Paleooceanography in the Western Pacific during Late Quaternary (IMAGES Activity) (*Hodaka Kawahata, Min-Te Chen*)
S02: Biogeochemical Cycling of Trace Elements and Isotopes in the Ocean and Applications to Constrain the Contemporary Marine Processes (GEOSECS II) (*Roger Francois, Toshitaka Gamo*)
S03: Marine Geochemistry of the Rare Earths, Actinides and Noble Metals: The Present and Past Oceans (*S. Krishnaswami, G. Ravizza*)
S04: Long-range Atmospheric Transport of Terrestrial Materials over the Ocean (*Maureen H. Conte, Kimitaka Kawamura*)
S05: Atmospheric Aerosols and Reactive Gases: Their Impacts on Atmospheric Composition and Air Quality over the Asian and Pacific Regions (*Kimitaka Kawamura, Yutaka Kondo, Barry Huebert, Shaw Chen Liu*)

Biogeochemistry

- S06: Global Biogeochemical Cycles (*Abraham Lerman, Fred T. Mackenzie*)
S07: Advances in the Use of Stable Isotopes to Study the Global Methane Cycle (*Atsuko Sugimoto, Edward Hornibrook*)
S08: Assessing biogeochemical cycles using nitrogen isotopes (*Carsten Schubert, Matt McCarthy*)
S09: Progress in subsurface microbiology and its development through Ocean Drilling: over bridging from ODP to IODP (*Kenji Kato, Ken Takai*)
S10: Biogeochemistry of Trace Metals in Shallow Estuarine Systems and Coastal Lagoons (*Wilaiwan Utoomprurkporn, Milena Horvat, Nicolas S. Bloom, Ligia M. Moretto*)
S11: The role of bacterial surfaces in chemical processes of metal ions in the environment (*Danielle Fortin, Yoshio Takahashi*)
S12: Weathering and the Biosphere (*Tasuku Akagi, James Drever*)
S13: Geochemical Role of Available Humus or Dissolved Organic Matter (DOM) in Soils and Sediments (*Adam Zsolnay, Tohru Miyajima*)

CONFERENCE SYMPOSIA

Origin and Evolution of Life

- S14: Origins and Distribution of Life in the Universe (*Andre Brack, Koki Horikoshi, Kensei Kobayashi, Koichiro Matsuno, Chris McKay, Tatsushi Murae, Satoru Nakashima, Hiroaki Sawai*)
- S15: Geochemistry of Biological Radiation and Extinction (*Peter Ward, Yukio Isozaki*)

Sedimentary Geochemistry

- S16: Chemical Diagenetic Processes in Sediments and Sedimentary Geochemistry (*S. Ohde, Sunil K. Singh*)
- S17: Biogeochemistry and Paleoenvironmental Implications of Metals in Marine Sediments (*Timothy W. Lyons, Ariel D. Anbar*)
- S18: Multivariate Methods and Heterogeneity in Geochemical/hydrochemical Surveys (*Pauline F.M. van Gaans, S.P. Vriend, Pieter-Jan van Helvoort*)
- S19: Merged with S20
- S20: Geology, Geochemistry, and Microbiology of Natural Gas Hydrates and Related Methane Seeps (*Charlie Paull, Ryo Matsumoto, Hideki Wada*)

Isotope Geochemistry

- S21: In Search of Isotopic Biosignatures (*Juske Horita, Alan Matthews*)
- S22: Non-traditional Stable Isotopes (*Ariel Anbar, Thomas Bullen, Mark Rehkämper*)
- S23: Molecular Isotope Geochemistry – From Natural to Anthropogenic (*Simon Poulson, Hiroshi Naraoka*)
- S24: New Advances in High Precision Trace Element and Isotopic Analysis (*Joel Baker, Bodo Hattendorf, Mark Rehkämper*)
- S25: Laser Ablation ICP-MS and MC-ICPMS with Applications in Earth Sciences (*T. Pettke, D. Günther, T. Hirata, U.H. Wiechert*)
- S26: Unraveling Geological Processes by Noble Gas Isotopes (*Daniele L. Pinti, Takuya Matsumoto*)
- S27: Lithium Isotope Geochemistry: From Oceans to Mantle (*Roberta L. Rudnick, Eizo Nakamura*)
- S28: Lanthanide Tetrad Effect and New Trends in REE Geochemistry (*Michael Bau, Iwao Kawabe*)

Crustal Fluids, Mineralization, and Natural Hazards

- S29: Following Giggenbach's Rulers and Witnesses of Crustal Fluids: Volcanic, Geothermal and Ore Systems (*Jeffrey W. Hedenquist, Stuart F. Simmons*)
- S30: Geochronology of Ore Formation Processes and Ore Genesis in Relation to the Magma Generation (*Jean-Louis Vigneresse, Albrecht von Quadt, Laurent Ameglio*)
- S31: Geochemistry Linked to the Reduction of Natural Hazards (*Pierre Delmelle, Naoji Koizumi*)

Mineral Sciences and Waste Confinement

- S32: Nano Materials/minerals in Geoscience by TEM (*J. Akai, T. Kogure, K. Fujino*)
- S33: Mineral-fluid Interfaces: Molecular-scale Insights to Macroscopic Processes (*Paul Fenter, Lionel Mercury, Takashi Murakami*)
- S34: Geochemical Immobilization and Long-term Isolation of Waste (*Reto Gieré, H. Dora Yoshida, Hiroshi Hidaka, Peter Stille, Russell Alexander*)

CONFERENCE SYMPOSIA

Crust, Mantle, and Core

- S35: Metamorphic Processes: Diffusion, Reaction and Fluid Flow (*T. Nishiyama, W. Carlson*)
S36: Subduction Zone Processes and Global Material Circulation (*H. Iwamori, J. Pearce, Y. Tatsumi*)
S37: HP to UHP Metamorphic Mass Transfer and Chemical Cycling in Convergent Margins (*Yong-Fei Zheng, Gray E. Bebout, Pascal Philippot*)
S38: Mantle Heterogeneity and Dynamics of Mantle Plumes (*E. Ohtani, C. Bina, Y. Fei, Hugh O'Neil*)
S39: Composition, Processes and Structure of the Mantle (*Suzanne Y. O'Reilly, Shoji Arai*)
S40: Hot Spots and Global Mantle Circulation (*Eiichi Takahashi, David Clague*)
S41: Structure and Properties of Silicate Melts and Fluids (*Xianyu Xue, Daniel R. Neuville, Tatsuhiko Kawamoto, Masami Kanzaki*)
S42: Geochemistry of Diamond, A Window to the Deep Earth (*Tetsuo Irifune, Hiroyuki Kagi*)
S43: Mantle-core Differentiation and Evolution from a Deep Magma Ocean (*Carl Agee, Michael Walter*)

Early Earth

- S44: First Billion Years (*Stephen J. Mojzsis, T. Mark Harrison, Yuichiro Ueno*)
S45: Co-evolution of the Biosphere, Atmosphere, Hydrosphere, and Lithosphere in the Early Earth (*Yasuhiro Kato, Hiroshi Ohmoto*)
S46: New Insights into Early Earth's Environments from the Multiple Sulfur Isotope System (*Shuhei Ono, Boswell Wing*)

Meteorites and Solar System

- S47: Early Solar System Processes (*H. Nagahara, K. Hashizume, B. Marty, F. Robert, A. Davis, N. Kita*)
S48: Martian Meteorites and the Evolution of their Parent Body (*Gerlind Dreibus, Emil Jagoutz*)
S49: Cosmogenic Nuclides Produced in situ in Solar System Matter (*Masatake Honda, A. J. Timothy Jull, R. Reedy*)

Geochronology

- S50: Merged with S44 with a new title
S51: Thermochronometry: Recent Developments in Calibrating (and Intercalibrating) the Thermal Sensitivity of Isotopic Dating Techniques (*Andy Gleadow, Takahiro Tagami*)
S52: Geochronological Decay Constants (*H. Hidaka, K. Suzuki*)
S53: Dating Methods for Quaternary Geochronology (*T. Itaya, S. Toyoda*)
S54: Archaeological Geochemistry: Isotopically Decoding Prehistoric Human Life and Nature (*Masao Minagawa, Paul Budd, Wolfgang Müller*)

Geochemical Mapping

- S55: Geochemical Mapping – Global and Local Geochemical Baseline, Exploration and Environmental Pollution (*Noboru Imai*) (poster only).

LOCATIONS OF ORAL PRESENTATIONS

	Time	A	B	C	D	E	F	G	H	I	J
Monday 08 September	09:00-10:30	S53	G03	S17	G04	G09	S21	S39	G06	S47	G08
	10:45-12:00	S53	G03	S17	G04	G09	S21	S39	G06	S47	G08
	Lunch time										
	14:00-15:30	S09	G03	S13	G04	G09	S22	S39	G06	S47	S27
	15:45-17:00	S09	G03	S16	G04	G09	S22	S38	G06	S47	S27
Tuesday 09 September	09:00-10:30	S01	S06	S46	G04	S29	S23	S38	G06	S47	S32
	10:45-12:00	S01	S06	S46	S07	S29	S23	S38	G06	S47	S32
	Lunch time										
	14:00-15:30	S02	S08	S45	S28	S29	S24	S43	S42	G07	S33
	15:45-17:00	S02	S08	S45	S28	S29	S24	S36	S42	G07	S33
Thursday 11 September	09:00-10:30	S03	S10	S45	S18	S30	S26	S36	G06	G07	S34
	10:45-12:00	S03	S10	S14	S18	S30	S26	S36	G06	G07	S34
	Lunch time										
	14:00-15:30	G02	G05	S14	S12	S30	S26	S36	S41	S48	S34
	15:45-17:00	G02	G05	S14	S12	S31	S25	S36	S41	S48	S34
Friday 12 September	09:00-10:30	S04	S20	S14	S11	S51	S25	S35	S44	S49	S40
	10:45-12:00	S04	S20	S14	S11	S51	S25	S35	S44	S49	S40
	Lunch time										
	14:00-15:30	S05	G01	S14	S11	S51	S54	S37	S44	S15	S40
	15:45-17:00	S05	G01	S14		S52		S37	S44	S15	S40

ROOMS USED FOR ORAL PRESENTATIONS (see map on page ii for locations)

Building 6		Building 1		Building 10	
	Room No.		Room No.		Room
A	101	G	125	K	Toka-Gakudo Hall
B	102	H	425		
C	305	I	505		
D	306	J	531		
E	315				
F	505				

TIMES OF ORAL AND POSTER PRESENTATIONS

Symposium	Oral Sessions Monday 8th		Posters (8th / 9th)	Oral Sessions Tuesday 9th		Symposium	Oral Sessions Thursday 11th		Posters (11th / 12th)	Oral Sessions Friday 12th	
	AM	PM		AM	PM		AM	PM		AM	PM
G01						G01			001-007		B
G02						G02		A	008-015		
G03	B	B	001-020			G03					
G04	D	D	021-051	D		G04					
G05						G05		B	016-020		
G06	H	H	053-078	H		G06	H				
G07					I	G07	I		022-032		
G08	J		079-088			G08					
G09	E	E	089-110			G09					
S01			112-122	A		S01					
S02			123		A	S02					
S03						S03	A		033-044		
S04						S04			045-048	A	
S05						S05			049-063		A
S06			124-126	B		S06					
S07			127-130	D		S07					
S08			131-132		B	S08					
S09		A	133			S09					
S10						S10	B		64		
S11						S11			065-071	D	D
S12						S12		D	072-076		
S13		C	134-136			S13					
S14						S14	C	C	077-093	C	C
S15						S15			094-095		I
S16		C	137-140			S16					
S17	C		141-142			S17					
S18						S18	D				
S20						S20			096-103	B	
S21	F		143			S21					
S22		F	144-151			S22					
S23			152-158	F		S23					
S24			159-164		F	S24					
S25						S25		F	104-108	F	
S26						S26	F	F	109-112		
S27		J				S27					
S28			165-167		D	S28					
S29			168-170	E	E	S29					
S30						S30	E	E	113-117		
S31						S31		E	118-123		
S32			171-172	J		S32					
S33			173-176		J	S33					
S34						S34	J	J	124-139		
S35						S35			140-146	G	
S36					G	S36	G	G	147-152		
S37						S37			153-156		G
S38		G	177-181	G		S38					
S39	G	G	182-187			S39					
S40						S40			157-161	J	J
S41						S41		H	162-169		
S42					H	S42					
S43			188		G	S43					
S44						S44				H	H
S45					C	S45	C		170-172		
S46			189	C		S46					
S47	I	I	190-199	I		S47					
S48						S48		I			
S49						S49			173-177	I	
S51						S51			178-181	E	E
S52						S52					E
S53	A		200-203			S53					
S54						S54			182-183		F
S55						S55			184-192		

ORAL AND POSTER PRESENTATIONS

Locating presentations

The time and location of each presentation can be found in the programme (starting on page 1).

For poster presentations, dates, symposia, and poster board numbers can be found in the programme from page 45.

The programme gives the date, room, and time for each oral presentation. The surname of the first author may be found on the timetable overviews (pages 100 – 115). The program index gives the date, time and location of each presentation, together with the page number on which it appears in the Program Volume, the Abstract Volume, the PDF files on the CD, and on the conference website.

The oral presentation rooms are identified alphabetically as follows:

Oral Sessions

Building 6		Building 1	
	Room No.		Room No.
A	101	G	125
B	102	H	425
C	305	I	505
D	306	J	531
E	315		
F	505		

Plenary Session

Building 10	
	Room
K	Toka-Gakudo Hall

Poster Presentations

There are two groups of poster sessions at Goldschmidt 2003. The first group of posters will be displayed on Monday and Tuesday (session 08/09PO: see pages 46 – 56). The second group will be displayed on Thursday and Friday (session 11/12PO: see pages 57 – 67).

Authors will be present to discuss their posters between 13:00 and 14:00 on Monday and Tuesday for the first group and Thursday and Friday for the second group. Posters should be put up no later than 10:00 on Monday and Thursday, and removed between 14:00 and 16:00 on Tuesday and Friday.

The poster sessions will take place on the ground floor of Building 1 and the fifth floor of Building 6. For poster location, see the map on page ii. Each poster board has a unique number attached. The poster board number for each poster presentation is given in the programme.

The maximum useable size of each poster board is 150 cm (width) by 130 cm (height). Posters should be attached to the boards using the pins available from the Helpdesk. No other adhesive method is permitted.

ORAL AND POSTER PRESENTATIONS

Oral Presentations

Each oral presentation is allocated 15 minutes, including 5 minutes for discussion. Most medallist and keynote lectures are allocated 30 minutes, including seven minutes for discussion. The presentation times are the same in all ten parallel sessions so that delegates may move between different symposia. We request symposium chairs to adhere strictly to the timetable for this reason.

Each lecture hall is equipped with one main screen and an additional sub-screen, two overhead projectors, and one LCD projector plus laptop computer for PowerPoint presentations.

SLIDE PROJECTORS WILL NOT BE AVAILABLE IN LECTURE HALLS!!

Overhead Presentations

Speakers are responsible for the changing of overheads themselves.

PowerPoint Presentations

Files for PowerPoint presentations should be saved on Compact Disk. The CDs need to be handed in and tested for projection at the Projection Center (Room 516 in Building 6) no later than the day before the talk is scheduled. Disks should be labelled with the name of speaker, symposium code, day and time of presentation, and the file name (e.g. Smith.ppt). Presenters are required to verify their PowerPoint presentations in the Projection Center.

YOU CAN NOT USE YOUR OWN COMPUTER!!

Projection Center hours:

Sept. 7 (Sunday)	13:00 – 18:00.
Sept. 8 (Monday)	08:30 – 18:00.
Sept. 9 (Tuesday)	08:30 – 18:00.
Sept. 10 (Wednesday)	08:30 – 15:00.
Sept. 11 (Thursday)	08:30 – 18:00.
Sept. 12 (Friday)	08:30 – 15:00.

All presentation files and CDs will be removed from the computers at the end of each session. Any CD not collected at this time will be destroyed.

The computers for PowerPoint presentations are installed with PowerPoint XP (from Office XP standard), running on Windows XP. Delegates should ensure that their presentations are compatible with this operating system and PowerPoint version. Please be sure that all graphics are embedded in the presentation file. Fonts should be standard fonts such as Times New Roman, Arial, or Courier. If nonstandard fonts must be used, they should be embedded in the presentation files. Delegates who use Macintosh system to prepare the file should confirm that the images in the file are properly displayed on the Windows system.

Computers in the Projection Center will be equipped with CD burning software, allowing on-site updates of PowerPoint presentations, if necessary. Revisions will not be accepted after the presentations have been loaded.

FIELD TRIPS

Mid-Conference Tours

Wednesday September 10th, 13:15 onwards

Two mid-conference tours are planned for Wednesday afternoon. The tours will leave Kurashiki Sakuyo University by bus at 13:30 after the Plenary Session. Both tours will return to Kurashiki after dinner (dinner is included in the fee). Bookings for these trips can be purchased from JTB at the Travel Information Desk while places remain.

OP-1: Okayama Castle and Korakuen Garden

Take a sightseeing cruise to enjoy the fascinating view of the Seto Inland Sea (Setonaikai). Visit Okayama Castle built in 1573, which is a typical example of castles built on a flat land. This castle is commonly called "U-jo" (lit. Crow Castle) because it is painted black. Nearby the castle is Korakuen Garden, which is regarded as one of the three finest gardens in Japan along with Kairakuen Garden in Mito and Kenrokuen Garden in Kanazawa. It is a typical pond-centered stroll garden containing several pavilions, small ponds, cascades, and old trees. It takes 2 hours to examine the gardening techniques and materials used in the garden.

OP-2: Himeji Castle

Himeji Castle has a 5-story main building built in 1609. Before that time, a fortress had been situated there since the 14th century. The castle consists of one 5-story donjon, several 3-story keeps and inter-connecting passages. In addition to these structures, many of the turrets, gates and stonewalls are also well preserved. The castle is commonly called "Shirasagi-jo" (lit. Egret Castle). It resembles the silhouette of a white egret that is often seen in nearby rice fields. It was designated as a national treasure in 1931 and World Cultural Heritage in 1993.

Goldschmidt 2003

FIELD TRIPS

Post-Conference Trip

Field trips leaving on Saturday morning after the conference have been organized. Bookings for these trips can be purchased from JTB at the Travel Information Desk while places remain.

Active volcanoes and Japan's largest spa in the rift zone in Kyushu

Date:	Saturday September 13th – Monday September 15th
Fare:	¥78,800 (based on double occupancy)
Leader	Prof. Takeru YANAGI (Kyushu University)

This field trip visits active volcanoes, Unzen, Aso, Kuju, and the Japan's largest spa resort, Beppu City, in the rift zone of central Kyushu. At the beginning, we make a stop for lunch and shopping at the famous site of porcelain kilns, Arita, where the world-famous Ko-Imari was produced. Aso is one of the world's most active volcanoes sitting in a 24 km-wide caldera. Unzen volcano erupted from 1990 to 1995 and built a dacite dome at the top of Mt. Fugen which repeatedly collapsed, resulting in the formation of many pyroclastic flows. Participants will feel the energy of active volcanoes and enjoy the volcanic scenery in central Kyushu.

September 13th, (Saturday): KURASHIKI – HAKATA – UNZEN

Board a Shinkansen for Hakata in the morning, transfer to Arita-machi, eat lunch at a local restaurant and enjoy shopping at Arita Porcelain market. Continue trip to Unzen and stay overnight at a hotel or ryokan in Unzen.

September 14th, (Sunday): UNZEN – ASO – BEPPU

Drive over the Nita Pass and look at the Unzen Fugendake, a volcano that erupted in 1990. Ride a ferry on the serene Ariake Bay to Kumamoto. Eat lunch at a local restaurant and enjoy the scenic drive along Yamanami Highway to Mt. Aso, where five peaks create a central volcanic cone with broad plateaus. Drive to Beppu and stay overnight at a hotel in Beppu.

September 15th, (Monday): BEPPU – FUKUOKA

Visit the hot spring "Hells" and see the show of thermal gas, water, and mud shooting up from 250 to 300 meters underground. This is a 'must see' tourist attraction in Beppu. Eat lunch at a local restaurant and transfer to Fukuoka Airport for departure around 17:00.

PC-2: Records of the Hanshin-Awaji Earthquake (lead by Takao Miyata):

Saturday September 13th – Sunday September 14th

Cancelled

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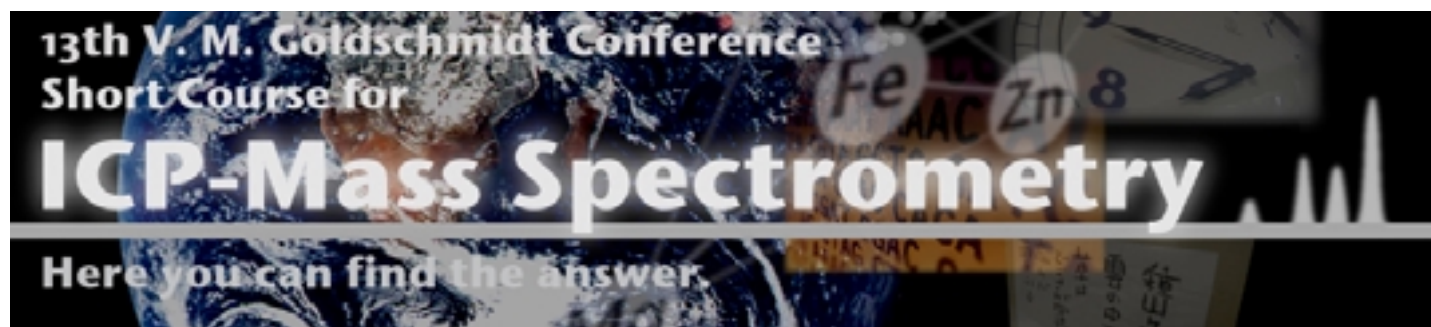
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13th V. M. Goldschmidt Conference

Short Course for

ICP-Mass Spectrometry

The inductively coupled plasma-mass spectrometry (ICP-MS) short course will be held from 6th to 7th September 2003, just before the Goldschmidt Conference at Kurashiki. The short course will cover the entire range of ICP-MS techniques, including basic principles of ICP-MS, laser ablation sample introduction technique, and applications for Earth and planetary science. The course will also cover basic theories of the isotopic fractionation mechanisms.

Program

Day 1	6th September 2003
12:30 - 13:20	Registration (Okayama Terrsa)
13:30 - 15:00	Lecture 1 <i>Gunther Detlef</i> (ETH, Switzerland): Principles of ICP-Mass Spectrometry
15:00 - 15:30	Coffee Break
15:30 - 17:00	Lecture 2 <i>Alex Halliday</i> (ETH, Switzerland): Application on Isotopic Chronology
18:00 - 20:00	Party
20:00 -	Night Session (Free Discussion)
Day 2	7th September 2003
9:00 - 10:30	Lecture 3 <i>Toshiyuki Fujii</i> (Kyoto Univ., Japan): Principles of Isotopic Effect
10:30 - 12:00	Lecture 4 <i>Simon E. Jackson</i> (GEMOC, Australia): Laser Ablation and MC-ICP-MS Techniques
13:15 - 14:45	Lecture 5 <i>Keith O'Nions</i> (Oxford Univ., UK): Isotope Geoscience for Biochemistry

Sponsored by Agilent Technologies, New Wave Research, Seki-Technotron, Gemmological Association of All Japan.

Date and Place of the Short Course:

September 6-7, 2003

Okayama Terrsa, Yao 793, Hayashima Town, Okayama 701-0301, Japan

Website for further information: <http://www.geo.titech.ac.jp/epss/ss2003/index.htm>

Organising Committee: Takafumi Hirata (Tokyo Institute of Technology, Tokyo, Japan)

MEDALS AND AWARDS

The Clarke Medal of the Geochemical Society

Paul D. Asimow

The Outstanding Service Award of the Geochemical Society

Hubert L. Barnes

The Patterson Medal of the Geochemical Society

William F. Fitzgerald

EAG–GS Fellows

Robert C. Aller, Richard W. Carlson

Marilyn Fogel, S. Krishnaswami

John W. Morse, Herbert Palme

David Rickard

The Geochemical Journal Award

Nicolas Dauphas, Laurie Reisberg, and Bernard Marty

The Geochemical Society of Japan Award for Young Researchers

Tomo Shibata, Kiyoshi Matsumoto

Tsuyoshi Watanabe

The Geochemical Society of Japan Award

Ichiro Kaneoka

The Houterman Medal of the European Association of Geochemistry

Jess Adkins

The Urey Medal of the European Association of Geochemistry

Sir Nicholas Shackleton

The V.M. Goldschmidt Medal of the Geochemical Society

Bernard J. Wood

Presidential Address

The Microbial Factor in the Geochemical Equation

JUDITH A. MCKENZIE

Geological Institute, ETH-Zentrum, 8092 Zürich, Switzerland (sediment@erdw.ethz.ch)

Located at the interface between geology and biology, the field of geomicrobiology has become a rapidly growing frontier in Earth Science. Geochemists, who have traditionally approached geological problems from an inorganic perspective, are directly affected by this development. Using a combination of geochemical and molecular biology techniques, geochemists can now introduce a microbial factor into the geochemical equation, which expands our understanding of biogeochemical mechanisms occurring at or near Earth surface conditions. This approach is really not new. At the turn of the 20th century, G. A. Nadson, a Russian microbiologist, had already proposed that microbes could serve as geologic agents, which control geochemical reactions. He astutely observed the role of microbes in the recycling, fixation and dispersion of elements in nature. The renewed interest to evaluate the impact of the microbial factor in natural systems has been strongly influenced by the application of technical advances, which enable geochemists to image and measure microbial interactions and processes at various scales.

Microbial activity has undoubtedly been modifying the Earth's uppermost lithosphere, hydrosphere and atmosphere since the appearance of life more than 3.5 billion years. The ability of microorganisms to mediate the transformation of dissolved and gaseous substances and concentrate them in inorganic minerals, such as carbonates, pyrite or phosphates, provides evidence of microbial activity throughout geologic time. Additionally, this activity leads to the isotopic fractionation of elements, such as carbon, sulfur and nitrogen, providing tracers to interpret biogeochemical processes related to the evolution of life in Earth history. Thus, we have geochemical and mineralogical tools to interpret the geologic record, but, in order to construct convincing models, we need to validate the actual microbial processes through the study of modern environments and laboratory experiments. Indeed, the present holds the key to the past!

Knowledge about early microbial processes can, in fact, be obtained from the study of their modern counterparts. For example, studies of modern microbial mats and stromatolites provide crucial information to develop models for their formation in the geologic record. From the study of modern analogue environments, it is possible to combine geochemical and biological analyses to estimate the impact microbial activity may have had on paleo-environments. Molecular biology techniques indicate the presence of microbial consortium and distinguish among groups of microbes. Interactions within these microbial communities result in biogeochemical reactions, which generate specific bio-products, including gases, dissolved species, organic matter and biominerals. These products represent microbial "fossils", which are indicative of specific environmental conditions.

Modern environmental settings with peculiar physico-chemical, biological and mineralogical characteristics can be considered as analogues for "fossil" environments, which are defined as those that were common in the geologic past but are rare today. Assuming that the microbial processes have remained relatively constant under specific conditions throughout geologic time, a combination of geochemical and microbiologic studies in such "fossil" environments can provide a better understanding of the boundary conditions associated with the large-scale microbial biomineralization observed in the geologic record. Further, the boundary conditions determined through the study of "fossil" environments can be used to design laboratory experiments to simulate the production of microbial "fossils" under controlled conditions. Thus, by combining studies of modern analogues with well-defined experiments and observations from the rock record, realistic models to evaluate ancient geomicrobiological processes can be developed.

For example, the origin of dolomite, a long-standing enigma in geology, is a geological problem with a probable geomicrobiological solution. In 1928, Nadson proposed that bacterial reduction of sulfate contributes to the precipitation of dolomite. He wrote, "Understanding the essential role played by this bacterial phenomenon may be the solution to the Dolomite Problem and the problems of the Mg cycle in the Ocean." Recently, studies have been conducted in two hypersaline coastal lagoons located east of Rio de Janeiro, Brazil, which represent "fossil" environments in which modern dolomite precipitates. Based on field observations and measurements, culture experiments have been designed to simulate the natural environment, and microbial dolomite has been precipitated *in vitro* (Warthmann et al., 2000; van Lith et al., 2003). Reproducing in the laboratory the processes and products observed in the studied "fossil" environments offers one of the best methods to validate the occurrence of microbial "fossils", such as the biomineral dolomite.

In summary, the study of microbial "fossils" produced in "fossil" environments combined with simulation experiments under controlled conditions provides geochemists a powerful tool to calibrate processes related to microbial activity in ancient systems. This geomicrobiological approach offers the possibility to glimpse into the environmental conditions of the early Earth and better interpret its evolving life forms.

References

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- Warthmann, R., van Lith, Y., Vasconcelos, C., McKenzie, J.A. and Karpoff, A.M., (2000), *Geology* **28**, 1091-1094.
- van Lith, Y., Warthmann, R., Vasconcelos, C. and McKenzie, J.A., (2003), *Sedimentology* **50**, 237-245.

Gast Lecture

Chemical and biological evolution of the early Earth:
A minority report

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A currently popular model for the chemical evolution of the atmosphere and its connection to the evolution of life on early Earth postulates the following scenarios: (1) methanogenic microbes were the primary producers in the oceans until cyanobacteria appeared ~2.7 Ga ago; (2) the atmosphere was rich in CH₄ but poor in O₂, and the oceans were rich in Fe²⁺ but poor in SO₄²⁻ and O₂ until the Great Oxidation Event (G.O.E.) ~2.3 Ga ago raised the *p*O₂ from <0.01% to ~15% PAL (present atmospheric level); (3) the *p*O₂ gradually rose to ~50% PAL, and the oceans became rich in SO₄²⁻ and biogenic H₂S but poor in Fe²⁺ during the period between ~2.0 - ~0.6 Ga; and (4) the second (or third?) major oxidation event occurred ~0.6 Ga, creating the modern oxygenated world and causing the appearance of metazoans (e.g., Canfield 1998; Anbar and Knoll, 2002; Holland, 2002; Kasting, 2002). The mass independent fractionation of sulfur isotopes (MIF), discovered by Farquhar et al. (2000) in Archean rocks, has been hailed by many researchers as the best evidence to support the above model. However, serious discrepancies exist between the MIF characteristics of natural samples and those of photochemical experimental products. The presence of MIF in geologic samples younger than ~2.3 Ga also poses a serious problem for the model that links the MIF to the atmospheric *p*O₂ level.

Our research group has conducted extensive investigations on the geological, mineralogical, and geochemical characteristics of Archean and Paleoproterozoic sequences in parts of Australia, South Africa, Finland, Canada, and USA. From comparisons of the various characteristics in stratigraphic sections of these districts, we recognize frequent fluctuations in the redox structure of oceans in local and regional scales, but not in global scale, since ~3.5 Ga. Similarities in petrochemical characteristics between pre- and post-2.3 Ga shales (e.g., relative abundances and distributions of black- and grey-shales, concentrations and morphology of organic matter and sulfide minerals, δ¹³C, δ³⁴S, and δ¹⁵N values, and trace element ratios) are difficult to explain if the global redox cycles of C, S, N, Mo, Fe, and other elements significantly differed between pre- and post-2.3 Ga periods. Without an effective mechanism to recycle kerogen in sedimentary rocks to CO₂ during weathering, the CO₂ and global carbonate reservoirs would have been completely converted to reduced C, and life on Earth would have become extinct in less than ~1 billion years since the first appearance of organisms. If the pre-2.3 Ga world was anoxic, what was the kerogen recycling mechanism?

Many Algoma-type BIFs formed in deep oceans. If the Archean oceans were anoxic, why do they possess essentially the same mineralogical and geochemical characteristics of deep submarine hydrothermal deposits of Phanerozoic age (e.g., abundant hematite; positive Eu and negative Ce anomalies)?

We also recognize that many lines of “evidence” for the popular evolution model are either “not true” or “ambiguous”: (i) the loss or retention of Fe in paleosols; (ii) the formation of “detrital”- vs. “groundwater”-type U deposits; (iii) the age distribution of banded iron formations (BIFs); and (iv) the distinction in δ¹⁵N values between early- and late-Archean kerogens. For example, contrary to popular belief, uraninite dissolves as fast in anoxic water as in oxic water. Therefore, the survival detrital grains of uraninite in some modern and ancient sediments should not be related to the atmospheric *p*O₂ level. The U content of organic-poor groundwater is primarily controlled by the availability of U in the aquifer rocks, not by the DO content; thus, the formation of groundwater-type U deposits may not be related to the atmospheric *p*O₂.

A popular mechanism for creating an anoxic atmosphere on early Earth postulates high fluxes of reducing volcanic gas; but there is no supportive evidence, such as low Fe³⁺/Fe²⁺ ratios in Archean igneous rocks. Furthermore, this theory has failed to provide satisfactory explanations as to why it took more than ~300 million years to raise the atmospheric *p*O₂ from <0.01% to ~15% PAL since the emergence of cyanobacteria; why the *p*O₂ gradually rose to ~50% PAL during the following ~1.5 billion-year period; and why the *p*O₂ jumped to ~1 PAL ~600 Ma ago and basically remained constant ever since.

All the available geochemical data on Archean and Proterozoic rocks are, however, consistent with the Dimroth-Ohmoto-Lasaga model that postulates the following scenarios: (a) major anaerobic and aerobic organisms (methanogens, sulfate-reducers, cyanobacteria, and possibly eukarya) appeared at least 3.5 Ga ago (possibly before 3.8 Ga); (b) an oxygenated world was established within ~10 Ma of the appearance of cyanobacteria; and (c) the *p*O₂ and oceanic SO₄²⁻ levels have been maintained within ±50% of the present values by the coupling of two major negative feedback mechanisms: the responses to a change in *p*O₂ of (i) the burial flux of organic C and (ii) the oxidation flux of soil kerogen.

The Geochemical Society of Japan Award Lecture
Terrestrial Noble Gases –
A Unique Indicator for the Chemical Structure and Evolution of the Earth

ICHIRO KANEOKA

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Noble gases are chemically inert and behave as incompatible and volatile elements during magmatic processes. They include lighter (He, Ne) to heavier (Ar, Kr, Xe) elements, and have higher diffusivity compared to the other elements. Especially He has the highest one except for hydrogen. Noble gases have both radiogenic (^4He , ^{40}Ar , ^{129}Xe) including nucleogenic (*e.g.*, ^{21}Ne) and fissiogenic (*e.g.*, ^{136}Xe) and stable isotopes. By utilizing such characteristics, noble gases can give us unique information which cannot always be drawn from isotopes of solid elements.

Noble gases are degassed easily from a magma at a shallow depth. Hence, to get information on magmatic signatures, pillow glasses and mantle-derived xenoliths were mostly used initially for MORBs and lithospheric mantle materials. For subaerial volcanic rocks, however, it is necessary to get different phases which should be equilibrated with a magma. Olivine and/or pyroxene phenocrysts have been found to be useful for this purpose and they have been successfully used to demonstrate the difference of noble gas signatures between MORBs and OIBs.

MORBs show the relatively uniform $^3\text{He}/^4\text{He}$ of around 8Ra (1Ra: the $^3\text{He}/^4\text{He}$ of the atmosphere, 1.4×10^{-6}) with the high $^{40}\text{Ar}/^{36}\text{Ar}$ up to about 40,000. They also show the $^{129}\text{Xe}/^{130}\text{Xe}$ of up to around 8 (the $^{129}\text{Xe}/^{130}\text{Xe}$ of the atmosphere, 6.48). In the $^{20}\text{Ne}/^{22}\text{Ne}$ - $^{21}\text{Ne}/^{22}\text{Ne}$ diagram, MORBs show a mixing trend between a magmatic component and the atmospheric one. On the other hand, typical OIBs show the $^3\text{He}/^4\text{He}$ higher than those of MORBs, though some OIBs show lower values. The $^{40}\text{Ar}/^{36}\text{Ar}$ of OIBs is systematically lower than those of MORBs. The $^{129}\text{Xe}/^{130}\text{Xe}$ of some Loihi and Iceland samples have been found to be higher than the atmospheric value, but its highest value is lower than that of MORBs. In the $^{20}\text{Ne}/^{22}\text{Ne}$ - $^{21}\text{Ne}/^{22}\text{Ne}$ diagram, OIBs show a steeper mixing trend between a magmatic component and the atmospheric value than those of MORBs at each site. Based on such noble gas signatures and the most depleted nature of the MORB source inferred, it has been considered that the OIB magma source retains more primordial noble gases than the MORB source. This implies that the OIB source is less degassed than the MORB source and the former is probably located in the deeper part compared to the latter. Such a model is compatible with the solid isotope data and supports the plume model of lower mantle origin. It should be noted, however, that only noble gas isotopes can designate the existence of relatively primitive parts in the mantle.

Recent seismic tomography suggests a possibility of slab penetration into the lower mantle. To explain it by a whole mantle convection model, inferred existence of the primitive mantle is a matter of troublesome issue. Hence, there have been trials to explain the occurrence of the high $^3\text{He}/^4\text{He}$ in OIBs by different models under various assumptions. They include the occurrence of the high $^3\text{He}/\text{U}$ due to remaining of ancient gases with no parent nuclides (U,Th) in the mantle, contribution of the depleted phase as a magma source without degassing, addition of ^3He from the core or incorporation of cosmogenic ^3He into the mantle through subducted slabs. If we consider physico-chemical properties of He (*e.g.*, fast mobility, low solubility in the metal, the low abundance in a depleted phase, *etc.*), however, none of such proposed hypotheses seem to succeed in explaining the observed data satisfactorily. It should be noted further that it is not only He but also all the other noble gas isotopes which support the less degassed state of the OIB magma source. It has been argued that OIBs do not contain larger amounts of He compared to MORBs (He paradox). In rocks or minerals, however, apparent concentrations of noble gases are controlled by many factors through magmatic processes. Hence, unless each magmatic process is evaluated properly for analyzed samples, it is insignificant to compare the apparent concentration of noble gases in samples statistically to infer the concentration in magma sources. In this respect, sample selection is quite important to get significant noble gas signatures by considering its geological and petrological circumstances.

In addition, most ^{40}Ar in the atmosphere has been explained by degassing of about a half of radiogenic ^{40}Ar accumulated in the Earth's interior for 4.5 b.y. Since He has higher mobility than Ar, this implies that the primordial He should be located in parts where radiogenic ^{40}Ar is retained. The deeper part in the lower mantle is the most likely part as the reservoir. Furthermore, the occurrence of excess ^{129}Xe in both the MORB and OIB magma sources suggests that the primordial components had not totally mixed with the atmospheric components and between each source since several hundreds of million years after the formation of the Earth. If the magma source of kimberlites is related to that of the plume source as inferred from the solid isotope data, kimberlites are expected to show similar noble gas signatures to those of Hawaii and Iceland samples. Our preliminary results for some kimberlites from Greenland support such a conjecture, indicating the definitely higher $^3\text{He}/^4\text{He}$ compared to the MORB values.

V. M. Goldschmidt Medalist Lecture

The principles controlling trace element partitioning in igneous processes.

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Understanding and predicting the behaviour of the chemical elements in the earth's crust, mantle and hydrosphere is a fundamental task in geochemistry. Qualitative predictions date from the work of Goldschmidt (1937) who used a small number of measurements of element concentrations in minerals as a means of systematizing element behaviour during crystallization from liquids or gases. This led to the 3 'rules' of element partitioning, which may be summarized as follows: 1) Any two ions of the same charge and very similar ionic radius have essentially the same crystal-liquid partition coefficient ($D = [I]_{\text{xtl}}/[I]_{\text{liq}}$ where $[I]$ is the concentration of element i). 2) If there is a small difference of ionic radius the smaller ion enters the crystal preferentially. 3) For ions of similar radius but different charges, the ion with the higher charge enters the crystal preferentially. These principles were taught to generations of students and, as I will show retain, under certain circumstances, a degree of validity. They are not, however, universally correct nor do they have any quantitative applicability.

Real advances in the quantification of the principles established by Goldschmidt date from the paper of Nagasawa (1966) who calculated from elastic strain theory the energetics of replacing a small (major) ion by a large trace ion in a crystal of known elastic properties. This demonstrated that Goldschmidt's rule (2) is correct, provided that the trace ion is larger than the major ion.

With the development of precise methods for measuring trace element partitioning between solids and melts (electron microprobe, SIMS, LA-ICPMS) a plethora of experimental data have, in the last 25 years, been collected under controlled conditions of pressure temperature and composition. Computer simulation methods have become powerful enough to enable the energetics of ion exchange processes to be investigated in detail. Together the experimental data and simulations provide the means to expand and quantify Goldschmidt's rules. Research carried out in Bristol demonstrates that equilibrium partitioning depends primarily on 2 energies of substitution into the crystal (a) the energy of elastic strain generated by inserting an ion which is either too large or too small for the site. (b) the electrostatic work done in inserting an ion which is either more or less highly charged than the major ion normally occupying the site.

Good approximations to trace element substitution energies are arrived at by treating the crystal as elastically isotropic and the area around the substituent as a dielectric continuum. Thus, following Brice (1975), we can calculate the crystal-liquid partition coefficient D_i of an ion of radius r_i as a function of its radius, the Young's modulus of the site

and D_o^{Z+} the partition coefficient for the ion which has the same charge as i , and which does not strain the lattice.

The link between D_o values for ions of different charge is established by calculating the electrostatic work done in replacing an ion of charge Z_o (which exactly matches the charge on the site) by a trace ion of charge Z_c . This gives us D_o^{Z+} as a function of charge Z , the effective dielectric constant of the medium and the radius of the ion r .

The theory requires modifications to Goldschmidt's rules (2) and (3). Rule (2) should now be: The site has a preferred radius of ion (r_o) which enters most easily. For ions of the same charge, those which are closest in radius to r_o enter most easily. Ions which are smaller or larger are discriminated against.

Rule (3): The site has a preferred charge Z_o . For ions of similar size, but different charge the one whose charge is closest to Z_o enters most easily.

These quantitative extensions to Goldschmidt's rules enable us to predict the geochemical behaviour of most ions quantitatively. A number of examples and applications to geological processes will be presented.