**Proposal for the establishment of a Task Force of the International Lithosphere Program (ILP) for 2022-2027**

# FORMATION, CHARACTER, HISTORY, AND BEHAVIOR OF EARTH'S OLDEST LITHOSPHERES


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## 1. Introduction

Obtaining constraints on the formation and evolution of Earth, from an early solar nebula to the present habitable planet with continental lithosphere, oceans, and an oxygen-rich atmosphere, is plagued with uncertainty but fundamentally important for understanding how deep Earth processes regulate our surface environment (Benner et al., 2019; Harrison, 2020; Miyazaki and Korenaga, 2022). Some constraints are firm: Earth was producing more heat by radioactive decay early in its history while losing primary heat acquired during planetary accretion. Our planet likely went through an early magma ocean stage, which rapidly solidified and evolved though the next 4.5 billion years to the plate-tectonic mobile-lid lithosphere that we have today. Whether this transition to a plate-tectonic Earth happened early, for instance as an immediate result of cooling of the outer crust of the magma ocean, or whether the planet evolved through different stages dominated by different mechanisms of heat loss, is one of the

great unresolved questions in Earth Sciences today (O'Neill, et al., 2016; Korenaga et al., 2018, 2020; Gerya, 2019; Harrison, 2020; Brown et al., 2020).

We propose to form a **Task Force of the International Lithosphere Program** aimed at **1)** obtaining a better understanding of early Earth's tectonic regime and its relationship to planetary heat loss, and **2),** determining when and by what mechanisms modern plate tectonics emerged on Earth. These topics were identified by the US National Academies (2020) as two of the greatest and most significant research frontiers for geoscientists in the next decade. Perhaps the most salient issue is determining how long the present-style mobile-lid tectonics – a system of numerous rigid plates moving relative to each other on a globally-linked network of divergent, convergent, and transform boundaries – has operated. Conversely, what other modes of planetary heat loss, such as stagnant lids, heat pipes, sagduction, or drip tectonics, operated prior to plate tectonics (Lenardic, 2018a, b; Brown and Johnson, 2018, 2019). ***We propose to address these issues by analyzing the complete geologic (structural, metamorphic, igneous, geochemical, sedimentary, geochronologic, etc.) archive preserved in Earth's fragmentary preserved record in ancient orogenic belts and cratons, and their geophysical expressions, to assess whether or not there is evidence for the operation of plate tectonics, including the lateral motion of plates and the resulting orogenic zonation that forms from their interactions***. Such records of plate tectonic interactions include: **1)** geologic gradations from orogenic hinterlands of high-grade accreted arcs and microcontinents, granite-cored gneiss domes, into zones of allochthonous nappes, ophiolite, mélange, and eclogite-bearing accretionary wedges, into flexural foreland basins (e.g., Kusky et al., 2016, 2018, 2020, 2022; Windley et al., 2021; Şengör et al., 2021; Huang et al., 2020; Zhong et al., 2021; Ning et al., 2022), **2)** paleomagnetically determined lateral motions and interactions between plates (Brenner et al. 2020; Mitchell et al., 2021), **3)** deep geophysical and petrological records of past plate collisions, deep subduction, or plume-lid interactions (Christensen and Mooney, 1995; Artiemeva and Mooney, 2001; Griffin et al., 2013; Stern and Gerya, 2018; Yang et al., 2021; Kusky et al., 2022), and **4)** accessing microrock records in zircons as old as nearly 4.4 Ga (Mojzsis et al., 2001; Valley et al., 2002, 2005; Harrison, 2020).

Some geoscientists see evidence for early plate boundary interactions similar to those on present Earth. Others interpret petrological evidence – or use numerical models to infer – that the global operation of plate tectonics was absent in the early Precambrian. The differences between these starkly different interpretations depends critically on the presence or absence of certain features (e.g., eclogites, blueschists, ophiolites, mélanges, horizontal fold nappes and thrusts, passive margins, etc., or the interpretations of map patterns that are thought by some to be unique-to or missing-from the Archean record (dominance of dome-and-basin structures, lack of linear orogens, lack of accretionary prisms, etc.). In this proposal to form an **ILP Task Force**, we address these issues by proposing to study regions covering the first two billion years of a significant rock record. Initial focus will be on the North China and Pilbara Cratons (Fig. 1), where some of these features are documented, or proposed, or disputed, and in some cases, where geoscientists from one school of thought propose plate tectonic interpretations of specific structures, whilst scientists from the other school of thought propose non-plate tectonic interpretations of the same features (Zhai et al., 2005; Kusky et al., 2021). Studies of these relatively large cratons will be coupled with the very fragmentary record from the rare Paleo-Eo-archean exposures on Earth (Fig. 1), including at Acasta, Nulliak, Nuuvuagittuq, Isua, and

Barberton (Windley et al., 2021) where regional data sets are only partly preserved, but many forms of data critical to determining early Earth evolution are extractable. Critically, we will address perhaps the most overlooked feature of Precambrian studies: the degree to which the preserved rock record represents a biased sample due to preternatural elements of stability (e.g., low heat production, high intrinsic mechanical strength).

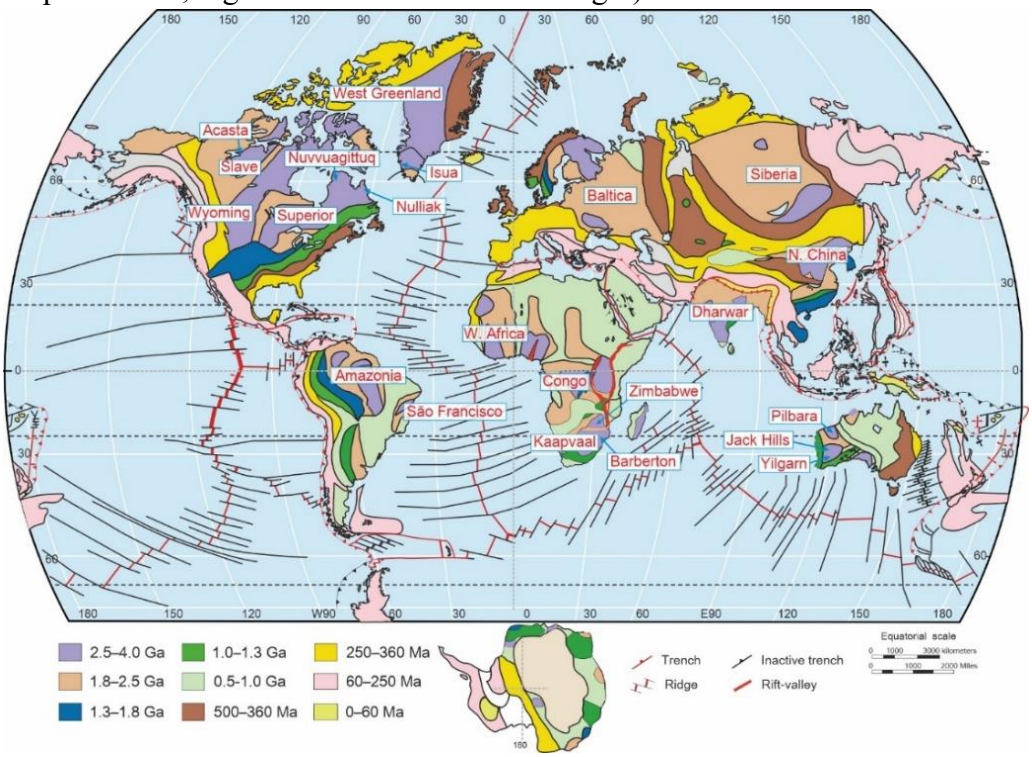


***Fig. 1.*** *Map of the world showing distribution of crust of various ages and locations of the main Eoarchean outcrop areas, belts, and cratons (from Kusky et al., 2021).*

What is clearly needed in the geological, geophysical, geobiological and numerical modeling worlds, is a better set of definitions and constraints from the geological record, using a uniform nomenclature, defining key indicators of the types of tectonic or non-tectonic behavior recorded in Precambrian orogenic zones, to test the diverse models outlined above. In forming this **ILP Task Force**, we will take a holistic Earth Systems approach to test the possibilities of plate tectonic vs. non-plate tectonic behavior over > 2.5 billion years of critical intervals in Earth history (Paleoarchean-Paleoproterozoic), from the North China Craton, and from the Paleo-Mesoarchean (3.6-2.9 Ga) from the Pilbara craton, and the older lithospheric relicts that may be as old as 4.2 Ga (Papineau et al., 2022; Drabon et al., 2022). Data synthesized from these cratons will be valuable for understanding the evolution of Earth's early lithospheres, the character of the early Earth, genesis of the continental crust, its contained mineral deposits, and what conditions led to the planet's ability to sustain life (Benner et al., 2019; Korenaga, 2018; Greber and Dauphas, 2019; Hawkesworth et al., 2020; Windley et al., 2021; Bauer et al., 2020; Turner et al., 2020; Keller and Harrison, 2020; Guo and Korenaga, 2020; Papineau et al., 2022). Lastly, we will provide encouragement and an information clearinghouse for exploration of the 15 sites beyond the Jack Hills from which >4 Ga zircons, spanning 5 continents, have been documented. None of these sites has been studied in the detail that the zircon population from Jack Hills has, leaving open a range of possibilities, including

revealing a range of concomitant tectonic processes.

On Earth, the age of two-thirds of the present surface (the ocean basins) is ~200 million years, less than 5% of the age of the planet. Atmospheric/aqueous-related erosion and plate tectonic recycling have resulted in the obscuration and loss of parts of Earth's earlier geological record. Earth-like (terrestrial) planetary bodies in the Solar System (Venus, Mars, Mercury and the Moon) provide a diverse record of geological processes and events characterizing the formative years of planetary history (Head and Solomon, 1981). Stable lithospheres preserve the record of early crust and lithosphere formation, mantle convection patterns, impact processes, lithospheric heat loss mechanisms, and the historical cadence of these factors as revealed in their geological records. Venus, the most Earth-like of the terrestrial planets (Ivanov and Head, 2011), has a mean surface age similar to Earth's, but no active plate tectonics, perhaps representing a framework of pre-plate tectonic history on Earth. We will call on these "planetary perspectives" to widen the parameter space of the plausible origin and configuration of Earth's oldest lithospheres.

By focusing the community on these questions, we will address key problems of the nature and evolution of early Earth, and the initiation time, mechanism, and style of plate tectonics, and linkages between the Deep Earth in Deep Time in Deep Space, and its links to Earth Surface Systems including development of the early biosphere.

## 2. Objective and Significance

The main scientific objective of our ILP Task Force proposal is to collect and assess quantitative data on the first two-billion years of well-preserved geological records from the North China, and Pilbara Cratons, the ancient section of the Kaapvaal (Barberton and Ancient Gneiss Complex), and the few scattered Eoarchean crustal fragments, to place quantitative constraints on the timing and mechanism of the initiation of plate tectonics. The significance of studies focused by the task force will be to understand how the planet responded to a decrease in heat production, loss of heat from accretion, and decreasing energy from orbital dynamics.

### 2.1 Key Topics to be addressed by Task Force

To reach the goals above the Task Force will direct systematic collection of quantitative data on the nature and evolution of the early Earth, and on the initiation time and mechanism of plate tectonics. The Task Force will focus on:

**1)** documenting how far back in time specific indicators of plate boundary processes can be documented;
**2)** using statistical analysis of data sets collected about specific structures, features, and characteristics of Earth through time to determine if there are major abrupt changes in tectonic style through the ages, cycles, or if the planet saw a gradual emergence of continents and modern style tectonics from its predecessor;
**3)** using quantitative geodynamic numerical models to constrain physical conditions that led to the initiation of plate tectonics, and their evolution through time;
**4)** make much better quantitative estimates of the relationships between the onset or gradual

development of modern plate tectonics, and;

**5)** assess deep crust / mantle circulation (e.g., the Carbon, and more-encompassing CHONSP cycles), relationships with changes in ocean and atmospheric chemistry (notably the GOE at circa 2.4 Ga), the gradual emergence of continents, and the development of advanced life forms on Earth.

## 2.2 Relation to main goals and themes of ILP

The proposed project falls directly under the main mission of the ILP, "to elucidate the nature, dynamics, origin and evolution of the lithosphere through international, multidisciplinary geoscience research projects and coordinating committees." The first-order, data-collection feature of the proposed work falls under the topic of "integrated mapping of the lithosphere," which the ILP seeks to promote. Since we seek to obtain a better understanding of the earliest lithospheres of the planet, the proposed topic also falls under the categories of "Continental Lithosphere," and "Oceanic Lithosphere," and since we seek a holistic approach to understanding the formation and evolution of the lithosphere, in particular the continents, we "Link Surface with "Deep Earth Processes," as they are inextricably intertwined. Further, since plate tectonics is the long-term stabilizer of a stable surficial environment and regulates the planet's habitability, the proposed program also has a solid foot in the door of the "Geoscience of Global Change."

The role of the Task Force will be to guide and lead scientific projects stemming from this program, organize coordinating committees for specific tasks, and organize international meetings and exchanges between leading scientists and their students.

## 3. International Cooperation

Our international cooperation will be coordinated through the Center for Global Tectonics at China University of Geosciences, under the auspices of the International Lithosphere Program. International activities in global tectonics that have been funded through the Center for Global Tectonics for the past 5 years will henceforth be focused for the duration of this proposed Task Force on themes related to Early Earth lithospheres. These will include but not be limited to:

- Field meetings on Early Earth hosted by CUG Center for Global Tectonics
- Sessions on Early Earth Annually at AGU/EGU/GSSA
- Planned workshops on Data Integration for Quantification of Early Earth Lithosphere, Modeling, and Linking Earth Systems, alternating meetings between Global North and Global South sites
- International Exchange of Faculty and Students, for joint PhD programs, visiting research appointments, and Integrated International Laboratories.
- Preparation of special issues of journals on the major topics addressed by the Task Force.

## 4. Outreach

- Development of a dedicated web page for the task force project
- On-line seminar series to promote the science of the evolution of Early Earth in Deep Time in Deep Space during pandemic times and beyond
- Publication of popular science general public articles on Early Earth and links to understanding how to make a sustainable planet
- Public Lectures in home countries of Key Members

## 5. Diversity, Inclusiveness of Early Career, Female, and Global South Participants

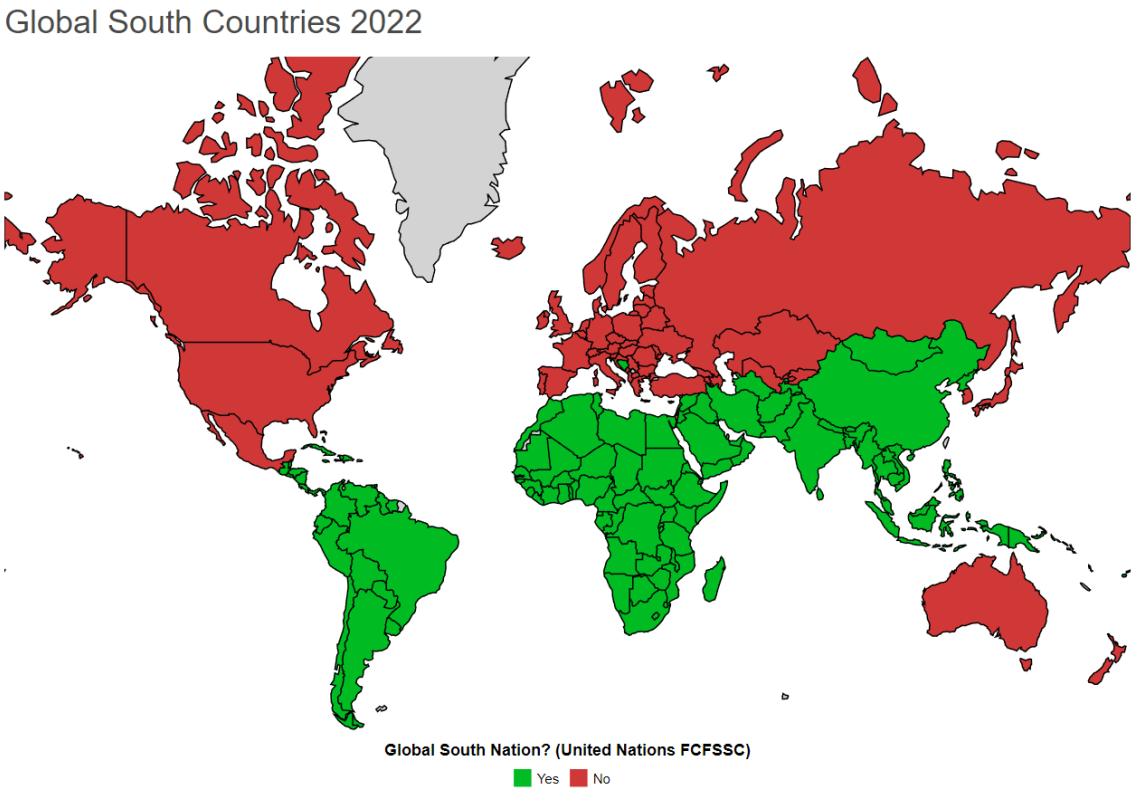


***Fig. 2.*** *Map showing "Global South" countries as defined by the UN, 2022* (https://worldpopulationreview.com/country-rankings/global-south-countries).

The ILP pays particular attention to diversity, inclusiveness, and training, a policy with which we comply. We note that more than half of the proposed members of the ILP Task force are either female, early-career scientists (<10 years since PhD), of from Global South countries as defined by the UN (2022; See *Fig. 2* above). This includes 7/10 members of the leadership committees, and 24/31 members of the whole proposed member group. The group also includes several senior scientists (e.g., five academicians) and many mid-career scientists, all of whom are training younger scientists and students in their university groups.

## 6. Key Partners and Proposed Members of the Task Force

| Participant, email | Institution | Country | Task | Diversity and inclusivity of underrepresented groups in science |
|---|---|---|---|---|
| Artiemeva, Irina, iartemieva@gmail.com | Istanbul Technical University | Turkey | Geophysics, heat flow, crustal structure | Female scientist |
| Ashwal, Lew lewis.ashwal@wits.ac.za | University of the Witwatersrand | South Africa | Precambrian tectonics, igneous petrology, anorthosites | Global South Scientist |
| Brown, Mike; mbrown@umd.edu | University of Maryland | USA | Metamorphic petrology | |
| Capitanio, Fabio, fabio.capitanio@monash.edu | Monash University | Australia | Geodynamic modeling | |
| Chen, Guoxiong; gxchen@cug.edu.cn | China University of Geosciences, Wuhan | China | Mathematical geosciences, Big data, Geophysics | Early career scientist<br>Global South Scientist<br>Subgroup leader |
| Cheng, Qiuming; qiuming.cheng@iugs.org | Sun Yat-Sen University | China | Geoscience statistics, geocomplexity, non-linear geosciences | Global South Scientist<br>Subgroup leader |
| Doucet, Luc; luc-serge.doucet@curtin.edu.au | Curtin University | Australia | Mantle dynamics in Deep Time | Early career scientist |
| Drabon, Nadja; ndrabon@fas.harvard.edu | Harvard University | USA | Hadean-Archean Earth habitability | Early career scientist<br>Female scientist |
| Head, Jim; James_Head@brown.edu | Brown Univ. | USA | Comparative Planetology | Subgroup leader |
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| Lenardic, Adrian; ajns@rice.edu | Rice University | USA | Geodynamic modeling | |
| Mitchell, Ross; ross.mitchell@mail.iggcas.ac.cn | IGG, Chinese Academy of Science | China | Paleomagnetism, geodynamics, and global tectonics | Early career scientist<br>Global South Scientist<br>Subgroup leader |
| Oliveira, Elson elson@ige.unicamp.br | University of Campinas Brazil | Brazil | Precambrian tectonics | Global South Scientist |

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|---|---|---|---|---|
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| Peng, Peng; pengpengwj@mail.iggcas.ac.cn | IGG, Chinese Academy of Science | China | Archean geology | Early career scientist (Elected Outstanding Youth in China 2021) Global South Scientist (Director China-Brazil Geoscience Center) |
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| Pehrsson, Sally; sally.pehrsson@canada.ca | Geological Survey of Canada | Canada | Archean Geology of Canada, Slave | Female scientist |
| Polat, Ali; polat@uwindsor.ca | University of Windsor | Canada | Geochemistry, Archean geology | |
| Rudnick, Roberta; rudnick@geol.ucsb.edu | Univ. California Santa Barbara | USA | Geochemistry, continental crust | Female scientist |
| Traore, Alhousseyni: tralfouss2@gmail.com | USTTB, Mali | Mali | Precambrian geology | Early career scientist Global South Scientist |
| Wang, Lu; wanglu@cug.edu.cn | China University of Geosciences, Wuhan | China | Geology, metamorphic petrology | Female scientist Global South Scientist Subgroup leader |
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| Zhai, Mingguo; mgzhai@mail.igcas.ac.cn | IGG, Chinese Academy of Science | China | Archean geology of North China craton | Global South Scientist |
| Zhang, Lei; zhanglei_cug@sina.com | China University of Geosciences, Wuhan | China | Sedimentary and isotopic geochemistry | Early career scientist Global South Scientist |

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Yang, J.S., Wu, W., Lian, D., et al., 2021. Peridotites, chromitites and diamonds in ophiolites. Nat. Rev. Earth Environ. 2, 198–212. https://doi.org/10.1038/s43017- 020-00138-4.

Zhai, M.G., Guo, J.H., Liu, W.J., 2005. Neoarchean to Paleoproterozoic continental evolution and tectonic history of the North China Craton: a review. J. Asian Earth Sci. 24(5): 547-561. https://doi.org/10.1016/j.jseaes.2004.01.018.

Zhong, Y.T., Kusky, T.M., Wang, L., Polat, A., Peng, Y.Y., Luan, Z.K., Liu, X.Y., and Wang, C.H., Wang, J.P., 2021. Alpine-style nappes thrust over ancient North China continental margin large Archean horizontal plate motions, Nature Communications 12, 6172. https://doi.org/10.1038/s41467-021-26474-7

# 8. Vitae of Key Members

## Timothy Michael Kusky, *M.A.E.*

Timothy Kusky is a Professor and Founding Director of the Center for Global Tectonics, College of Earth Sciences, China University of Geosciences, Wuhan, and also a Professor in the State Key Lab for Geological Processes and Mineral Resources, and Badong National Observatory and Research Station for Geohazards, all at CUGW.

Contact: tkusky@gmail.com (tel: 086-189-7157-9211)

(web site: https://cgtch.cug.edu.cn/en/)

**Principal Research Interests:**

Tectonics, Natural Hazards, Structural Geology, Precambrian Geology and Crustal Evolution, Evolution of Orogenic Systems, Early Earth, Tectonics and Mineral Deposits. Timothy M. Kusky's research focuses on plate tectonics and the early history of the Earth, convergent margin tectonics, natural hazards and disasters, satellite imagery, mineral and water resources, and relationships between people and the environment. He has worked extensively in North America, Asia, Africa, Europe, the Middle East, Anatolia, and the rims of the Indian and Pacific Oceans. He has authored more than 30 books, several hundred research papers and public interest articles.

**Google Scholar and Citation data:**

Total citations (20,731) h-index (77); i10 index (244). SCI Indexed Papers (~400); Books Authored (31); Special Issues Edited (11); Maps and Government Reports, etc. (53); Conference Abstracts (>250). Total: ~750

**Summary of Research and Teaching Positions:**

2018-present Adjunct Professor, Middle East Technical University, Ankara, Turkey

2015-present Professor (part time), University of Chinese Academy of Sciences, Beijing
2014-present Director, Center for Global Tectonics, China University of Geosciences, Wuhan
2009-present Distinguished Professor and Changjiang Scholar, China University of Geosciences, Wuhan
2007-2009 Founding Director, Center for Environmental Sciences, Saint Louis University.
2003-2009 P. C. Reinert Endowed Professor of Natural Sciences, Saint Louis University.
2003-2008 Research Geologist, GS 15, U.S. Geological Survey, intermittent appointment.
2000-2009 Assistant/Associate Professor, Saint Louis University.
1992-2000 Research Assistant Professor, Boston University.
1991-1995 Geologist GS-1350-12, U. S. Geological Survey, Excepted/ Intermittent App. (WAE).
1990-1992 Visiting Assistant Professor, University of Houston, Department of Geosciences.
1989-1990 Post-Doctoral Researcher, University of California, Santa Barbara.

**Education:**

Ph.D. Earth and Planetary Sciences, The Johns Hopkins University, May 1990.
M.A. Arts and Sciences, The Johns Hopkins University, June 1988.
M.S. Geological Sciences, State University of New York at Albany, August 1985.
B.S. (magna cum laude) Geological Sciences, State University of New York at Albany, December 1982.

**Select Fellowships and Awards:**

2022-Elected Academician, *Academia Europaea,* The Academy of Europe (42 countries)
2022-Ranked as #297 global (#18 in China) top Earth Scientist by Research.com (https://research.com/scientists-rankings/earth-science).
2022-Elected Fellow of the Geological Society of London (nominators John F. Dewey and Brian F. Windley). Member number 1043151.
2021-Rated in Stanford Universities list of "Global Top 2% Scientists" (rated 265/185,720 in all fields, globally, or top 0.001%).
2019-Friendship Award and Medal Laureate from China Central Committee, the highest award to foreigners in China.
2019-Hubei Province Ministry of Science and Technology, Top Research Award for Advances in Precambrian Tectonics.
2018-Life-Fellow of the Geological Society of America (life).
2016-present; Yearly, listed as Elsevier Highly Cited Researcher.
2016- Foreign Affairs (Overseas Chinese Affairs) Office of Hubei Provincial Government, Chime Bell Award (highest award from Provincial level).
2015- Elsevier highly cited scientist, 2nd in China, 12 globally in Earth and Planetary Sciences.
2000- Distinguished Carl Tolman Memorial Colloquium, Washington University, "Precambrian Tectonics and Growth of Continental Crust."
1990-onwards: Geological Society of Africa member.
1986-1989 Graduate Researcher, NASA Laboratory for Terrestrial Physics, Goddard Space Flight Center.
1985-1989 Gilman Fellowship, The Johns Hopkins University.
1983-1985 Research Scholarship, State University of New York at Albany.
1980-1982 Regents Scholarship, undergraduate tuition, State of New York.
1985-onwards: Geological Society of America member.

1985-onwards: American Geophysical Union member.

**Select Editorial and Advisory Board Responsibilities**

2021-present, co-Editor in Chief, Earth Science Reviews
2018-present, Associate Editor, Geological Society of America Bulletin
2018-2021, Tectonics and Structural Geology Sub-Editor, Encyclopedia of Geology, Elsevier, 2nd Ed.
2016-present, Editorial Board Member, Lithosphere (Geological Society of America)
2015-present, Associate Editor, Geodinamica Acta (Taylor and Francis)
2009-present, Vice Editor in Chief, Journal of Earth Sciences (China)
2014-2015-Managing Guest Editor, Tectonophysics (2014-2015)
2013-present, Member of Senior Advisory Board for Arab Geosciences Union http://arabgu.com/files/index.php/arabgu-senior-advisory-board
2005-2009-Member, International Committee for World Heritage Site Evaluation
2007-2009, 2014-2015-Editor, Journal of Asian Earth Sciences
2006-2008; 2010-2014-Associate Editor, Gondwana Research

# Timothy Mark Harrison

**Research Interests:**

Application of isotope geochemistry to the study of lithosphere dynamics; evolution of the Tibet-Himalaya orogenic system; development of thermochronology; experimental determination of kinetic laws; origin and transport of crustal magmas; development of secondary ion mass spectrometry applications; $^{40}Ar/^{39}Ar$ dating; interpretive models for heat and mass flow; evolution of petroleum reservoirs and geothermal systems; investigations of early Earth and conditions for the emergence of life.

**Education:**

B.Sc. (Hons.), Department of Geological Sciences, University of British Columbia, 1977
Ph.D., Research School of Earth Sciences, The Australian National University, 1981

**Fellowships and Awards:**

First Prize, Canadian Institute of Mining and Metallurgy Thesis Competition, 1977
Ph.D. Scholarship, Australian National University, 1978-1980
Presidential Young Investigator Award, National Science Foundation, 1985
Outstanding Young Alumnus Award, University of British Columbia, 1988
N.L. Bowen Award, Volcanology, Geochemistry, Petrology Section, American Geophysical Union, 1995
Outstanding Contributions in Geoscience Research, Department of Energy, 1996
Fellow, American Geophysical Union, 1996
Highly Cited Researcher, Institute for Scientific Information, 2002
Cited as one of the most influential Earth Scientists in *Notable Scientists*, 2003
Fellow, Australian Academy of Science, 2005

Fellow, Geochemical Society and European Association of Geochemistry, 2007
Fellow, Geological Society of Australia, 2007
Daly Lecture, Volcanology, Geochemistry, Petrology Section, American Geophysical Union, 2009
Arthur L. Day Medal, Geological Society of America, 2009
Life Fellow, Geological Society of America, 2010
Member, National Academy of Sciences, 2011
Einstein Professor, Chinese Academy of Sciences, 2013
*h* = 117; >61,000 citations

**Professional Service:**

Member, NRC Physics and Chemistry of Earth Materials Report, National Academy Press, 1987, 122 p.
Member, NRC Committee on Status and Research Objectives in the Solid Earth Sciences Panel 10, 1989
Panel Member, Lawrence Livermore National Laboratory IGPP Grants Program, 1989
Chair, Ion Probe Task Group, NRC Facilities for Earth Materials Research Report, National Academy Press, 1990, 62 p.
Panel Member, NASA Planetary Materials Review Panel, 1990-1992
Member, U.S. Geodynamics Committee, National Research Council, 1990-1993
Member, Editorial Board, GEOLOGY, 1993-1995
Member, Advisory Board, School of Earth Sciences, Stanford University, 1994-2000
Member, AGU Fellows Selection Committee, VGP Section, 1998-2000
Visiting Committee, Dept. of Earth and Oceanographic Sciences, University of British Columbia, 1999
Editorial Board, Earth and Planetary Science Letters, 2000-2008
Associate Editor, Geochimica Cosmochimica Acta, 2001-2008
Board Member, Australian National Seismic Imaging Resource, 2001-2005
Board Member, Tectonics Special Research Centre, University of Western Australia, 2001-2004
Member, National Strategic Plan for the Geosciences, Australian Academy of Sciences, 2003, 74 p.
Member, College of Experts, Physical, Chemical and Earth Sciences Panel, and Co-chair Infrastructure, Equipment and Facilities Panel, Australian Research Council, 2004-2006
Chair, Linkage, Infrastructure, Equipment and Facilities Panel, Australian Research Council, 2006
Reviewer, Crafood Prize, Royal Swedish Academy of Sciences, 2009
Panelist, NSF EAR Geochemistry and Petrology Panel, 2010-2012
Member, NRC Panel, Assessment of Staffing Needs of FAA Systems Specialists in Aviation, 2012-2013
Chair, NSF Consultation on the future of U.S. geochronology report, 2013-2015
Member, Tibetan Multiple Spheres Interactions Strategic Priority Program Committee, 2014-present
Reviewer, FAAs Approach for Determining Future Air Traffic Controller Staffing Needs, NRC, 2014
Member, NRC Panel, Aligning the Governance Structure of the NNSA Laboratories, 2013-2014
Editor-in-Chief, Earth and Planetary Science Letters, 2008-2014
Member, Editorial Committee, Annual Review of Earth and Planetary Sciences, 2009-2014
Member, Board of Earth Sciences and Resources, National Research Council, 2015-2018
Numerous invited and keynote lectures

**Professional Experience:**

Distinguished Professor, University of California, Los Angeles, Department of Earth and Space Sciences, 2003-present

Director, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, 2006-2011
Visiting Professor, Tibetan Plateau Research Institute, Chinese Academy of Sciences, 2004-present
Director, Research School of Earth Sciences, Australian National University, 2001-2006
University Professor, Research School of Earth Sciences, Australian National University, 2001-2007
Chair, Department of Earth and Space Sciences, University of California, Los Angeles, 1997-2000
Professor, University of California, Los Angeles, Department of Earth and Space Sciences and Institute of Geophysics and Planetary Physics, 1989 to 2003
Professor, State University of New York at Albany, Department of Geological Sciences, 1988-1989
Associate Professor, State University of New York at Albany, 1985-1988
Assistant Professor, State University of New York at Albany, 1982-1985
Research Associate, Carnegie Institute of Washington, 1981
Research Scholar, Australian National University, 1978-1980

**Professional Licenses:**

U.S. commercial pilot, instrument; U.S., Canada and Australia PPL certificates. Authorized to fly on University of California business.

**Military Service:**

Royal Canadian Artillery Reserve, 1970-1972; Artilleryman pay level C

# Qiuming Cheng, *M.A.E.*

Qiuming Cheng is a professor and the founding director of the State Key Lab of Geological Processes and Mineral Resources, China University of Geosciences (Beijing), with a current appointment at Sun Yat-Sen University, in Zhunhai, China. He received both his BSc in Mathematics and MSc in Mathematical Geology at Changchun University of Earth Sciences (1982,1985). Dr. Cheng has served as associate editors for Computers & Geosciences, and Journal of Exploration Geochemistry. He served as President of International Association for Mathematical Geosciences (IAMG) (2012-2016), the President of International Union of Geological Sciences (IUGS) (2016-2020), and member of the Committee for Science Planning of International Science Council (ISC) (2019-2022). He is the holder of the UNESCO Chair in Deep-time Digital Earth and Mineral Resources (2022-). He is a member of Chinese Academy of Sciences (CAS) and a foreign member of Academia Europaea (AE).

**Research Interests**

Professor Chengs's research involves in the development and application of modern mathematical geocomplexity theory for modeling nonlinear geo-processes and for the quantitative prediction of mineral resources. His pioneering research on the new fractal density theory and local singularity analysis made major impacts on several geoscientific disciplines, including those concerned with mineralization, magmatism, mid-ocean ridge heat flow, earthquakes, marine sediment subduction and floods. He has published more than 300 refereed journal papers and book chapters, and delivered over 100 invited and keynote presentations. His work published in 1994 on geochemical anomalies recognition by multifractal method has opened a new and emerging sub-field of exploration

geochemistry and the paper has become one of the most cited papers in the field. Applications of his methods have led to several discoveries of new mineral deposits in China and elsewhere. He received several prestigious awards including the Krumbein Medal, the highest award given by the International Association for Mathematical Geosciences (IAMG), and AAG Gold Medal, the highest award bestowed by the International Association for Applied Geochemists (AAG).

**Appointments, Fellowships, and Awards**

Professor of School of Earth Science and Engineering, Sun Yat-sen University, Zhuhai, Guangdong, China 519000. Email: qiuming.cheng@iugs.org, Tel: 86-13871563488.

Professor and Founding Director of the State Key Lab of Geological Processes and Mineral Resources (China University of Geosciences), 29 Xueyuan Rd, Beijing 100083 and 388 Lumo Rd, Wuhan 430074, China.

Professor (retired) of Department of Earth and Space Sciences and Engineering, Department of Geography, York University, 4700 Keele St, Toronto, ON M3J 1P3 Canada.

Member of Chinese Academy of Sciences (CAS) (2019)

Foreign Member of Academia Europaea (MAE) (2020)

Recipient of the William Christian Krumbein Medal, the highest award given by IAMG (2008)

Recipient of the AAG Gold Medal - highest award given by the Association of Applied Geochemists (AAG) (2020)

President of International Association for Mathematical Geosciences (IAMG) (2012-2016)

President of the International Union of Geological Sciences (IUGS) (2016-2020)

Past President of IUGS, Chair of IUGS Nominating Committee (2020-2024)

Member of the Committee for Science Planning (CSP), International Science Council (ISC) (2019-2022)

Chair of the Steering Committee of the IUGS Deep-time Digital Earth (DDE) Big Science Program (2018-)

International Association for Mathematical Geosciences (IAMG) Distinguished Lecturer for 2022

UNESCO Chair in Deep-time Digital Earth and Mineral Resources (2022-)

## Academic Summary

Qiuming Cheng obtained his PhD in Earth Science at the University of Ottawa in 1994, spent a year as PDF at the Geological Survey of Canada and soon become a professor with cross appointments in the Dept. of Earth and Space Science and Dept. of Geography at York University, Toronto.

Professor Cheng's research focuses on the development and application of modern mathematical geocomplexity theories for modeling nonlinear geo-processes and for the quantitative prediction of mineral resources.

His pioneering research on the new fractal density theory and local singularity analysis made major impacts on several geoscientific disciplines, including those concerned with extreme geological events originated from nonlinear processes of plate tectonics such as formation of supercontinents, magmatism, mid-ocean ridge heat flow, earth quakes and mineralization.

He has authored and co-authored more than 300 refereed journal papers and book chapters and delivered over 100 invited and keynote presentations.

His work on geochemical anomalies recognition by fractal methods has opened a new and emerging sub-field of exploration and environment geochemistry and his paper has become the most cited papers in the field.

Applications of these methods have led to several discoveries of new mineral deposits in China and worldwide. Professor Cheng has received several prestigious awards including the Krumbein Medal, the highest award given by the International Association for Mathematical Geosciences.

Professor Cheng has served as associate editors for Computers & Geosciences and Journal of Exploration Geochemistry. He has served as President of International Association for Mathematical Geosciences (IAMG) (2012-2016) and President of International Union of Geological Sciences (IUGS) (2016-2020).

# James W. Head, III

Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912
Telephone: 401-863-2526 - Email: james_head@brown.edu

James W. Head III is the Louis and Elizabeth Scherck Distinguished Professor in the Department of Earth, Environmental and Planetary Sciences at Brown University. He earned an undergraduate degree from Washington and Lee University (BS, 1964) and received his PhD from Brown University in 1969. From 1968 to 1972, while serving at NASA Headquarters (Bellcomm, Inc.), he participated in the selection of landing sites for the Apollo program, in training Astronaut crews in geology and surface exploration, in planning and evaluating the package of experiments to be deployed on the Moon, in mission operations in Houston during lunar surface exploration, and in preliminary analysis of the lunar samples returned by the Astronauts. For these activities he received the NASA Medal for Exceptional Scientific Achievement and the Geological Society of America Special Commendation. He continues to be involved in training of NASA Astronauts. In 1973-1974 he served as Interim Director of the Lunar Science Institute in Houston, Texas. He has served on the editorial board of numerous journals. He has been elected to Fellowship in the American Academy of Arts and Sciences, the American Association for the Advancement of Science, the American Geophysical Union, the Geological Society of America, and the Meteoritical Society, and President of the Planetary Geology Division of the GSA and Planetology Section of the AGU.

Dr. Head's research centers on the study of geological processes that form and modify the surfaces, crusts and lithospheres of planets, how these processes vary with time, and how such processes interact to produce the historical geological record preserved on the planets. He has followed up his research on volcanism, tectonism and glaciation with field studies on active volcanoes in Hawaii and at Mt. St. Helens, on volcanic deposits on the seafloor with three deep-sea submersible dives, and during five field seasons in the Antarctic Dry Valleys, and one in the Arctic. National and International space mission involvement includes Soviet Venera 15/16 and Phobos, Russian Mars

1996, Luna and PSRM and the US Magellan (Venus), Galileo (Jupiter), Mars Global Surveyor, Moon Mineralogy Mapper experiment on the Chandrayaan-1, MESSENGER (Mercury), GRAIL (Moon) and Space Shuttle missions. He is presently participating in the US lunar laser altimeter experiment (LOLA) (Lunar Reconnaissance Orbiter mission), and the European Space Agency's Mars Express mission. He has published over 700 papers in professional journals (Google Scholar citations: >72,000, h-index 132; i-10 index 841). He has received several NASA Public Service Medals, as well as the Geological Society of America's G. K. Gilbert award presented for "Outstanding contributions to the solution of fundamental problems in planetary geology," the European Geosciences Union's Runcorn-Florensky Medal for "Exceptional contributions to planetology", the American Geophysical Union's Norman L. Bowen award for "Outstanding contributions to volcanology", the M.V. Keldysh Medal, "For International Space Science Collaboration for four decades", the Penrose Medal, the highest award of the Geological Society of America, "Awarded in recognition of eminent research in pure geology, for outstanding original contributions or achievements that mark a major advance in the science of geology", the NASA Solar System Exploration Research Virtual Institute's Shoemaker Distinguished Lunar Scientist Medal, "Awarded for significant contributions to the field of lunar science throughout the course of their scientific career", the Russian Federation of Cosmonautics Alexander Kemurjian Medal for "Significant contributions to planetary surface exploration", and in 2022, the Committee on Space Research (COSPAR) Space Science Award for "Outstanding contributions to Space Science".

He has a keen interest in international scientific activities, having chaired the International Union of Geological Sciences Commission on Comparative Planetology and served as a NASA delegate on the US/USSR Joint Working Group on Solar System Exploration, the NASA delegation to the Interagency Consultative Group, and on the NASA Advisory Council Task Force on International Relations. He was a founding member of the International Space University, and in 1989 was inducted into the International Academy of Astronautics. He has worked closely with Soviet and Russian space scientists, is the Co-convener of 60 Brown University/Vernadsky Institute (Moscow) Microsymposia. and was elected to the Russian Academy of Sciences. Dr. Head has traveled to China to present multiple lectures at universities and Chinese Academy of Sciences institutes. While there he meets with students and Chinese colleagues to discuss future lunar and planetary exploration and research. He is a Distinguished Advisor, Macau University of Science & Technology, and Guest Faculty member at the China University of Geoscience-Wuhan.

Dr. Head's teaching has ranged from an introductory-level course in planetology (enrollment ~150 yearly) through graduate education (having been principal advisor to over 55 Master's Degree recipients and over 45 PhD recipients), and he involves his students in all international projects, missions and meetings.