Title of Project : Construction of world's most reliable deposited-aerosol database on the Anthropocene (from 1850 to 2020)

Yoshinori Iizuka
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Research Project Number : 18H05292 Researcher Number : 40370043
Keywords : ice core, aerosol, Greenland, high-accumulation area

【Research Purpose and Background】

According to a 2013 IPCC report, anthropogenic contribution factors to global warming are mainly greenhouse gases (warming) and aerosols (cooling). Among these factors, the aerosol-cloud interactions are the least understood scientifically. Thus, enhanced understanding of aerosol-cloud interactions is vital to more precisely evaluating the future prospects of global warming.

One promising approach to evaluating aerosol-cloud interactions is to follow the aphorism, "Discover new things by studying the past." Understanding the past relationships among aerosol concentrations, aerosol-cloud interactions and temperature fluctuations will lead to better forecasts of temperature change.

Aerosols from the past are preserved in snow and ice (cryosphere) through their solid precipitation. A highland in the Greenland ice sheet is an ideal area to evaluate past anthropogenic aerosol trends. In this study, we will drill into the Southeastern Greenland Dome, where aerosols have been extremely well preserved, to obtain a 250-meter-long ice core. Then, we will construct the most reliable database for aerosol concentrations and compositions during the Anthropocene (from 1850 to 2020).

【Research Method】

In our previous project (a study supported by MEXT/JSPS Kakenhi Grant Number 26257201), we obtained a 90-meter-long ice core from the Southeastern Greenland Dome (figure 1), and reconstructed changes in aerosol concentrations and compositions over the most recent 60 years. We found that nitrate aerosols are well-preserved at this site compared to other Greenland sites. In the present research project, we plan to drill a 250-meter-long ice core at the same site in 2020. We will analyze aerosol concentrations of sulfate, nitrate, ammonium, sea salt, dust, black carbon and organic matters, which are often studied for use in aerosol transportation models. Based on the analyzed data, we will construct the world's most reliable deposited-aerosol database on the Anthropocene (from 1850 to 2020). We will apply unique methods that can measure composition and isotopes of aerosol to better understand the mechanisms of aerosol fluctuations and aerosol-cloud interactions.

Figure 1: Ice core drilling at the Southeastern Greenland Dome.

【Expected Research Achievements and Scientific Significance】

The most reliable deposited-aerosol database on the Anthropocene (from 1850 to 2020) will be opened and published for climate model researchers and used as a scenario builder in IPCC reports. By tapping information contained in the database, researchers can provide more reliable forecasts of temperature change. Improved understanding of mechanisms involving aerosol fluctuations and aerosol-cloud interactions is expected to reduce uncertainty in predictions of future climate change.

【Publications Relevant to the Project】

Furukawa et al., Journal of Geophysical Research: Atmospheres, 122, 10,873–10,887, 2017, https://doi.org/10.1002/2017JD026716
Iizuka et al., Journal of Geophysical Research: Atmospheres, 123, 1, 574–589, 2018, https://doi.org/10.1002/2017JD026733

【Project term】 FY2018-2022

【Budget allocation】 147,000 Thousand yen

【Homepage Address and Other Contact Information】

SE-Dome ice core database
https://eprints.lib.hokudai.ac.jp/dspace/handle/2115/67127

【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project : Environmental electrophiles exposome and reactive sulfur species as its regulator molecule

Yoshito Kumagai
(University of Tsukuba, Faculty of Medicine, Professor)

Research Project Number : 18H05293 Researcher Number : 00250100
Keyword : Electrophiles, Exposome, Redox signaling, Reactive sulfur species, Sulfur adduct

【Purpose and Background of the Research】

We are exposed to a variety of environmental electrophiles (EEs) through food life, life style and life environment on a daily basis. While it has been reported that such reactive species covalently bind to protein nucleophiles, we found that EEs activate redox signaling pathways at lower doses and disrupt these pathways and substantial cytotoxicity at higher doses. It was also found that reactive sulfur species (RSS) negatively regulate modulation of redox signaling and toxicity caused by exposure to EEs, presumably through formation of their sulfur adducts.

Exposome has been defined as the cumulative environmental exposures, including diet, lifestyle, pollutants, and others across the life span; however, the full characterization of the exposome throughout the whole lifespan remains an outstanding challenge. In the current study, we attempt modeling an exposome specialized for EEs with cultured cells and mice in the absence and presence of RSS. We also explore how sulfur adduct derived from methylmercury (MeHg), a model of EEs, undergoes biotransformation by RSS, and then is excreted into out of the body.

【Research Methods】

We perform combined exposure to naphthoquinones, MeHg, cadmium, crotonaldehyde, 1,4-bennzoquinone, acrylamide and/or (*E*)-2-alkenals, and then assess covalent modifications to cellular protein, modulation of 4 different types of redox signaling and toxicity under treatments with and without RSS. We identify unknown metabolites of bismethylmercury sulfide produced from MeHg during interaction with RSS from biological samples of cultured cells and mice given MeHg.

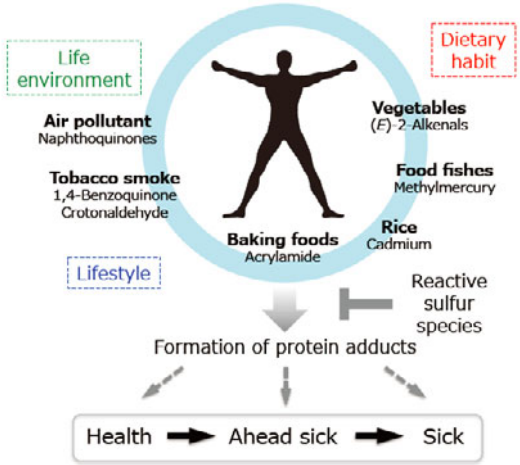

Figure 1 Combined exposure to environmental electrophiles on a daily basis and its regulation by reactive sulfur species

【Expected Research Achievements and Scientific Significance】

We postulate that combined exposure to EEs would lower the threshold for modulation of redox signaling and toxicity negatively regulated by RSS. It was also speculated that RSS plays a role in discharging MeHg into out of body. Therefore, the current study is associated with not only advance in the exposome study for EEs but also a proposal for relief of the health risk caused by EEs.

【Publications Relevant to the Project】

1. Kumagai Y, Abiko Y. Environmental electrophiles: protein adducts, modulation of redox signaling and interaction with persulfides/polysulfides. *Chem Res Toxicol* **30**: 203-219, 2017.
2. Akaike T, Ida T, Fan-Yan Wei FY, Nishida M, Kumagai Y *et al.* Cysteinyl-tRNA synthetase governs cysteine polysulfidation and mitochondrial bioenergetics. *Nature Commun* 8: 1177, 2017.

【Term of Project】 FY2018-2022

【Budget Allocation】 150,200 Thousand Yen

【Homepage Address and Other Contact Information】

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Title of Project : Study on physics and layers of ice cores containing information of climate change over the past 720 k-years, and study on the "oldest ice"

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Research Project Number : 18H05294 Researcher Number : 30250476
Keyword : Antarctica, ice sheet, ice core, climate change, dating, paleo climate

【Purpose and Background of the Research】

Ice cores collected in inland of Antarctica is one of important information sources for histories of climatic changes that occurred over 1.5 M years. At ice core drilling sites, ice is older in deeper layers; such deep layers are subject to vertical compressions by ice flow. In addition, various time-dependent metamorphic processes undergoes by influences of the geothermal heat flux. If such very deep signals are once resolved with high time resolutions, we can uncover the history of rapid climate changes. Such ice-core-based knowledge will be crucial for building strategies to make sustainable society under global warming. However, current state of our knowledge is based on limited and discrete sampling from ice cores. High resolution continuous methods for analysis has just begun in recent years. In this study, we will use cutting-edge methods for high-resolution and continuous measurements for ice cores, based on crystal physics and continuous flow analysis (CFA); we will analyze layers of ice cores spanning ca. 200,000 years and ca. 720,000 years. Based on it, we will (i) produce valuable information of the climate in the past, (ii) clarify nature of the time-dependent metamorphic processes, (iii) synchronize multiple very deep ice cores, and (iv) predict quality of information from ice cores that cover 1.5 M years.

【Research Methods】

At an inland site called Dome Fuji in East Antarctica, ice core researchers organized by the National Institute of Polar Research, Japan, collected ice cores covering 720,000 years. We will analyze portions of the ice cores spanning ca. 200,000 years and ca. 720,000 years. Such very old portion constitute deepest ~1000 m span within the ~3000 m-thick ice sheet. Such layers are subject to vertical compressions. In this study, key questions are as follows:

(i) Can we synchronize these very old portions of ice between to major ice cores drilled at Dome Fuji and Dome C?

(ii) How old age of ice back in time, can we clarify detailed histories of rapid changes of climate?

As actions tackling the questions, we will use two major methods to read the layered strata. One of them is to read layers of crystal textures using a method to measure dielectric permittivity tensor with the millimeter wave resonators. Spatial resolutions of this method is ~20mm. Another method is "Continuous Flow Analysis" (CFA) method to read layers of Si, Na and Ca, with a resolutions of ~10 mm.

【Expected Research Achievements and Scientific Significance】

First, we will produce invaluable ice core data. The data will be used to tackle the key questions. Based on the data, we will synchronize two very old ice cores at Dome Fuji and Dome C, based on collaborations of the European deep ice study community. In addition, we will examine timing difference between the climatic change records between the two ice cores. We aim to accomplish the first reliable and detailed synchronization between very old ice cores up to 720,000 years back in time. we will study change of the climatic mode over the 720,000 years. Furthermore, we will study how very old ice older than 1 M years, can be preserved near the base of the ice sheet.

【Publications Relevant to the Project】

・**Dome Fuji Ice Core Project members** 2017. State dependence of climatic instability over the past 720,000 years from Antarctic ice cores and climate modeling. Sci. Adv. 3(e1600446)
・**Fujita S.** et al. Volcanic synchronization of Dome Fuji and Dome C Antarctic deep ice cores over the past 216 kyr. Clim. Past, 11, 1395-1416, 2015

【Term of Project】 FY2018-2022

【Budget Allocation】 88,600 Thousand Yen

【Homepage Address and Other Contact Information】

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【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project：Methanogenesis from root organic matters in deep subsurface

Yoichi Kamagata
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Research Project Number：18H05295　Researcher Number：70356814
Keyword：deep subsurface, methanogenesis, syntrophic network, high pressure cultivation

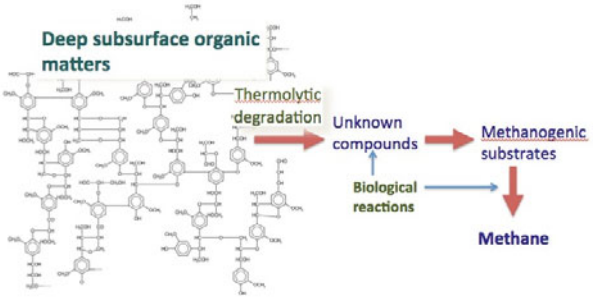
【Purpose and Background of the Research】

Methangenesis occurring in deep subsurface environments involve 1) thermolysis of highly polymeric organic matters present in rocks, coals and oils 2) fermentative degradation of those matters into acetate, methyl compounds, H_2/CO_2, 3) all of which are subsequently converted to methane by methanogenic archaea. However, depending upon *in situ* temperatures and other physico-chemical conditions, the boundary between abiotic and biotic reactions remains largely unknown, thus a whole picture of methanogenesis needs to be clarified to better understand how geochemical and biological process are tightly connected. Questions we raise are 1) what types of chemicals are supplied to microbial communities as a result of thermolytic reactions of organic matters buried in deep subsurface 2) what types of functional microbes including methanogens are associated with bioconversion of organic matters.

【Research Methods】

PI and his collaborators have strong background of geology, geochemistry, microbiology, and genome informatics. In this study, we employ the following approaches. 1) Coals and argillaceous rocks are incubated at high temperatures under high pressure conditions to determine the structures of organic matters released from those rocks by using GC-MS and/or LS-MS. 2) High throughput sequencing technique is applied to comprehensively determine the genomes of microbial communities of deep subsurface biosphere where methanogenesis occurs. RNAseq is also conducted. By combining these methods, we determine what types of fermentative organisms including syntrophs and methanogens are present *in situ* and what functional genes are being expressed under the conditions. Genomes of representative microbes are reconstructed. 3) We cultivate microbes in natural gas-, coal- and oil- associated waters by using a high pressure cultivation apparatus and see what microbes grow and what products are generated using GC-MS and/or LC-MS together with genomic analyses.

【Expected Research Achievements and Scientific Significance】



The hypothesis is that abiotic organic matters and their theymolytic degradation matters sustain the methanogenic biosphere in deep subsurface environments. The hypothesis is already well-known but there have been no direct evidences to support it. Metagenomic research has been focusing solely on community and functional genomics, but has never linked with geochemistry of organic matters buried in deep subsurface. There should be a boundary between abiotic geosphere and biosphere and that boundary may play an important role in transferring organic matters available for microbial community to biosphere. The research outcome would address what types of organic materials are really produced *in situ* and what organisms greatly contribute to methane formation.

【Publications Relevant to the Project】

・Mayumi, D. et al. Methane production from coal by a single methanogen. Science 354: 222-225 (2016).

【Term of Project】FY2018-2022

【Budget Allocation】148,800 Thousand Yen

【Homepage Address and Other Contact Information】

https://unit.aist.go.jp/georesenv/geomicrob/member.html
https://unit.aist.go.jp/bpri/bpri-dir/