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Japan Agency for Marine-Earth Science and Technology
Kyoto University

Global Distribution of Chlorophyll *d* Widespread Photosynthetic Production Using Near-Infrared Light

Outline

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC; Yasuhiro Kato, President) and the Kyoto University (Kazuo Oike, President) have discovered that all of marine and lake deposits collected from various settings in the world contain chlorophyll(*1) *d* and its degraded products. It indicates that photosynthetic organisms which synthesize chlorophyll d are ubiquitous in various aquatic environments on this planet.
Chlorophyll *d* absorbs near infrared light of 700~750 nm wavelength, unlike chlorophyll a, the most common photosynthetic pigment. Thus, it has to be admitted that the near infrared light is utilized for photosynthesis and is a considerable driving force of the carbon cycle (*2) on the earth. The result suggests that light energy use for photosynthetic production on the earth's surface needs to be re-evaluated considering the contribution of chlorophyll d-based photosynthesis.
This achievement will be on August 1 issue of the American science magazine "Science".

Background

Chlorophyll *d* had been reported in 1996 by the co-researcher Hideaki Miyashita, the associate professor at Kyoto University, as "new chlorophyll", discovered from a kind of cyanobacteria (*3), Acaryochloris marina, living symbiotically with ascidian in coral reefs.
In past studies, chlorophyll d had been found only in limited settings so that it has been considered that its role in biological production must be very small and ignorable.
JAMSTEC collected samples and detected presence of chlorophyll *d* and determined its abundance, as part of the study based on its midterm plan and the Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) titled "Development of Stable Isotope Indices for Assessing Health and Sustainability of Watershed Ecosystems" (Toshi Nagata, Prof. Kyoto University).

Details

JAMSTEC and Kyoto University have detected chlorophyll d and its derivatives (pheophytin *d*, pyrochlorophyll *d*, pyropheophytin *d*) in marine deposits from polar to temperate area (Arctic Sea, Bering Sea, Uchiura Bay, Otsuchi Bay, Sagami Bay, Tokyo Bay) and some fresh- and saline-water lake

deposits (Biwa Lake, Antarctic Salt Lake), by employing high-performance liquid chromatography(*4).
Concentrations of chlorophyll d and its degraded products are only 4% at maximum relative to chlorophyll *a*. Chlorophyll *d*-based photosynthesis has unique feature to utilize near-infrared light of 700~750nm wavelength. In contrast, the common photosynthesis with chlorophyll *a*, *b* or *c*, does not use the near-infrared light; hence, it is thought that, in general, the near-infrared light is not used for photosynthesis in aquatic environments. However, our findings suggest that the near-infrared light is in fact utilized in aquatic photosynthesis and thus has impact on the carbon cycle on the Earth.

Future Prospective

As a next step, we plan to determine the source organism(s) that synthesize chlorophyll *d* in both phycological and genetic levels. At present, the only known organism that produces chlorophyll *d* is Acaryochloris marina. We will thus try to identify what actually produces chlorophyll *d* in these environments, which may be other photosynthetic organisms than *A*. marina. The achievements should present significant information for studies of evolution of chlorophylls and photosynthesis. Furthermore, quantitative investigations, such as how much the chlorophyll *d*-based photosynthesis is involved in biological production in oceans and lakes or in the global carbon cycle, would contribute to studies of global environmental changes. Furthermore, such investigations will explore potentials of this new biomarker for the primary production (photosynthesis) in an aquatic environment.

Glossary

*1: Chlorophyll
Photosynthesis is a process to synthesize organic matter from water and carbon dioxide by using light energy. In this process, chlorophylls perform as antenna to collect light energy. There are 4 kinds of chlorophylls, named chlorophyll a, b, c, and d in the order of their discoveries.

*2: Carbon cycle
In the Earth environment, which includes atmosphere, ocean, and biosphere, carbon flows through many processes in various chemical forms. The probable factor of global warming, CO2, is one of its forms, and photosynthesis is one of its processes which transfer it from atmosphere to biosphere.

*3: Cyanobacteria
Cyanobacteria are procaryotes which perform oxygenic photosynthesis, that have various mode of life, from planktonic to periphytic. Once they were called blue-green algae.

*4: High-performance liquid chromatography
It is an analytical instrument that separates or quantitates compounds dissolved in solvents by differences of transfer rates through the adsorbent coated stationary phase.

Fig.1. Extracted Chlorophyll *d*

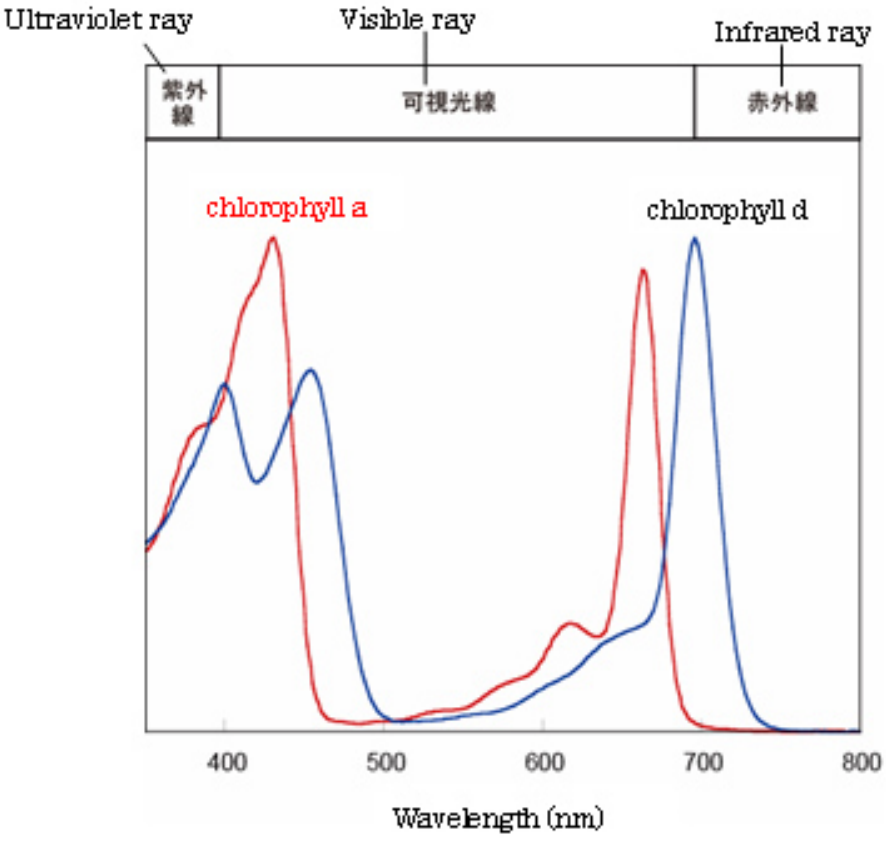

Fig.2. Absorption spectra of chlorophyll *a* and *d*

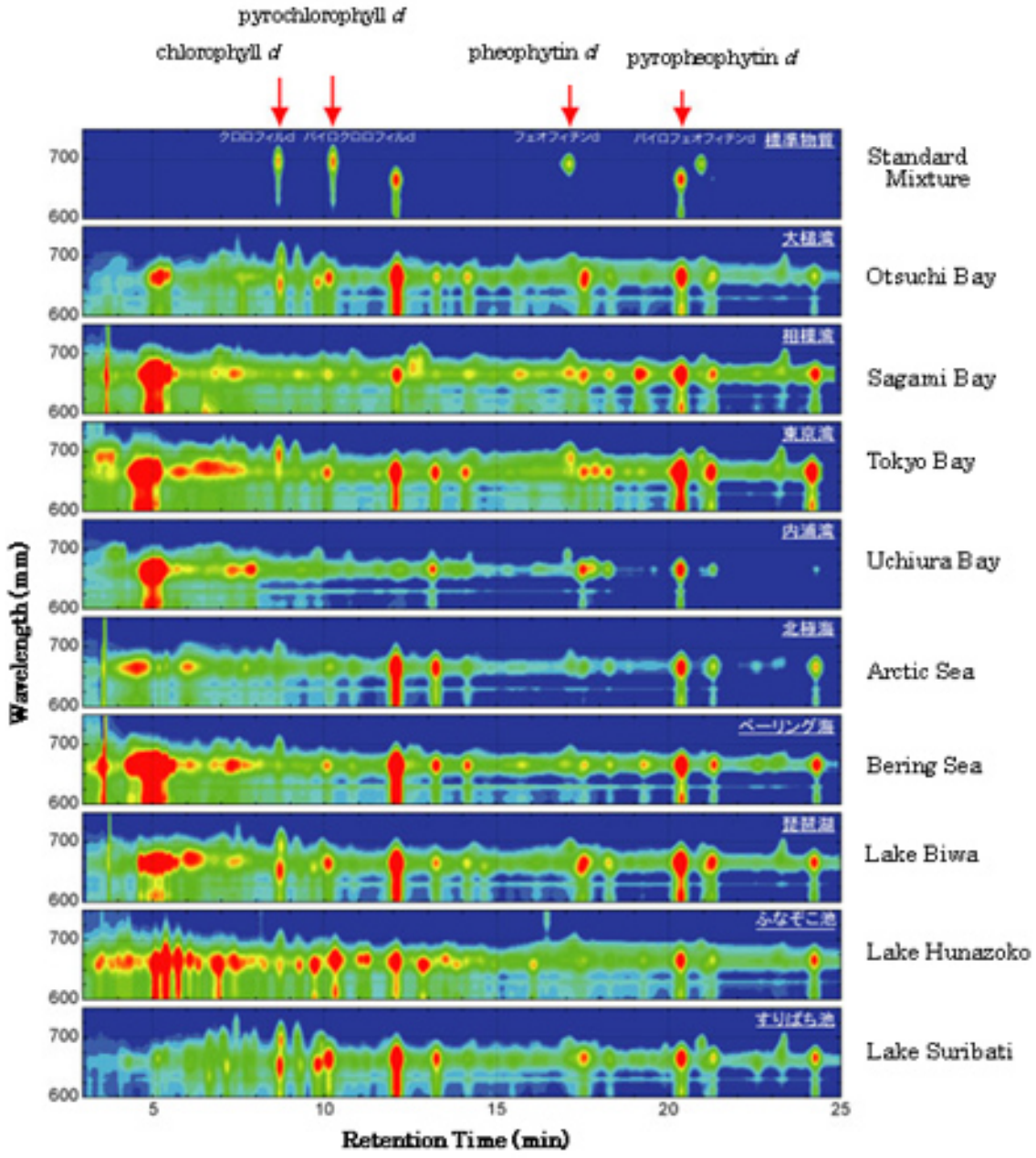

Fig.3. High-performance liquid chromatography analysis of the extract from oceanic and lacustrine sediments all over the world (Kashiyama et al., 2008). Red color indicates high concentration, and blue indicates low concentration. Red arrows show chlorophyll d and its derivatives.

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