The Miracle Lake

Lake Suigetsu Varves

The key to unlocking mysteries of the past hidden in striped patterns beneath the lakebed

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Fukui Prefecture

The Miracle Lake

Lake Suigetsu Varves

What are those stripes?

The key to unlocking mysteries of the past was hidden in striped patterns beneath the lakebed!

Lake Suigetsu is the largest lake of the Five Lakes of Mikata (area: 4.15 km^2, depth: 34 m). Striped patterns called “varves” have formed at the bottom of this lake through the accumulation of sediment over 70,000 years. Sediment core research was carried out in 1993, 2006 and 2012, in order to research and study the varves. The 70,000 consecutive years’ worth of varves and the results from research of them are attracting attention from both Japan and around the world.

The Five Lakes of Mikata (Fukui Prefecture)

(Photo provided by Wakasa Mikata Jomon Museum)

The Five Lakes of Mikata, designated as one of the country’s places of scenic beauty, refers collectively to Lakes Kugushi, Hiruga, Suigetsu, Mikata and Suga located within the Wakasa Bay Quasi-National Park.

Remains from the Jomon period have been discovered in the area around the lakes. They were registered as a Ramsar Site in 2005, being considered internationally important wetlands.

Varves (shown in the photo on the right) are formed by deposits of different types of materials depending on the season. A varve is a pair of light and dark colored stripes that corresponds to one year, and important clues to understanding the history of climate change and natural disasters are recorded in these stripes.

Through analysis of the varves, highly accurate data on the natural environment (air temperature, water temperature, vegetation, etc.) and natural disasters (earthquakes, tsunami, floods, volcanic activities, etc.) that occurred in the past can be obtained and research is advancing worldwide.

Furthermore, the varves are used to calibrate radiocarbon dating that identifies the chronology of fossils and relics, and the IntCal13 calibration curve, utilizing data obtained from the Lake Suigetsu varves, was published in September 2013. This has led to the Lake Suigetsu varves being regarded in archaeology and geology as a global standard measure, dramatically improving the accuracy of dating more than ever before.

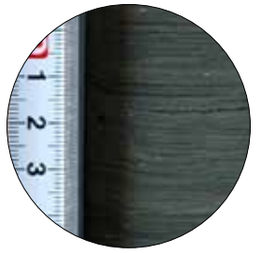

Varves of
Lake Suigetsu

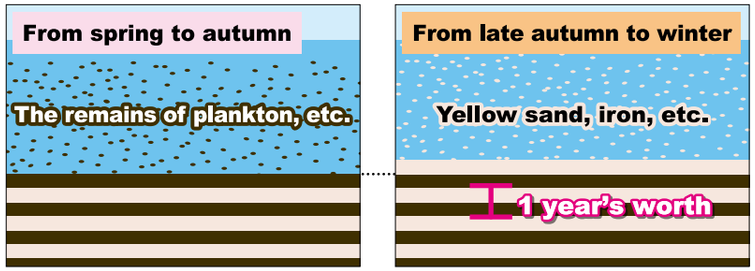
The process of varve formation

Why do the striped patterns form in the varves?

At the bottom of Lake Suigetsu, deposits of soil and organic matter such as the remains of plankton occur from spring to autumn, and those of mineral matter such as iron that has precipitated in the lake water and yellow sand from the continent occur from late autumn to winter. The striped pattern is formed by pairs of light and dark colored layers which correspond to a year's time, with the dark layers containing more organic matter, and the light layers containing more mineral matter.

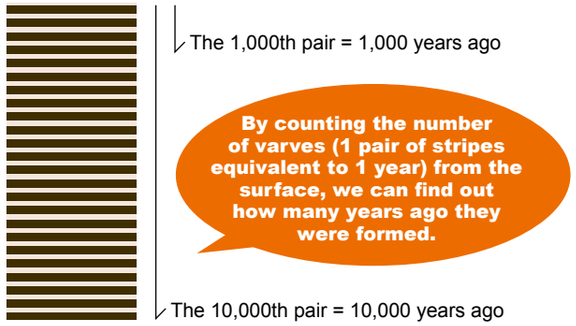
The varved sediment of Lake Suigetsu, averaging to a 0.7 mm thickness per year, has been deposited over 70,000 years.





When did the striped patterns form?

Varves allow the year a stripe formed to be identified, by being able to count the pairs that form each year, as with tree rings, in the striped pattern. For example, the 1,000th pair of stripes from the surface can be identified as that which formed 1,000 years ago, or the 10,000th pair of stripes as that which formed 10,000 years ago.

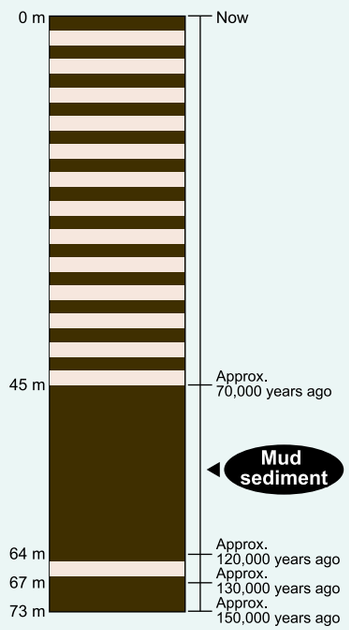


■ Lake Suigetsu Varves

A sediment core approximately 73 meters in length was obtained in the 2006 research, the first 45 meters of which contained well-defined varves. Around 70,000 years' worth of stripes were counted with uninterrupted varves, being the first of this type ever seen around the world.

The section between 45 and 64 meters consisted of mud sediment. It is speculated that this was due to the shallowness of Lake Suigetsu during this period.

Varves appear again from the 64-meter mark, with sediment from the deepest section being believed to be that from about 150,000 years ago.



A diagram of Lake Suigetsu varves

The favorable conditions that allowed the world's best varves to form

The topography and surrounding environment of Lake Suigetsu

Topography and surrounding environment have a strong influence on varve formation. Lake Suigetsu has several conditions that have allowed the pairs of stripes to accumulate without disturbance and form each year. The four main conditions are listed below. As lakes with such favorable conditions for varve formation are a rarity around the globe, it is fittingly known as the miracle lake.

❶ A topography with no large feeding rivers

The lakebed is left undisturbed by the inflow of soil and stones, and large amounts of water such as from heavy rain, due to the lake's depth and the absence of any large rivers directly feeding it.

❷ A topography surrounded by mountains

The lake water is kept from being stirred up as the surrounding mountains block winds and prevent waves from building up.

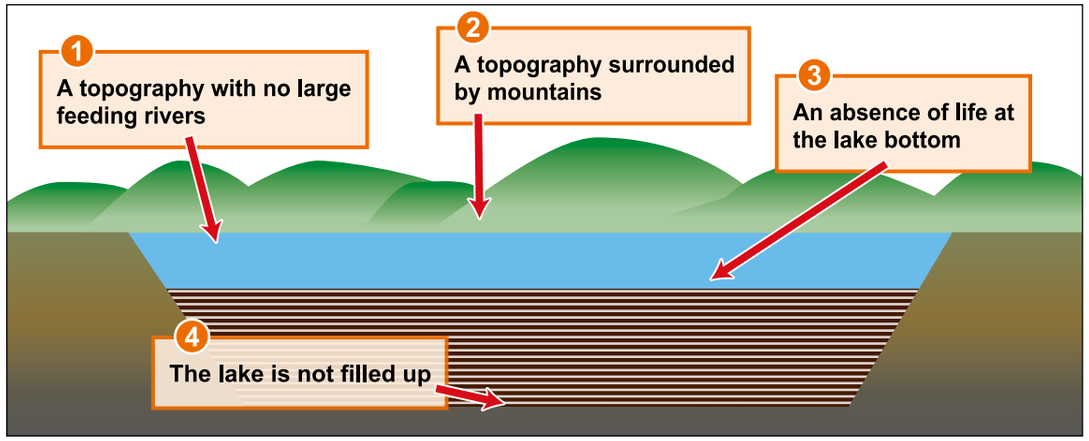
❸ An absence of life at the lake bottom

As the lake water is not stirred up, a layer that lacks oxygen forms in the deep parts. In other words, living things are unable to exist at the bottom of Lake Suigetsu, meaning that the varves are not disturbed by them.

❹ The lake is not filled up

Lakes in general become filled up with sediment over time, such as with soil and sand from upstream. Lake Suigetsu, however, has continued to subside due to the influence from surrounding faults for a long time. This has resulted in the lake not filling up with sediment, instead allowing a steady accumulation of sediment on the lakebed.

An aerial photograph after heavy rain. The brown-looking Lake Mikata has had sand and mud washed into it, but the muddy water has not flowed into Lake Suigetsu pictured above it. A photographic record showing the favorable conditions for varve formation. (Photo provided by Fukui Shimbun)



What we can learn from the varves

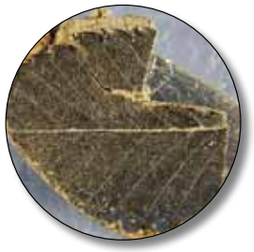
Varves, which allow chronology to be identified by year, contain substances such as leaves, pollen, volcanic ash and yellow sand. By analyzing them, it is possible to reconstruct past events year by year, including changes in air temperature, water temperature and climate.

The varves of Lake Suigetsu, having accumulated over 70,000 years, are a source to understanding valuable information about the natural environment in the past.

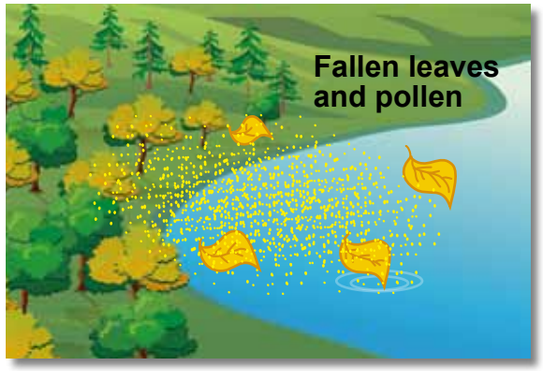
What we can learn about past climate change from the varves

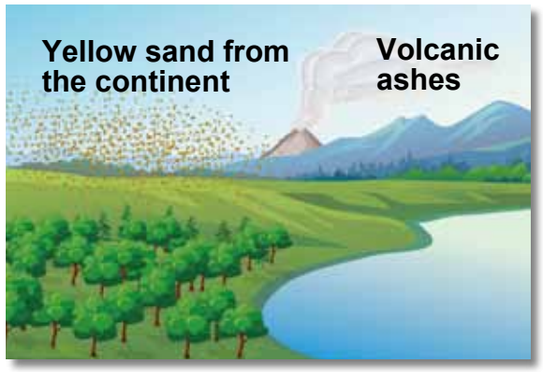
From leaves and pollen contained in varves

Fossil leaves and pollen contained in the varves enable us to identify the species of plants that grew around the lake, and learn about the climate and environment at the time. Studying the changes of such species leads to an understanding of variations in the climate and environment, with the varves giving us a detailed understanding of the conditions at the time year by year.



A fossil leaf contained in the varves of Lake Suigetsu (Photo provided by the Lake Suigetsu Project)





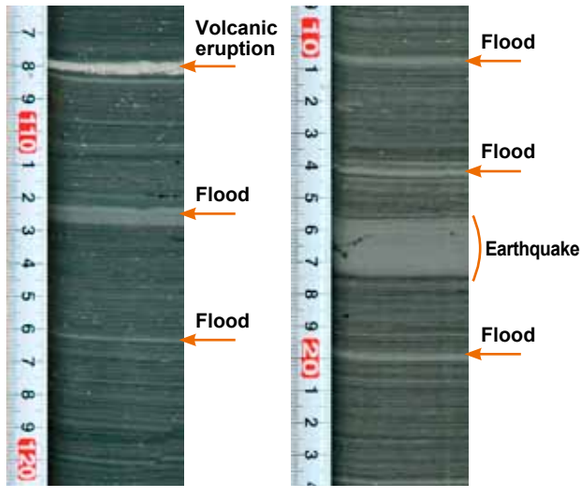
From volcanic ash and yellow sand contained in varves

Varves also contain yellow sand, which were carried on the prevailing westerlies from the Asian continent, and volcanic ashes. Other things that can be identified include the date of a volcanic eruption (using the volcanic ashes), and changes in the direction of the westerlies (using the yellow sand).

From changes in the appearance of sedimentation

Upon close inspection of the very thinly deposited varves, areas of thick accumulations and differences in color are noticeable. These are indications of earthquakes and floods. When an earthquake occurs, it causes a large amount of soil and sand from around the lake to flow in, forming a thick layer of sediment. A difference in the way sediment forms is also apparent after a flood has occurred.

By studying the varves of Lake Suigetsu, 12 examples were found of thick layers caused by earthquake over the last 30,000 years. This record of earthquakes and floods is expected to be used in the future for disaster prediction.



Sections of Lake Suigetsu varves

People's lifestyles and changes in the environment around the Five Lakes of Mikata

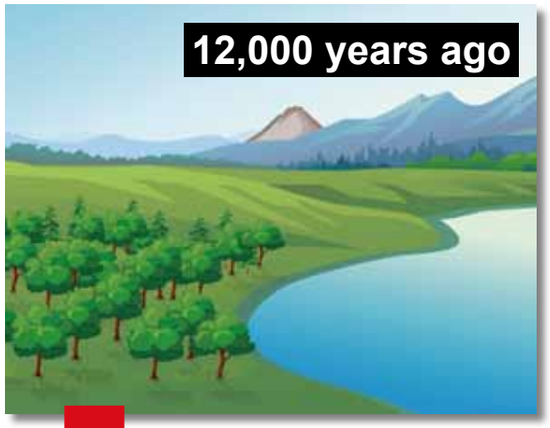
30,000 years ago, the area around the lakes was grassland with sparse coniferous trees such as spruces under a cold and dry climate. Thereafter, following the glacial period, the vegetation around the lakes gradually turned into a temperate forest with deciduous broad-leaved trees such as beeches.

12,000 years ago, after a period of instability during which the temperature would fluctuate quite considerably, it gradually changed into a warm climate. As for the vegetation, there was a stretch of forest containing trees such as beeches, oaks, and walnuts. It is believed to be around this period that the Jomon people began to live around the lakes.

Around **5,700 years ago**, forests of evergreen broad-leaved trees, such as camellias, and those of cedars stretched out. Many relics have been excavated from areas around the lakes, where those relics, including the Torihama Shell Midden, tell how the people of the Incipient-to-Early Jomon period (between 12,000 years ago and 5,500 years ago) lived. Owing to the woodlands abundant with nuts, etc., and lakes that provided many fish, it was most likely a very inhabitable place abundant with food.

Dugout canoes made of cedar displayed at the Wakasa Mikata Jomon Museum. They were excavated from ruins around Lake Mikata located to the south of Lake Suigetsu.

The lakeside with sparse coniferous trees



The lakeside transition from coniferous trees to deciduous broad-leaved trees

The lakeside in the Jomon period

The Varves of Lake Suigetsu — A Global Standard Scale for Dating

Radiocarbon Dating and the Global Standard

The radiocarbon dating to identify the ages of fossils and relics is an age determination method, which uses a substance called radiocarbon (carbon 14) contained in animals, plants, and other things.

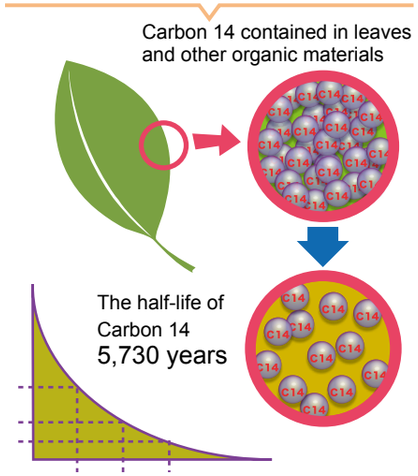
The amount of carbon 14 halves every 5,730 years after the death of the animal or plant. Therefore, examining the amount of residual carbon 14 in the object, such as the remains of a living thing, allows us to estimate the number of years that have passed since the death of the organism.

However, the amount of carbon 14 contained in an animal or plant varies depending on the date, and is not uniform. This leads to an inaccuracy of the date estimated from the carbon-14 content alone, and the error needs to be compensated. It is necessary to accurately determine the amount of carbon 14 for that date in order to calibrate the error.

Tree rings give the most effective samples for evaluating the amount of carbon 14 contained in remains up to about 13,000 years from present. Counting the number of tree rings and measuring the carbon-14 content of each ring enable us to determine an accurate date in relation to the carbon-14 content, which can be applied to other objects. For dates older than 13,000 years ago, as it is difficult to acquire such old tree samples, ocean basin varves and shallow-water coral were conventionally used. Unfortunately, the use of these aquatic materials entailed uncertainty due to such factors as the carbon dioxide contained in the seawater.

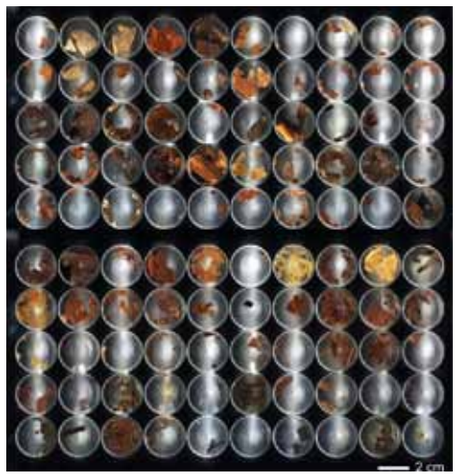
Since the varves of Lake Suigetsu have been continuously deposited without a break for 70,000 years, it is possible to identify the date by counting the number of stripes, as with tree rings. Furthermore, measuring the amount of carbon 14 contained in the fossil leaves in the varves enabled us to accurately identify the amount of carbon 14 for the date when the same leaves had fallen. This made it possible to identify radiocarbon dates anywhere in the world, by comparing the measured radiocarbon level with the data from Lake Suigetsu, and finding the stripe that contains a fossil leaf with the equivalent radiocarbon level. The varves of Lake Suigetsu are used as the most accurate “global standard timescale” for determining age.

Carbon 14



Carbon 14 produced in the atmosphere is absorbed by plants through photosynthesis, and into animals via the food chain. The amount of carbon 14 in animals and plants continuously decreases after their death as it ceases to be taken in anymore. This nature, as well as the 5,730-year half-life of carbon 14, allows the dating. The concentration of carbon 14 in the atmosphere varies from year to year because this element is sensitive to changes in the geomagnetic field and solar activity.

Currently, the limit of measurement using the amount of carbon 14 is that up to approximately 50,000 years ago.



Fossil leaves from Lake Suigetsu
(Photo provided by the Lake Suigetsu Project)

Overview of the Calibration Curve (IntCal13) and the Roles and Meaning of Lake Suigetsu

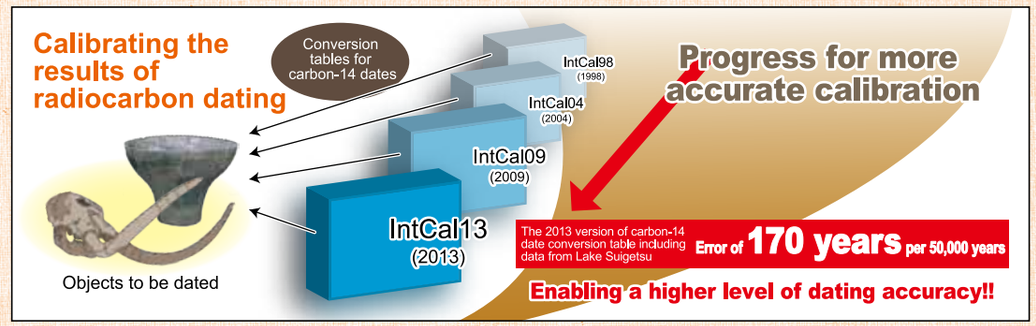
Professor Takeshi Nakagawa, Ritsumeikan University

We humans are instinctively interested in our own origin — who we are, and where we are from. When and why did our ancestors leave Africa, what dangers have we faced, and how have we been able to survive up to the present time? This is not only a question of anthropology and archaeology, but also an important issue about philosophy and values. In connection, a timescale that can measure a long period of time in the order of thousands or tens of thousands of years is necessary to answer questions such as, “When exactly did the Neanderthal die out and why did they make way for Homo sapiens?” and “When did the Jomon people produce their earthenware for the first time?” Needless to say, there were no such devices as mechanical clocks or atomic watches in those days. A specific timescale has been used in the field of geology, and continued efforts have been dedicated to improve its accuracy. Lake Suigetsu in Fukui Prefecture has played an important role in bringing about a tremendous leap in the quality of the timescale, almost to the point of perfection.

The most common method used around the world to measure time within the period ranging up to 50,000 years ago is radiocarbon (14C) dating. However, the date obtained from the amount of residual carbon 14 alone is not necessarily accurate, and a conversion table, or a calibration model, to convert the measured value to a true value is required for accurate dating.

The conversion table must not differ depending on the researcher, and must be unified based on an international agreement. At present, the most widely used calibration model in the world is known as IntCal, which was first proposed in 1998 and updated in 2004 and 2009. IntCal is, so to speak, a global standard timescale to define geological points in time, just like the meter standard and the Royal Greenwich Observatory. The IntCal was updated again, and announced as IntCal13 in September 2013. The data from Lake Suigetsu, which was not adopted in the previous version IntCal03, was fully incorporated in IntCal13 as its outstanding quality was highly appreciated.
As there is a rule with IntCal to avoid excessive dependence on data from only one location, data from places other than Lake Suigetsu was also incorporated in IntCal13. Nevertheless, it is obvious that the presence of Lake Suigetsu is overwhelming among the elements constituting IntCal13. This refers to the aspects of the amount of data used, the ability of dating through calibration, and the “purity” of the data with which it is not necessary to take into account the old carbon coming from deep-sea water, limestone, etc.

IntCal13 is a standard scale of history created with the tremendous efforts of many researchers, the foundations of which are supported by Lake Suigetsu. In relation to the study of history and archaeology, Lake Suigetsu is the equivalent of the Royal Greenwich Observatory for people in contemporary society. It is expected that the use of IntCal13 will shed light on past events in detail and greatly facilitate progress in the understanding of our roots, enhancing our insight into the future based on this understanding.



Progress of the Research into the Varves of Lake Suigetsu

The First Research in 1993

Lakebed sediment was first collected from Lake Suigetsu in 1991. The research team lead by Emeritus Professor Yoshinori Yasuda (International Research Center for Japanese Studies) conducted exploratory boring and discovered the existence of varved sediment for the first time in Asia. In 1993, the team extracted approximately 75 meters of sediment. Based on the analysis of fossil pollen taken from the varves, research findings on paleoclimatic changes before and after the beginning of the Jomon period were published.

The Second Research in 2006

In 2006, the research team lead by Professor Takeshi Nakagawa (Newcastle University, UK) conducted four borings and successfully formed a perfect sediment core of approximately 73 meters long. The team spent a number of years counting the stripes of the extracted sediment core (designated as SG06), as well as applying radiocarbon dating to fossil leaves contained in the core sample. The research results were published in the American academic journal “Science” in 2012, and in the following year, the varves of Lake Suigetsu became the global standard timescale for dating within a period of up to 50,000 years ago.

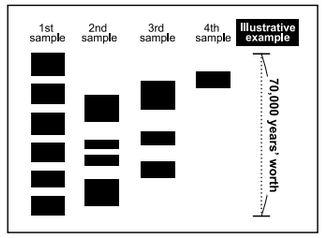
The Third Research in 2012

The 2012 research was conducted by a team lead by Professor Ryuji Tada (Graduate School of Science, University of Tokyo). Their research included study on changes in the westerlies over the years using the yellow sand and other substances contained in the varves, and the estimation of precipitation based on the rate of sedimentation of clay flowing in from rivers.

Boring site on the lake

Sediment core tube leading to the bottom of the lake. The entrance to the 70-thousand-year time tunnel.

This cottage, nicknamed “Suigetsu Hilton,” accommodated the researchers during the 2006 research.



Four sediment core samples were combined to form continuous varves extending to approx. 73 meters with no missing parts.

Prof. Takeshi Nakagawa working on the preservation of collected varves

Future Prospects of Applied Development

Associate Professor Hitoshi Yonenobu,
School of Natural and Living Sciences Education, Naruto University of Education

What does “knowing the past” exactly mean?
James Hutton, a Scottish geologist in the 18th century, said, “The present is the key to the past,” and laid a foundation for modern geology. At present, under the concept that the past is the key to understanding the future, the history of climatic changes is being actively researched in detail throughout the world. The sixth Assessment Report of the Intergovernmental Panel on Climate Change, which was reported in the media on September 27, 2013, was a result of examining and compiling the content of such research. Providing solutions for such urgent issues that should be solved through international cooperation is, of course, an important role for the science that looks into the past.

Research dealing with phenomena that change with the passage of time (historical science) requires an accurate perception of the order of occurrence of events, as well as of the timing and time lags at different places, in order to correctly think about the causal relationships between matters. In this respect, a high-precision chronological scale is necessary. Recently, archaeologists from our research group (the “Pan Pacific Environmental Changes and Civilizations” Project for the Grant-in-Aid for Scientific Research on Innovative Areas by the Ministry of Education, Culture, Sports, Science and Technology; lead by Kazuo Aoyama, professor, Ibaraki University) conducted thoroughgoing excavation of remnants for the initial to terminal phases at Seibal, a representative archaeological site of the Maya civilization in Guatemala, and collaborating natural scientists carried out carbon-14 dating of many samples.
The results of dating were applied to IntCal curves, which are often referred to as wiggles, using a Bayesian statistics method, and greatly accurate estimation of the duration of the civilization was obtained. The outcome produced evidence against the traditionally prevailing hypothesis that this ancient city is the oldest public ritual construction of the Maya civilization and that the Maya civilization arose due to the unidirectional influence of the adjacent Olmeca civilization.
The application of IntCal13 to a large number of carbon-14 dates will also lead to the progress of archaeological research in Japan based on accurate chronological axes.
Efforts toward this are ready to start, and enhanced accuracy of chronological frameworks from the late Paleolithic period and the Jomon period across historical times is expected.

Ruins of Seibal
(Photo provided by Professor Kazuo Aoyama, Ibaraki University)

Varves Around the World

Varves have been discovered in several places in the world including the Eifel district in Germany, the Cariaco Basin in Venezuela, Monticchio in Italy, and Lake Sihailongwan in China. Varves have also been found in other places in Japan, apart from Lake Suigetsu; namely, Lake Ichinomegata (Akita Prefecture), Lake Togo (Tottori Prefecture), and Lake Fukami (Nagano Prefecture).

As with the varves of Lake Suigetsu, research is conducted on various subjects including the natural environment in the past, natural disasters such as earthquakes and floods, and the relationship between the lifestyle of people and history. It is expected that research outcomes in the future will contribute to the elucidation of various things such as global warming, the mechanism of natural disasters, and the history of humankind.

Waterfowl resting their wings on Lake Suigetsu before sunset in early winter.
The Five Lakes of Mikata, that includes Lake Suigetsu, were designated as Ramsar Sites in November 2005.

Access

Wakasa Mikata Jomon Museum

Permanent exhibits include actual samples and videos of the varves of Lake Suigetsu.

For detailed tourist information on the Five Lakes of Mikata

Fukui Prefecture's tourist information website

福井「越前・若狭」の旅情報
ふくいドットコム

http://www.fukui-e.com/lang/english/

A commentary video about the Lake Suigetsu varves is available on the Fukui Prefecture website.

http://www.pref.fukui.jp/doc/shizen/nenkou.html

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