Image Processing of Fossil Growth Patterns for Paleo-Geochronology.

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Abstract

Utility of an image processing device combined with the high resolution CCD camera is explored for paleo-geochronogical investigation of fossil growth patterns. Bivalve fragment (Miocene, Japan), spiriferid brachiopod (Permian, Australia) and stromatolite (Precambrian, Mauritania) are analyzed. Enlargement of high contrast images turns out to be very useful to reveal hitherto unseen features preserved in these fossil growth patterns.

Key Words: Paleo-geochronology; fossil growth pattern; stromatolite; image analyzing system.

1 Introduction

Stromatolite is believed to be a layered structure formed by blue-green algae which grew in the Precambrian shallow sea producing oxygen molecules in the earth atmosphere for the first time. Astronomers went to Mauritania for solar eclipse expedition (1973) were amazed to find Precambrian stromatolite fossils in their observing stations. Two specimens were given to one of the present authors from two friend astronomers (Drs. Z. Mouradian and E. Hiei) to whom we are very grateful. Recently we have installed a personal image analyzing system (PIAS). Preliminary image processing of the stromatolites with PIAS suggests better resolution of growth layers of the sample than by naked eyes. This positive preliminary result encouraged us to study the layered structures of fossil organisms with PIAS.

Many organisms form hard skeletons. Physiological processes responsible for skeleton formation often vary with the fluctuation of environmental factors. In this way environmental factors are reflected within the skeletal parts as growth patterns. Most familiar example may be tree rings recording annual environmental fluctuations. It has been claimed that annual, monthly, daily as well as semi-diurnal rhythms are recorded in the growth layers of organic skeletons.

If we can measure these rhythms in growth patterns of fossil skeletal parts, we can get estimates on such as number of days per year or that per month, which are important parameters in reconstructing the history of our earth-moon system.

Weathering and other chemical as well as physical decomposition often make original growth patterns of fossils obscure. Thus it is necessary to develop a method to make faded growth patterns visible once again. Computer based digital image processing seems to be the most suitable method for this purpose.

Our aim in the present paper is to test the ef-

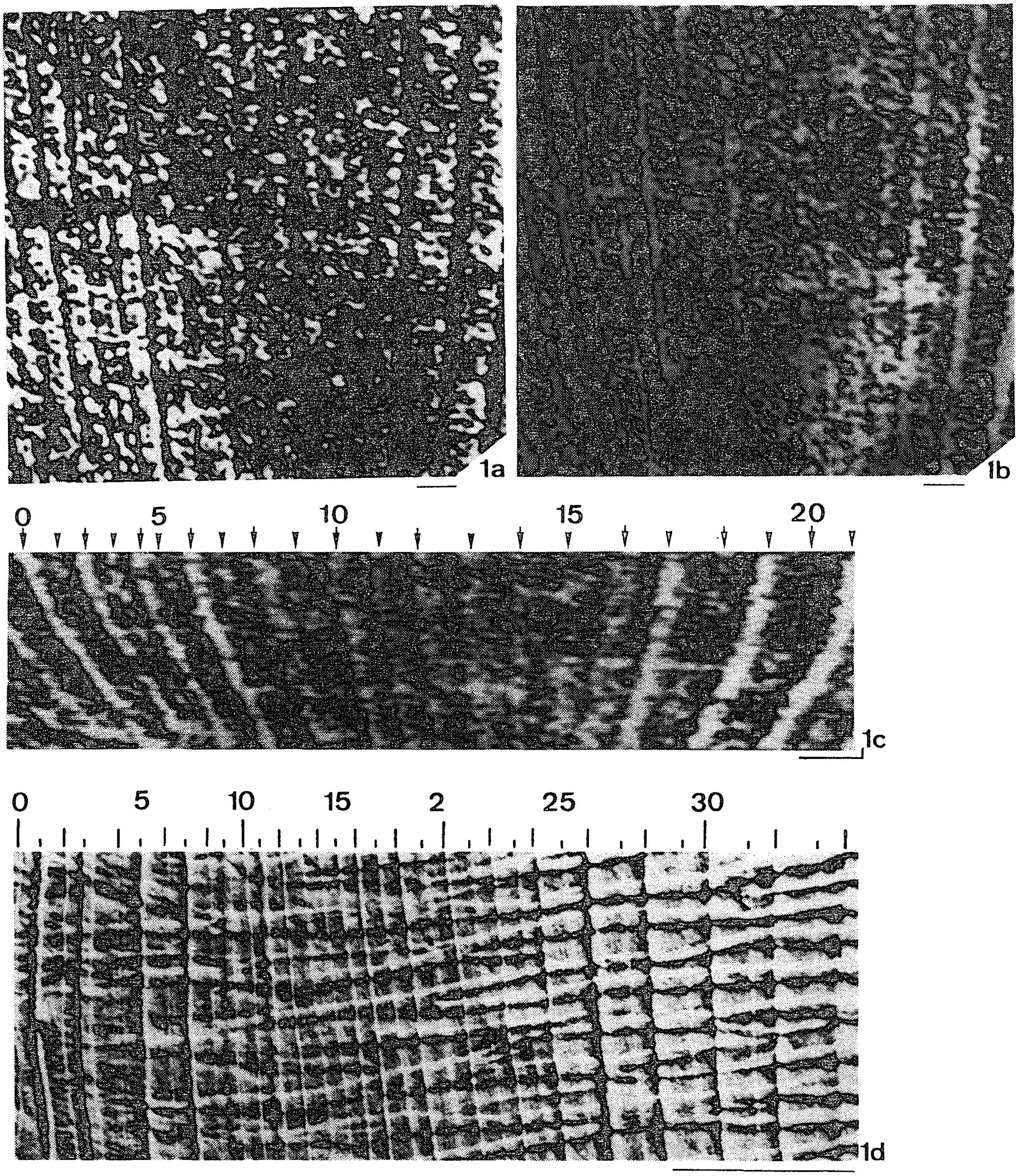


Figure 1. SEM photo-micrograph of a Miocene fossil bivalve shell fragment.

1a. original photo-micrograph image (scale = 10 micron)

1b. negative image of Fig. 1a (scale = 10micron)

1c. contrast enhanced image of Fig. 1a. The image is condensed vertically so that the vertical length becomes 20alternating thicker and thinner growth lines marked with arrows. The order of arrangement of thicker and thinner growth lines inverts from left to right, so that in arbitrary numbering the lines with even numbers are thicker near the left corner, whereas lines with odd numbers are thicker near the right corner.

1d. SEM photo-micrograph of a Recent intertidal bivalve Cerastoderma edule (Linne). (scale = 100 micron). Note the similarity in alternation and inversion of arrangement of growth line thickness between this figure and Fig. 1c.

fectiveness of the digital image processing in revisualizing fossil growth patterns. For this purpose we used PIAS (personal image analyzing system) installed recently in our laboratory. It has CCD camera to get data input into the system. CCD has a resolution of 256×256 points. CCD-image is then processed digitally.

Three fossil samples from different geological age and of varying preservation condition are used for the analysis:

1. Fossil bivalve fragment, Miocene (ca. 15Ma), Mizunami, Japan
2. Fossil spiriferid brachiopod, Permian (ca. 250Ma), Gerowa, Australia
3. Stromatolite structure, Precambrian, (> 650Ma), Atar, Mauritania.

2 Results:

2.1 Shell fragment from Miocene

In the Recent intertidal zones, growth of shell is interrupted at each low tide when bivalves are exposed to air and this is recorded as thin growth line in the shell. Thus formed growth lines are arranged into patterns which occur exclusively to the intertidal zone. One of them is alternating thicker and thinner growth lines (Fig. 1d). This is due to the difference of air or substratum temperature during daytime and night time tidal exposures: thicker lines are formed during day time exposure and thinner ones during night time exposure (Ohno, 1989). Because low tide occurs about 50 minutes later than on each preceding day, the "daytime" low tide will change into the "nighttime" low tide after a fortnight. Consequently the order of appearance of thicker and thinner lines inverts after every fortnight (28.54 semidiurnal tidal cycles).

A photo-micrograph of a recent bivalve shell taken by scanning electron microscope (SEM) shows the alternating growth line thickness clearly (Fig. 1d). Another SEM photo-micrograph is prepared from a Miocene bivalve (Fig. 1a). The sample comes from the Miocene Mizunami Group of Gifu Prefecture, Japan. It is known that wide intertidal zone spreaded in the area about 15 Ma ago. The fossil's micrograph seems to indicate alternating growth line thickness. Weathering of the sample, however, obscured the pattern.

To confirm whether alternating growth line thickness really exists or not, the photo-micrograph of the fossil bivalve shell (Fig. 1a) is processed with PIAS and compared with that of the recent one (Fig. 1d). Both micrograph is taken from polished and HCl-etched surface of the section vertical to the bivalve shell surface. In the recent material, growth lines are more resistant than the remainder of the shell material so that growth line appear as thin white ridges on the micrograph (Fig. 1d). The fossil material is weathered and growth lines on the photo- micrograph appear as thin black grooves (Fig. 1a). To make the comparison easier, a negative image of the photo-micrograph of the fossil material is produced (Fig. 1b). Then its contrast is enhanced. Finally the image is condensed in a direction roughly parallel to the growth lines (Fig 1c). The resulting, condensed image of the fossil material (Fig. 1c) clearly shows the growth lines of alternating thickness as well as inversion of the order of the arrangement of the thicker and thinner growth lines. Thus in analogy with the recent tidally formed growth lines, it is concluded that the examined fossil material lived in the intertidal zone and formed one growth line at each semi-diurnal tidal exposure.

2.2 Permian brachiopod specimen

The umbonal area of the ventral valve of a spiriferid brachiopod is processed by PIAS. On the cut surface of thickened calcite shell there are several visible growth lines on the original (non-processed) CCD image (Fig. 2a). After enhancing the contrast, growth lines become more clear (Fig. 2b).

On low magnification image, zones of densely arranged growth lines alternate with zones with no growth lines (for example, left half of the zone marked with white line on Fig 2b). In the enhanced image of higher magnification, however, growth lines are also visible within the zones of no growth lines (Fig. 2c). If we take these faint lines into account, the line spacing becomes more regular. Besides Mazullo's (1971) brief report on supposed daily and annual growth, very little is known about brachiopod growth patterns and their chronological meaning. The growth line spacing of the order of 0.2 to 1 millimeter in the

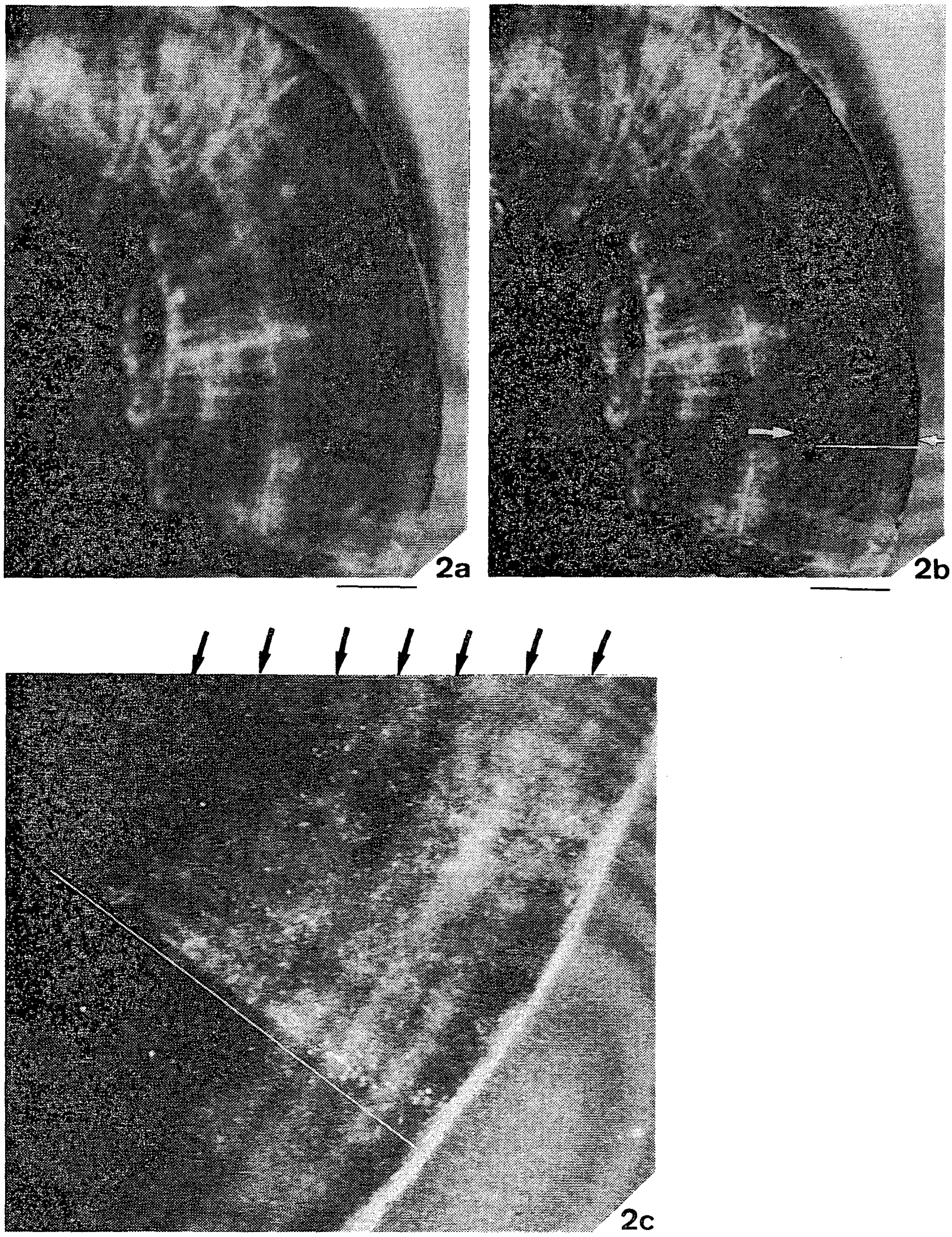


Fig. 2 Permian spiriferid brachiopod.

2a. original (non-processed) image of the umbonal region (scale = 2mm).

2b. the same image after contrast enhancing (scale = 2mm). White line on the right bottom corner between two white arrows roughly corresponds to the white line on Fig. 2c. Note that the left half of the zone marked with white line is almost without growth lines.

2c. part of Fig. 2b (strongly enlarged). Growth lines are visible also on the left half of the zone marked with white line.

present material is too wide to attribute it to daily or semi-daily growth. Monthly, seasonal or annual periodicities may be responsible for the line spacing.

2.3 Stromatolite sample

Figure 3a shows the CCD input image of the ground surface of the stromatolite. The size of the specimen is roughly 5 x 10 cm. Specimen shows concentric growth layers of different thickness. After the enhancement of contrast (Fig. 3b), layering is more clear to be seen. These layers are fairly continuous throughout the section.

Minute growth layers become obvious on the enhanced image of the partial enlargement of the sample (Fig. 3c). They often fuse together.

The existence of growth layers of two different magnitudes tempts us to hypothesize their chronological relationship such as daily growth layers in monthly band, or monthly layers in annual band, etc. However, the number of the fine layers within a broad layer varies considerably. Thus we give up to give any conclusive remarks about their chronological relationship. For the present, we should be contented with the fact that we successfully applied the digital image processing method in visualizing fine growth layers in this Precambrian material, which is otherwise not easily to observe.

3 Discussion

Our image processing system used in the present study is a simple one. We may conclude that the application of this simple system improves growth pattern recognition of the examined fossil material significantly. We recommend to use image processing system in estimating fossil growth pattern from now on.

To attribute any growth structure to certain rhythm is another and rather difficult problem. For example, stromatolites have long been attracting paleontologists' and geophysicists' interest as a possible candidate to provide us with the information on the number of the day per year in the early times of the earth's history. Stromatolite is a structure formed by the sediment trapping blue-green algae. Among the recent stromatolites, several growth layer formation rhythm are reported which coincide with periods of geophysical interest:

solar daily (Jones, 1981; Monty, 1967, 1973);
tidal (Davies, 1970; Park, 1973);
weekly (Monty, 1967);
fortnightly (Monty, 1967);
seasonal (Monty, 1967, 1973);
annual (Davies, 1970).

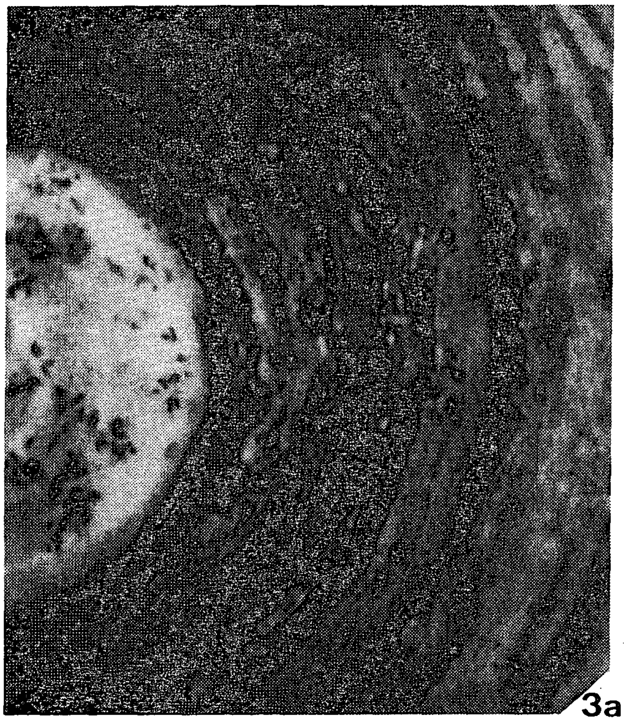
These data are obtained by observing stromatolite growth at the place where they grow. There is, however, almost no reliable criterion to recognize between structures formed with different periodicities, when we only observe dead specimens. This is because, for example, daily layer and annual layer from different habitats may have the same order of thickness and appearance. There are also non-rhythmic lammella formation known among recent stromatolites (Jones, 1981).

Yet, there are several promising reports about the utility of the Precambrian stromatolites as effective tool for paleo-geochronology. Vanyo and Awramik (1982), for example, described 850 Ma old sinusoidally meandering columnar stromatolites (wave length about 7.7 to 9.6 cm) from Australia. They supposed that sinusoidal meandering is the proof of the phototropism of the blue-green algae grown near equator. Near equatorial region, the sun shines from north during the summer and from the south during the winter. Blue-green algae followed the orbit of the sun in the sky to utilize the energy of the sun light most effectively for their photosynthesis activity. The resulting stromatolite structure has a sinusoidal form. A one full cycle of sinusoid represents one year.

Based on this assumption they counted the number of micro- lamella per wave length. Their count of 410 agrees fairly well with the predicted number of the days per year extrapolated from the rate of slowing of the earth's rotation velocity.

Although there is a large amount of stromatolite material in the regions where Precambrian sedimentary rocks are exposed, their growth patterns are not yet fully analyzed. This is, for a considerable part, because their original growth structures have been obscured by weathering and metamorphism.

Image Processing of fossil materials made in the present paper demonstrates that the method is effective in re-visualizing the obscured fossil growth patterns. In the future, application of



3a

3b

3c

Fig. 3 Precambrian stromatolite.

3a. original (non-processed) image (scale = 5mm)

3b. contrast enhanced image of the Fig. 3a(scale = 5mm)

3c. enlargement of the stromatolite, (marked with black circle and small white arrows) original image (scale = 0.5mm) the image processing in analyzing fossil growth patterns will surely yield meaningful information on the number of days per year and other paleogeochronological parameters.

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