# Evaluation of ichnodiversity by image-resampling method to correct outcrop exposure bias

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This study proposes a new method to evaluate the diversity of ichnofossils from the outcrop records. Ichnofossils are records of responses of benthic animals to marine environmental conditions. Therefore, detailed analyses of ichnoassemblages provide information of the paleoenvironmental conditions on ancient seafloor. Activities of benthic animals affect superficial to subsurface sediment on seafloor. For instance, burrowing or grazing by infauna may rework sediment and destroy sedimentary structures. These behaviors may raise pore water oxygenation level, and may result in accelerated decomposition of the organic matter in sediment (Aller, 1994). Thus, it is important to evaluate ichnoassemblage in quantitative way from various aspects (e.g. diversity, abundance, disparity, and bioturbation intensity) to reveal the paleoenvironmental conditions from geologic records. Particularly, ichnodiversity (defined here as number of ichnogenera in an ichnoassemblage) is regarded as an important parameter that characterizes sedimentary environments (e.g. Cummnings and Hodgson, 2011). However, numbers of ichnogenera observed in outcrops reflect not only actual diversity in activities of benthic animals but also exposed area of observed outcrops. Even though there are several established methods for correcting such sample size biases in studies of paleobiodiversity, such as rarefaction (Sanders, 1968) or shareholder quorum subsampling (SQS; Alroy, 2010), these methods cannot be applied to analyses of ichnodiversity because number of individuals of ichnofossils is difficult to identify due to their morphological characteristics. For instance, an individual specimen of planar-formed regular network graphoglyptids that may be preserved in fragments cannot be defined in observation on outcrops.

To this end, this study proposes a new method to evaluate the ichnodiversity independent of exposed area of outcrops by using of image-resampling technique with application of the SQS method. The procedures of our method are following. First, the line-of-interest for data resampling is randomly set in the acquired outcrop image. The number of ichnogenera on the line is then counted. As the length of the line-of-interest increases, the number of counted ichnogenera increases. Repetition of this resampling process derives the relationship between the observed length and number of ichnogenera, which can be approximated by the non-linear function fitted to the resampled data. The obtained curve can be regarded as the equivalent of “rarefaction curves” of the biodiversity. Next, the ichnodiversity (the expected number of ichnogenera) of the examined outcrop image is calculated at a given value of the “coverage” of the actual diversity, which is estimated from the slopes of the tangential lines of “rarefaction curves” (Chao and Jost, 2012). Consequently, fluctuation of the ichnodiversity in the outcrop image data at any given “coverage” is obtained independent of differences in the exposed area of outcrops. This method was applied to artificial data of ichnoassemblages to verify the methodology particularly on effects of distribution patterns of ichnofossils on bedding planes. Ten kinds of artificial ichnofossil images were allocated on the virtual bedding planes to generate artificial outcrop images showing ichnoassemblages. In these series of experiments, two types of spatial distribution pattern of ichnofossils were examined: uniform and patchy distributions. Our method indicated that the distribution patterns did not affect ichnodiversity at sufficiently high “coverage.”

This method was also applied to the field data of deposits of the submarine channel-levee complex in the Izaki olistolith of the Nichinan Group distributed on the southeastern part of Kyushu, southwestern Japan (Sakai, 1987). Our method revealed that the ichnodiversity of the successions in the Izaki olistolith is relatively high in channel deposits and is low in levee deposits.

 

Keywords: Ichnofossil, Ichnodiversity, Outcrop exposure bias, submarine channel-levee deposits

 