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Scientific study advancements: Analysing Japanese historical materials using archaeobotany and digital humanities

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Over the last two decades, the study of starch grain assemblages in archaeological contexts has become progressively widespread across East Asia (Shibutani, 2017b). Similarly in Japanese archaeology, extensive starch data has been accumulated from stone artefacts (e.g. Kamijo, 2013; Kobayashi & Kamijo, 2012; Shibutani, 2017b, 2018; Shibutani, Aono, & Nagaya, 2015; Yamamoto, Shibutani, & Kamijo, 2016), pottery residues (Shibutani, 2007, 2014, 2017a; Shoda, Matsutani, Kunikita, & Shibutani, 2011; Yamamoto et al., 2016), wooden materials (Kamijo, 2014), soil sediments (Aono, Shibutani, Soeda, & Nagaya, 2021), and human and animal dental calculus (Shimono & Takenaka, 2014; Yamazaki, Shibutani, & Yoneda, 2021). These data have mainly been emphasis placed on determination of the tool functions, identification of processed plants and field crops, and reconstruction of the past plant foods and dietary habits. Such microbotanical methods are now applied to analyse paper components and mixtures of Japanese historical materials.

In Japan, papers used for historical documents and diaries have mainly been studied in palaeography, history, and the conservation of cultural property (Shibutani, 2019a). These studies have focused on ancient and medieval materials, but in recent years there have been promoted the classification of materials through microscopic observations and the analysis of early-modern documents (Shibutani, 2020). Any surveys of Japanese historical materials are essentially non-destructive, and their papers are observed with the transmitted and reflected lights of microscopes, mostly with 100 times magnification (e.g. Okawa, 2017; Tomita, 2013, 2014, 2016; Yuyama, 2010, 2017). These microscopic observations aim to examine morphological features such as thickness and density of the fibres, the existence and quantity of

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additives such as rice powder and kaolin, and the conditions of other materials such as plant parenchyma. Based on these results, preliminary studies explore the past methods of making and using papers, binding techniques, the classification of paper types, recognising the two sides of paper, and analysing other materials such as sumi ink and vermillion (Shibutani, 2019a; Shibutani & Goto, 2019; Shibutani & Kojima, 2018). In addition, USB digital cameras for microscopy and lenses of megapixel cameras have been upgraded, and researchers and analysts can easily gain distortion-free and high-definition images (Shibutani & Goto, 2020). Thus, scientific studies of historical paper-based materials have rapidly developed using sophisticated analytical approaches (e.g. Enomae, 2012; Laboratory, 2021; Sakamoto, 2018; Sakamoto & Okada, 2017; Shibutani, Nomura, Takashima, Amano, & Yamada, 2021), and the diverse scientific information in historical materials has been accumulated in greater depth.

While the accumulation of scientific analysis of historical materials is progressing, previous studies have pointed out that different researchers use different methods to acquire data and different data items to be analysed, and that there is no objectivity in the respective identification criteria. It is difficult to share the research data generated and accumulated among researchers and analysts (Shibutani, 2020; Shibutani & Goto, 2020). Some of the analytical data have been published in papers and other publications, or have been attempted to be made available on websites through databases or as data sets. However, this is only a partial and superficial presentation of the data. Some researchers have examined numerous historical paper-based materials, and others do not have easy access to numerical data that can be used in comparison processes (Shibutani, 2020). Furthermore, the preliminary morphological analyses are conducted simply with a visual examination by 'specialised' researchers with no experience in scientific approaches (Shibutani, 2019b, 2020). Without resolving this current situation, it will be difficult to conduct comprehensive and exhaustive searches or to acquire research data that can be presented in relation to the historical materials themselves.

The author has organised an interdisciplinary research group in cultural property science, plant breeding, history, digital humanities, and archaeology, especially has applied archaeobotanical and other scientific methodologies to conduct comprehensive scientific studies of historical materials. Our group is conducting the international standardisation of historical material studies with the following three axes: 1) Standardising scientific methods of historical materials; 2) Constructing a research data sharing management system, and 3) Advancing a scientific research community using the data sharing management system (Shibutani, 2020; Shibutani et al., 2021). Why should we promote scientific studies of historical materials? The reason is that there is a need for capturing data provenance and diversity while promoting attribution and acknowledgement of its use. This paper's position is that archaeobotanical

and digital humanities' applications can solve the technological and sociological challenges inhibiting global open access and data provenance of analytical results in historical studies.

Establishing scientific research methods for historical materials, and integrating, sharing, and standardising large amounts of diverse analytical data will not only ensure the reproducibility and objectivity of analysis results, but will also enable to share and to use the previous research data. It is needed to set up analysis items and identification criteria that focus on the acquisition of objective data containing numerical values, and to establish an analysis process (Shibutani, 2020; Shibutani et al., 2021). Based on archaeobotanical techniques, we first established the basic data items for scientific analyses containing their botanical characteristics. They propose to identify the types of paper components taxonomically and to measure their quantity and density based on the numerical data in previous studies. Also, for examining the transition in the past paper-making methods, our data items emphasise starch grains as additives and their taxonomic identification together with the presence or absence of minerals and glues. By sharing these criteria into a research group and among researchers, it is enabling to identify issues in each analysis process of historical materials and to examine them from multiple perspectives.

The next challenge is how to share the generated and accumulated analysis data among researchers and how to promote multi-faceted examination. It is important to standardise the scientific information of various historical materials internationally and to use it widely throughout historical research (Shibutani et al., 2022). Especially image data are rich data files because they present various parameters in a multidimensional space and are acquire using complex microscopy instruments. The real benefit of the easy sharing and reuse of digital data is that they aid data provenance and reproducibility of results. With more openly accessible resource data, researchers can enhance and accelerate scientific advances in history. By applying Linked Open Data, digital object identifiers, and other systems such as institutional repositories, our research data can be resource data that can be valued and shared around the world (Shibutani & Goto, 2020; Shibutani et al., 2022).

Our current project is to develop an image data management tool for open science in history. It manages the multi-layered information of historical materials. Users of this application can preserve any resource data, easily update the content, and perform the easiest and fastest image annotation. Multiple labels on an image are useful to specify the contextual similarity for image retrieval. By generating a similarity matrix between labels, systematic network linking with other analysis data can be done more effectively, and researchers can visualise each process to improve the reproducibility of analysis data. The application can also be operated both online and offline. Image metadata can be edited easily and comfortably. Just like a notes application, users can easily write notes during and after an investigation.

Our application seeks to create a research process improvement by linking it to information infrastructure, and thus we can accelerate digital transformation (DX) in historical studies.

Together with introducing the current research status about Japanese historical paper-based materials, this paper presented that scientific approach to historical materials with transcending the boundaries of the humanities and natural sciences can produce the perspective of comprehensive and multifaceted research. Our project continues to expand and build up case studies, and promotes the sharing and opening scientific research data for contributing to open science in history.

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