# Provenance study of excavated amber by inelastic neutron scattering

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A large number of buried cultural properties made from amber have been excavated from Jomon, Kofun, Nara, and Heian-period archaeological sites. In Japan, amber production areas are limited, and the physical properties of amber vary from region to region. Therefore, clarifying the provenance of excavated amber by scientific analysis is important information for study of the ancient distribution and exchange network. The previous study mainly used FT-IR and thermal analysis to estimate the provenance of ancient ambers. On the other hand, the provenance of ancient ambers has been studied by archaeological approach. However, there are differences between the results of archaeological and scientific studies. In particular, there have been many negative opinions about the results of scientific analysis that the amber was transported from the Tohoku region to the Kinki region. Therefore, it is essential to establish a more accurate scientific characterization method of ancient amber in order to clarify the distribution and exchange network at the time.

In this study, we attempt to estimate the provenance of amber by observing boson peaks by inelastic neutron scattering experiments. The provenances are estimated by comparing the peak positions of excavated artifacts with modern samples of each provenance. Amber is fossilized tree resin produced by the polymerization of terpenes that are 100 million to 10 million years old. Each producing region has different geological formation ages and source plants. The material density of amber will reflect the differences in the producing regions. On the other hand, it has been reported that the peak position and intensity of the boson peak are affected by density [1]. Thus, the producing region of the excavated amber will be clarified by measuring the boson peak position as material density.

The neutron scattering experiments at 5, 100 and 300 K were carried out on modern amber from 7 producing regions. Figure 1 shows the differences in the neutron scattering spectra at 100K. The boson peaks were observed at around 1.2 meV and the peak positions were different. The peak positions and geological time of each samples are shown below.

| | | |
|---|---|---|
| Choshi: | 1.06 meV, | 110 - 130 Ma |
| Nakagawa: | 1.13 meV, | 113 - 125 Ma |
| Kuji: | 1.27 meV, | 83 - 89 Ma |
| Iwaki | 1.33 meV, | 83 - 89 Ma |
| Ishikari: | 1.26 meV, | 23 - 66 Ma |
| Kitakyushu: | 1.23 meV, | 23 - 65 Ma |
| Mizunami: | 1.20 meV, | 10 - 16 Ma |

Therefore, it is proposed that the measurement of boson peaks may be an indicator for the provenance study of the ancient ambers.

[1] H. Nakagawa *et al.*, Biophysical journal, **117**, 229-238 (2019)

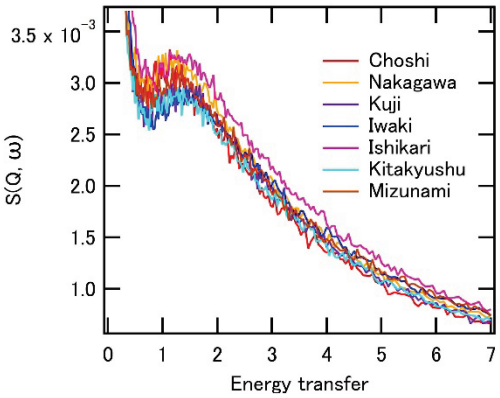


Fig. 1 Inelastic neutron scattering spectra of amber, *red*, *yellow*, *purple*, *blue*, *pink*, *light blue*, and *brown* show Choshi, Nakagawa, Kuji, Iwaki, Ishikari, Kitakyushu, and Mizunami amber, respectively.