Bayesian statistical evaluation method for detrital zircon geochronology

*Tan Furukawa[1], Tatsuki Tsujimori[1]

1. Tohoku University

Over the past two decades, detrital zircon U-Pb geochronology has become an essential method not only in sedimentary provenance analyses but also in characterization of sedimentary and metamorphic strata. Although the age data has been conventionally evaluated by using relative frequency plots (here after called histograms) and density curves, the lack of statistical verification can cause miss reading of data. In order to overcome the statistical issues raised, this study proposes new statistical evaluation method for detrital zircon geochronology.
The new method is based on Bayesian statistics, adapted a theory proposed by Riihimäki and Vehtari (2014) that provides a flexible modeling for density curve using the Logistic Gaussian Process (LGP)
For introducing non-negative consistency for density curve, the logistic density transformation is performed by $p(x)=\exp(f(x))/\int\exp(f(\mathbf{s}))d\mathbf{s}$; x is age, p(x) is density curve, and f(x) is Gaussian Process; $f(x)\sim GP(0, \kappa(x,x'))$. The covariance matrix $\kappa(x,x')$ is calculated by Gaussian kernel with hyperparameters ρ and σ. For the actual computation, the logistic density transformation has integral difficulties, then, M discretized softmax function is used for approximation for it.
The likelihood function is $L(\mathbf{p}|\rho,\sigma)=\mathbf{y}^{T}\mathbf{p}$. $\mathbf{p}$ is M discretized p(x), and $\mathbf{y}$ is vector of y_i, which is the number of observations that fall within the i'th M discretized age subregion.
We have used programming language R and Stan for the MCMC computation of the statistical model above. When the number of detrital zircon data is several hundred or less, the hyperparameters of Gaussian process ρ and σ do not converge, and Bayesian estimation can not be performed. For this reason, the author estimated most plausible ρ and σ by WAIC. Using zircon data from our own data and the literature, in this presentation, we will demonstrate powerfulness of our new statistical evaluation.

Keywords: Bayesian statistics, detrital zircon geochronology, MCMC algorithm