Automatic hypocenter determination by deep learning for microseismic networks in geothermal areas

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A dense seismic network including deep borehole sensors is ordinally employed in developing geothermal areas to detect a change in seismicity regarding the geothermal developments. It is possible that illuminating subsurface fluid flows in detail by tracking the microseismic clouds in high-resolution. However, hypocenter determinations based on manual phase picks are sometimes difficult due to lack of manpower as well as cost. Moreover, automatic event picks based on STA/LTA still need manual corrections of the picks for high-resolution hypocenter determinations,

In this study, we aimed to develop an automatic event pick method based on deep learning that could substitute for manual picks especially for microseismic networks in geothermal areas. We developed the method by using seismic data observed by a dense seismic network (five borehole sensors, four surface sensors) employed in Okuaizu Geothermal Field (Fukushima, Japan) since May 2015. We also examined applicability of this method to another geothermal field by using seismic data observed by a dense seismic network (six borehole sensors) in Basel geothermal field (Switzerland).

Deep learning was conducted by “teachers”: manual picks of 33,008 P-waves and 65,925 S-waves from microseismic events (local magnitude range: -1.5 –2.5) observed in the Okuaizu Geothermal Field. Then, the accuracy of the learning was evaluated by 3,344 P-waves and 3,310 S-waves. As the result, the accuracy for P-waves was average = ˜0.03 s and standard deviation = ˜0.46 s and that for S-waves average = ˜0.01 s and standard deviation = ˜0.30 s. We applied this deep learning phase picker to the seismic events detected from continuous seismic waves by STA/LTA in Okuaizu Geothermal Field, and found that the hypocenter distribution based on the deep learning pick showed a shape similar to that based on the manual pick. When applying to this deep learning phase picker to 3,069 seismic events in the Basel geothermal field (17,138 P-waves, 13,702 S-waves), the accuracy for P-waves was average = ˜0.15 s and standard deviation = ˜0.58 s and that for S-waves average = ˜0.16 s and standard deviation = ˜0.65 s.

For further applying this method to other seismic networks in geothermal areas, it is needed to consider transfer learning and optimization of the structure of hidden layers.

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Keywords: Deep learning, Phase pick, Microseismic monitoring, Geothermal development, Fluid flow

