Lithospheric seismic fabrics of Sulu ultrahigh-pressure metamorphic belt

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Abstract Calibration of seismic reflectors appearing in the crust of the Chinese continent scientific drilling site can be completed through the correlation studies between direct evidences, such as the drill cores, and geophysical signatures; therefore the interpretation of geophysical data could produce reliable results of crustal structure and composition. On the other hand, there are two Cenozoic volcanoes close to the scientific drilling site; analyzing composition of xenoliths existent in the volcanoes and evaluating their seismic velocities can also offer information about the mantle and lower crust. After the calibration via cores and well-logging data, the seismic reflectors appearing in the UHP belt can be caused by lithological changes within the UHP rock slice, ductile shearing rock-suites, and later fracture zones. Among these sources, ductile shearing resulted in displacement and detachment of original rock-sheets, producing some rock-interbeds of several hundred meters thick that are named the ductile shearing rock-suites. A suite consists of mylonized gneiss and eclogite slices that underwent shearing, becoming the major mechanism responsible to generate regional strong reflections. The UHP rock-slice is characterized by complicated structures and high density, high seismic velocity and high electrical resistivity, its thickness is usually less than 11 km. Velocity and density of the gneiss-layer beneath gradually tend to normal with increasing depth. Based on the xenoliths we can infer that the middle crust contains a lot of gneisses, and the lower crust consists of different granulites. The lithospheric mantle has multi-layer structures and consists mainly of spinal lherzolite and harzburgite, implying late Mesozoic lithospheric thinning. The seismic fabrics with different origins were possible products of different geodynamic processes. For instance, the UHP rock-slice was produced by the UHP metamorphic process and the exhumation of subducted supracrustal rocks after the Triassic collision between the Yangtze and Sino-Korean cratons; whilst the ductile shearing rock-suites resulted from shearing deformation processes during the subduction and exhumation. The normal velocity below the UHP rock-slice was correlated with Mesozoic extension processes in the area. Through careful calibration of seismic reflectors and analyzing xenoliths, one can find the relationship between the causes of seismic reflectors and corresponding geodynamic processes, offering a new basis for reconstruction of regional dynamic evolution history.

Keywords: deep seismic reflection, ultrahigh-pressure belt, Sulu China, calibration of reflectors, lithospheric fabrics.

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The Sulu UHP belt is a regional metamorphic belt, consisting of mainly gneisses. It also shows the exposed mountain root of a collisional orogenic belt. The mountain root means the thickened crust during the Triassic collision between the Yangtze and Sino-Korean cratons. In the Mesozoic, entire eastern China underwent extensive magmatism and volcanism, which caused great changes of lithospheric composition and structures, and left some signatures in deep seismic reflection profiles. In recent years the Chinese continent scientific drilling (CCSD) project has been carrying out within the UHP belt, and geophysical investigations, including seismic reflection as the key method, have been performed around this area, discovering many reflectors that occurred in the crystalized crust. Studying seismic fabrics and these reflectors may provide valuable information about composition and structures of the lithosphere in the Sulu UHP belt.

Since 1975 deep seismic reflection investigations have globally been carried out, producing hundred thousands kilometers of reflection profiles and discovering various reflection patterns in continent lithospheres\(^1\)\(^\text{--}\)\(^4\). The common seismic reflection patterns in the crust and mantle are called seismic fabrics, which are usually related to heterogeneity of the Earth with different scales and were results of different geodynamic processes. For sources of the seismic reflection fabrics, scientists have made various explanations, but they have not accurately calibrated the fabrics because the direct evidences that can be used for the calibration are very few. Whether from the global scale or regional scales, the seismic method is the most important one to exploring the Earth’s interior. Unfortunately seismology can only provide indirect evidences; whilst direct evidence must come from drilling. Due to the restriction of funds and technology, drilling into the middle crust to take cores seems not realistic in the near future. However, some rocks originally buried in the middle or lower crust sometimes could be pushed into the surface by tectonic movement, making it possible to get them with quite deep drill holes. Calibration of seismic reflectors appearing in the crust can be completed through the correlation studies between direct evidences, such as the drill cores, and geophysical signatures; therefore the interpretation of geophysical data can correctly infer deep crustal structure and composition. On the other hand, there are two Cenozoic volcanoes close to the scientific drilling site, they acted like natural super-deep drill holes, brought up deep xenoliths included in basalt magma into the surface. Analyzing composition of xenoliths existent in the volcanoes and evaluating their seismic velocities can also offer information about the mantle and lower crust\(^5\),\(^6\). After calibration of seismic reflectors in the Sulu area through cores and volcano xenoliths, we establish the crustal lithological column of seismic fabrics, useful for comparison of global UHP belt lithospheres and for study of interaction between the crust and mantle. The calibration also offers rulers for interpretation of deep seismic data in eastern China.

1 Geological and geophysical setting

The main hole of the Chinese continent scientific drilling (CCSD) is located in the southern part of Donghai County, eastern China. The aim of the drilling project is to study ultrahigh-pressure metamorphism and related geodynamic processes. This UHP belt is located in the eastern part of the Qinling-Dabie-Sulu orogen, which was formed during the Triassic collision between the Yangtze and Sino-Korean cratons. The continental crust in Dabie-Sulu was subducted into the mantle in the Triassic, and then quickly exhumed back up to the upper crust, creating the largest UHP belt in the world\(^7\)\(^\text{--}\)\(^16\). The rocks on the surface in the southern Donghai area are mainly gneisses, including monzonitic gneiss, biotite gneiss and biotite plagioclase gneiss. These gneisses were formed in the Proterozoic or older, and underwent ultrahigh-pressure metamorphism in the Triassic; therefore the gneisses around the CCSD site often contain coesite. But in southern Donghai County some gneisses do not contain coesite (as around Fangshan Mount), meaning that some gneisses did not undergo the UHP metamorphism. The UHP gneiss-massifs contain a lot of eclogite and peridotite bodies. Eclogites usually contain coesite, their protolith was Proterozoic mafic volcanic rocks, also under-