

SCIENTIFIC DRILLING IN SULU ULTRAHIGH PRESSURE METAMORPHIC BELT

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I. Introduction

The Chinese Continental Scientific Drilling Program (CCSD) has been approved as a national key scientific engineering project by China government and as an international project by ICDP. A 5000-m-depth scientific hole will be drilled in the Donghai area of the Dabie-Sulu ultrahigh pressure metamorphic (UHPM) belt, eastern-central China (Fig. 1). So far many detailed geological and geophysical surveys have been completed, and two pre-pilot holes (CCSD-PP1, 432-m-depth; CCSD-PP2, 1000-m-depth) have been drilled at the Donghai selection site of CCSD. The main hole of 5000-m-depth will penetrate through coesite-bearing eclogite, garnet peridotite, gneiss, schist and other rocks unexposed possibly on the surface. These rocks have been subducted to at least 100-km depth of upper mantle and experienced UHP metamorphism, and then exhumed to the earth surface. The CCSD aims to reveal deep geological processes and dynamics of the convergent plate boundary, to understand crustal behavior and crustal-mantle interaction related fluid and mineralization, and the mechanism of formation and exhumation of UHPM rocks, to test geophysical data in the deep structure and composition of the crust, and to establish a long-term, natural laboratory for study of the deep continental crust. A pilot hole of 2000-m will be carried out in the end of this year.

II. Geological background of the CCSD site

The Donghai site of CCSD is located in the eastern part of the Dabie-Sulu UHPM belt between the Sino-Korean plate and the Yangtze plate (Fig. 1). The lithospheric tectonic profile crossing the Sulu UHPM belt, which inferred based on the deep seismic reflective data, shows that the Sulu terrain consist of the upper UHP and HP metamorphic slice including gneiss, eclogite and peridotite, and the lower unexposed metamorphic slice associated with emplacement

of granites, and the Yangtze craton subducted beneath the Sulu terrain (Fig. 2). The protoliths of most UHPM rocks are supracrustal rocks with a formation age of about 800 Ma. Isotopic age measurements show that the collision between the Sino-Korean and the Yangtze plates began at about 240 Ma and the UHP metamorphism about 220 Ma.

In comparison with other UHP terrains in the world, the Sulu UHPM rocks are unique in the occurrence of: 1) many volatile-bearing phases in eclogites and ultramafic rocks; 2) the lowest ^{18}O values (-15 per mil) for eclogitic minerals, the highest REE total content for UHP ultramafic rocks and the highest ϵNd (0) values (+170 to +264) ever measured for terrestrial rocks for eclogites; 3) at least two distinct types of garnet peridotites. Type A mantle-derived peridotites are fragments of mantle wedges of the North China plate; Type B crustal-hosted peridotites are portions of mafic-ultramafic complexes of the Yangtze plate emplaced into continental crust prior to subduction. Rutile, kyanite and pyrope deposits related to UHP and HP metamorphism have been identified and prospected by the shallow drilling and trenching. A larger grain of diamond crystal is also discovered in eclogite from Donghai site. Tectonically, the Donghai area consists of 5-stacked structural slices separated by four ductile shear zones with NE-SW striking and gently dipping southeastward. Geophysical investigations demonstrate the presence of a high resistance, high reflectivity, high density (3200kg/m^3) and high velocity (6.8 Km/s) layer at depths between 3.2 km to 4.3 km, which can be penetrated by a 5-km-deep drillhole.

III. Inferred petrotectonic column for the main hole of CCSD

According to the detailed investigation of geology and geophysics, the 5000-m depth main hole of CCSD will penetrate five tectonic slices separated by four ductile or brittle deformation zones (Fig. 3). They are from the upper to

lower: 1) slice A, consisting mainly of coesite-bearing eclogites and minor thin layers of gneiss and garnet peridotite; slice B, biotite-amphibole gneiss with thin layers of schist and amphibolite, and lenses of eclogite; slice C, aegirine-bearing gneiss with thin layers and lenses of eclogite and amphibolite; slice D, eclogite and peridotite, characterizing by the high reflectivity, high seismic velocity (6.8 km/s) and high density (3200kg/m³); slice E, biotite gneiss with lower velocity than that of the upper slice.

IV. A preliminary investigation of the pre-pilot hole

The first pre-pilot hole with 432-m-depth (CCSD-PP1) is located in the Zhimafang ultramafic body, southeast 9km of Donghai country. The three large petrologic units can be distinguished in the drillhole, they are as following from the upper to lower: (1) Gneiss unit (0-137.82m), consisting mainly of biotite two-feldspar gneiss, amphibole-bearing two-mica two-feldspar gneiss and epidote biotite amphibole plagioclase, and minor layers of eclogite and epidote amphibole schist; (2) peridotite unit (137.82-256.37m), including garnet buchnerite, garnet peridotite and harzburgite. Intensively serpentinization occurs in the upper part and lower part of the unit; (3) gneiss and granitic gneiss unit (256.37-432m), including epidote amphibole plagioclase gneiss and amphibole biotite plagioclase gneiss with layers of phengite eclogite and kyanite phengite quartz schist. The three layers of granitic gneisses were recognized. A mylonite zone with 20 m thickness formed at the bottom of peridotite segment. Preliminary study of the drillcore of CCSD-PP1 indicates that the protoliths of UHPM rocks derived from supracrustal rocks of different chemical composition, including ultramafic, mafic, intermediate, intermediate-acidic and acidic rocks, and sediments. The granitic gneiss with no evidence of UHP metamorphism was formed by the partial melting of UHPM rocks during the uplift. Shearing strain analysis and fabric measurement of quartz from gneiss indicate the existence of shearing sense from NW to SE at the early stage of deformation and from SE to NW at the late stage. The P-T conditions of peak metamorphism of UHP rocks are more than 28-40 kbar and

700-860 °C.

The second pre-pilot hole (CCSD-PP2) is located in Maobei of Donghai, where is the main hole site of CCSD. The geothermal survey of the hole indicates that the temperature on the bottom of 5000m main hole will less than 150 °C. The drilled main rock types are paragneiss, schist, eclogite, amphibolite and granitic gneiss.

The study of the Dabie-Sulu UHP metamorphic belt is a great scientific problem with international significance. The specialist advisory group (SAG) of International Continental Drilling Program (ICDP) has given a very high recommendation for the “Dabie-Sulu scientific drilling project proposal”: the primary goal of this project is the reconstruction of the boundary conditions inherent to the formation and exhumation of continental crust. This is considered to be a highly attractive problem of crustal behavior in convergent margin settings. In fact, the Dabie-Sulu Mountains provide outstanding conditions for such kind of study, probably the best in the world.

Fig. 1 The sketch map of Sulu UHP metamorphic belt, showing the site of CCSD main hole.

YXF, Jiashan-Xiangshui Fault; WQYF, Wulian-Yantai Fault.

Fig. 2 Inferred deep structural profile cross the Sulu orogenic belt.

Wulian supracrustal nappe; Jiaonan UHPM nappe; Donghai UHPM thrust slice; Northern HP thrust slice; Southern HP thrust slice; Sulu metamorphic slab; YZB, Yangtze Block; A-A and B-B, the top and bottom boundary of Yangtze Block, representatively; M, Moho.

Fig. 3 Inferred petro-tectonic column of CCSD main hole.