Tectonophysics 475 (2009) 318–326

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Fission track analysis and thermotectonic history of the main borehole of the Chinese Continental Scientific Drilling project

S.S. Liu [a,*], U. Weber [b,c], U.A. Glasmacher [b,c], Z.Q. Xu [d], G.A. Wagner [c]

[a] Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China
[b] Institute of Earth Sciences, Research Group: Thermochronology and Archaeometry, University of Heidelberg, D-69120 Heidelberg, Germany
[c] Max-Planck-Institute of Nuclear Physics, D-69117 Heidelberg, Germany
[d] Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China

ARTICLE INFO

Article history:
Received 24 December 2007
Received in revised form 30 November 2008
Accepted 17 March 2009
Available online 24 March 2009

Keywords:
CCSD
Fission track dating
Thermochronology
Ultrahigh-pressure metamorphic belt
Apatite
Donghai

ABSTRACT

The Chinese Continental Scientific Drilling (CCSD) project, part of the International Continental Drilling Program (ICDP), has completed drilling a 5158 m hole in the eastern part of the Dabie–Sulu ultrahigh-pressure metamorphic belt. This study reports on an apatite fission track analysis of core samples from 0 to 4000 m depth in the CCSD main hole (CCSD-MH). We determined the fission track ages of 38 apatite samples from different depths. The ages range between 98.6 ± 17.0 and 3.2 ± 1.3 Ma, showing a general decreasing trend with depth, from 87.1 ± 11.2 Ma at the surface to 3.2 ± 1.3 Ma at 3899 m depth. As a first approximation, an average uplift rate of ~35 m/Ma is calculated for the period 90–30 Ma. The trend in ages within the borehole shows some fluctuations, and indicates movements along major faults. It is inferred that the highest-level major normal fault occurs at a depth of ~350 m, recording a vertical displacement of ~400 m. Movement along another prominent normal fault at a depth of ~2150 m occurred subsequent to ~25 Ma. Three major reverse faults occur at about 2450, 3050 and 3250 m depth. Testing geological constrains against the fission track data set indicated an agreement with a reheating of the area during the late Cretaceous and Eocene, followed by cooling to ~80 °C during the Eocene and a low cooling until the samples reached their present-day position in the Donghai area.

1. Introduction

The Qinling–Dabie–Sulu (QDS) orogen in East-Central China resulted from the Triassic collision and subduction of the Yangtz Plate beneath the North China Plate (Sino-Korean Plate) (Hacker et al., 1995, 1998; Xu et al., 2003; Li et al., 2005).

The results of previous multidisciplinary investigations indicate that the Dabie–Sulu high-pressure–ultrahigh-pressure (HP–UHP) metamorphic terrain underwent sequential tectonic stages of subduction, exhumation and uplift (Ratschbacher et al., 2000; Xu et al., 2003; Li et al., 2005). A large amount of material from the Yangtz Plate was subducted northwards beneath the North China Plate at 240–220 Ma, underwent periods of rapid exhumation at 220–200 Ma and 180–170 Ma, and was subsequently uplifted. Ultimately the HP–UHP rocks of the Dabie–Sulu orogen became exposed at the surface over a large area (Xu et al., 2003).

Systematic age-dating is required to constrain the exhumation, uplift and tectonic history of the Dabie–Sulu HP–UHP terrain. Fission track analyses of apatite play an important role in studies of the late-stage thermotectonic and uplift history of HP–UHP terranes because of the annealing characteristics of apatite (i.e., track lengths become shorter and ultimately disappear with increasing temperature, Wagner et al., 1992).

Previously, we analyzed the fission tracks within surface samples collected from the Dabie–Sulu HP–UHP metamorphic belt (southern Tan-Lu fault zone). The ages range from ~146.6 Ma to ~31.0 Ma, with most being between 110 and 50 Ma (Chen et al., 1995; Jonckheere et al., 2000; Grimmer et al., 2002). The apatite fission track (AFT) ages of surface outcrop samples from the Sulu HP–UHP metamorphic belt (northern Tan-Lu fault zone) vary between ~97.3 ± 6.0 and ~31.9 ± 1.6 Ma (Hu et al., 2005, Liu, Wagner and Jonckheer, unpublished data). Fission track analyses of borehole samples obtained as part of the Chinese Continental Scientific Drilling (CCSD) project would provide insight into the thermal history, in particular the late-stage uplift history of the Sulu HP–UHP metamorphic body.

2. Geological setting and sample location

The Dabie–Sulu HP–UHP metamorphic belt, the largest belt in the world resulted from the Triassic collision between the Northern China (Sina-Korea) Plate and the Yangtz Plate, with associated subduction of the Yangtz Plate. Most of the HP–UHP rocks within the belt originated from subducted continental crust. The rocks were rapidly subducted down to mantle depths of more than 100 km, then uplifted, denuded, and exhumed over a large area.

* Corresponding author. Tel.: +86 20 85290290; fax: +86 20 85290130.
E-mail address: liuss@gig.ac.cn (S.S. Liu).

0040-1951/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2009.03.015

The belt is cut by a continent-scale strike-slip fault (the Tan-Lu Fault) that separates the Dabie and the Sulu HP–UHP metamorphic belts (see inset map in Fig. 1). The Sulu HP–UHP metamorphic belt consists of the northern UHP metamorphic belt and the southern HP metamorphic belt, and is subdivided into the following units: (1) imbricate stack of sheared high-pressure–low-temperature metamorphic rocks at South Sulu; (2) imbricate stack of sheared high-pressure–mid-temperature metamorphic rocks at South Sulu; (3) imbricate stack of sheared ultrahigh-pressure metamorphic supracrustal rocks at North Sulu; and (4) imbricate stack of sheared ultrahigh-pressure granitic metamorphic rocks at North Sulu.

The CCSD project is based in the southern part of the Sulu UHP metamorphic belt, Donghai County, Jiangsu Province, China (Fig. 1) (Xu et al., 2003). The rocks encountered in the 4000 m core extracted from the CCSD main hole (CCSD-MH) are dominated by eclogite, amphibolite, paragneiss, and orthogneiss, along with thin layers and blocks of ultramafic rocks (Liu et al., 2005).

In the present study, 43 samples were collected at approximately 100 m intervals from the surface down to 4000 m depth (Fig. 2). These samples include all of the main rock types encountered in the borehole. We systematically analyzed apatite from 38 of these samples according to the fission track method. We were unable to obtain reliable data from the remaining five samples because of either limited sample size, small size of apatite grains, or low density of fossil tracks. We determined confined track lengths for 9 of the 38 samples used for AFT dating. We were unable to determine the confined track length for the remaining samples because of a lack of apatite grains and the very low uranium content of the apatite grains in the sample.

3. Experimental procedure

Core samples collected from CCSD-MH were crushed, sieved, and washed. Mineral species were separated using electro-magnetic

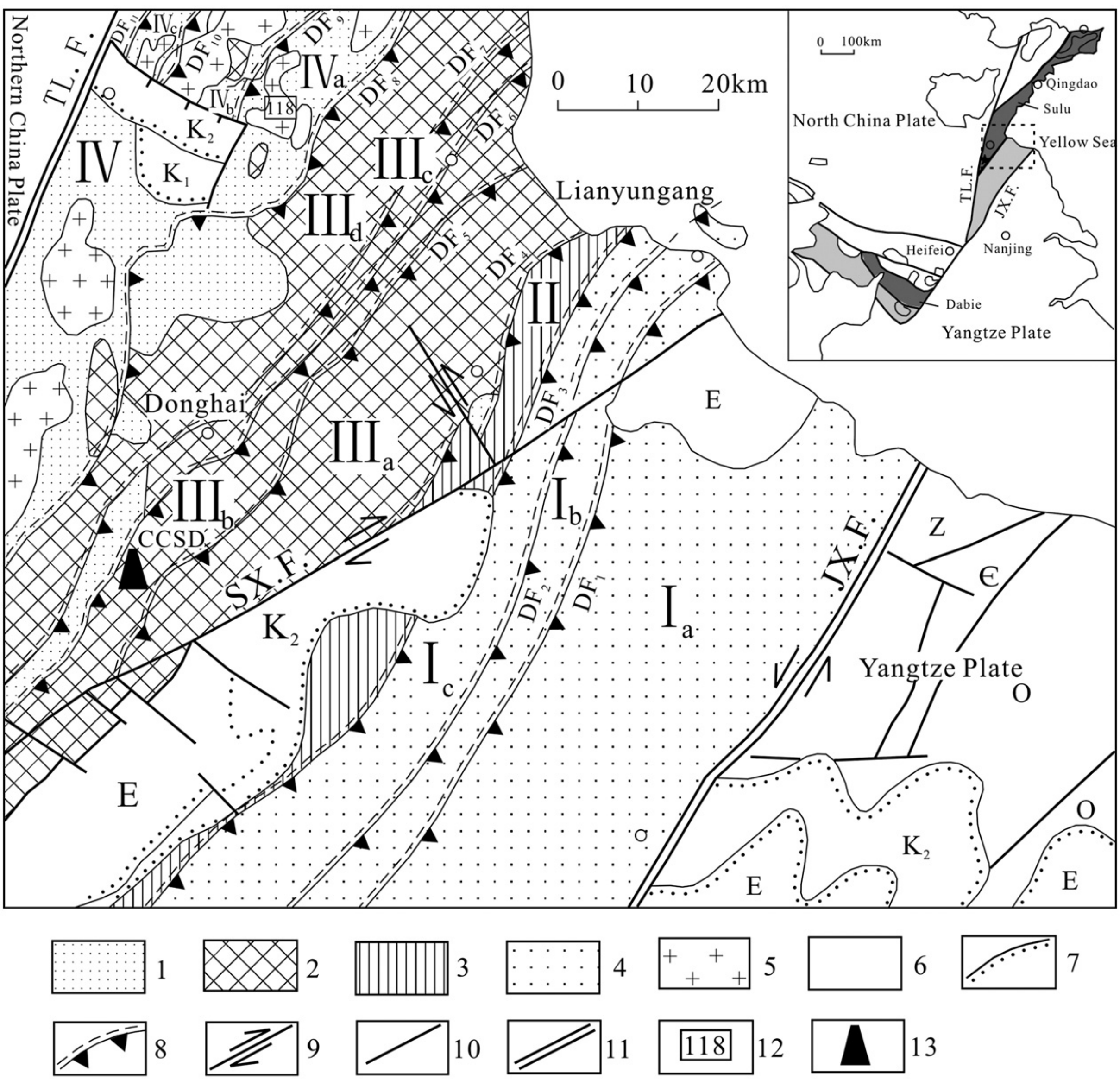

Fig. 1. Structural map of the high-pressure and ultrahigh-pressure metamorphic belt in the Lianyungang area (modified after Xu et al., 2003). 1 — Imbricate stack of sheared ultrahigh-pressure granitic metamorphic rocks at the North Sulu (IV); 2 — imbricate stack of sheared ultrahigh-pressure metamorphic supracrustal rocks at the North Sulu (III); 3 — imbricate stack of sheared high-pressure/mid-temperature metamorphic rocks at the South Sulu (II); 4 — imbricate stack of sheared high-pressure/low-temperature metamorphic rocks at the South Sulu (I); 5 — Mesozoic granite; 6 — stratigraphic unit except HP–UHP metamorphic rock; 7 — angular unconformity; 8 — ductile shear zone (DF1-10); 9 — strike-slip fault; 10 — fault; 11 — lithospheric fault (TL.F. — Tan-Lu fault, JX.F. — Jiashan-Xiangshui fault); 12 — isotopic ages of Mesozoic granite; 13 — CCSD location.