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SHRIMP Dating and Recrystallization of Metamorphic Zircons from a Granitic Gneiss in the Sulu UHP Terrane

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Abstract An unusual zircon SHRIMP dating result of a granitic gneiss from the Qinglongshan eclogite-gneiss roadcut section is presented in this paper. The very peculiar and complicated internal structures, as well as the very low Th/U ratios (0.01–0.08) of the zircons indicate that they were formed by metamorphic recrystallization. Strongly in contrast with previously published zircon U-Pb ages of the Dabie-Sulu UHP metamorphic rocks where protolith ages of 600–800 Ma are commonly recorded, only metamorphic age of 218±5 Ma, defined by 18 analytical spots either in rim or in core of zircons, are recorded in this granitic gneiss. This age represents the time of the complete metamorphic recrystallization overprint on primary magmatic zircons. The recrystallization was derived by the UHP metamorphism, and was strengthened by the early stage of retrograde metamorphic fluid activity.

Key words: recrystallization of zircon, metamorphic fluid, SHRIMP dating, granitic gneiss, Qinglongshan, Sulu, China

1 Introduction

The Dabie-Sulu UHP Terrane is the eastern part of the Qinling-Dabie Orogen, which was formed by the collision between the Sino-Korean and Yangtze cratons. From west to east, it can be subdivided into three tectonic blocks: Hong'an, Dabie and Sulu blocks (Fig. 1). The Dabie-Sulu Terrane contains the most extensive exposure of UHP metamorphic rock in the world, and the UHP metamorphic rocks include eclogites, meta-ultramafic rocks and meta-sedimentary rocks (kyanite quartzite, jadeite quartzite, meta-pelite, marble and paragneiss). The UHP metamorphic rocks are enclosed within widespread regional orthogneisses. The occurrence of coesite inclusions within zircons (Ye et al., 2000; Hu et al., 2001; Liu et al., 2001a) and the presence of index UHP mineral assemblage in the orthogneisses (Carswell et al., 2000) strongly argue for that the orthogneisses have also experienced UHP metamorphism.

The results of geochronological studies in the last decade seem to have established that the continental collision and UHP metamorphism took place at ~220 Ma (Li et al., 1993, 1994, 1999, 2000; Okay and Sengor, 1993; Ames et al., 1993, 1996; Chavagnac and Jahn, 1996; Rowley et al., 1997; Hacker et al., 1998, 2000), and most protoliths of the UHP rocks were formed in the Neoproterozoic, which is supported by most zircon U/Pb upper-intercept ages of 600 to 800 Ma for both eclogites and orthogneisses (Ames et al., 1993, 1996; Rowley et al., 1997; Xue et al., 1997; Hacker et al., 1998, 2000; Chen et al., 2000; Cheng et al., 2000; Chavagnac et al., 2001).

An unusual SHRIMP dating of zircons from a granitic gneiss of the Qinglongshan roadcut section, which only records the Triassic metamorphic age of 218±5 Ma, is presented in this paper. By this case, considering the internal structures and chemical characteristics of the zircons, the author tries to give a reasonable interpretation to the dating result, and to discuss the effect of metamorphic fluid on the zircon U-Pb isotope system.

2 Geological Setting and Sample Description

The Sulu Terrane is bounded by the Wulian-Qingdao-Yantai Fault in the northwest, and the Jiashan-Xiangshui Fault in the south, and can be subdivided into two fault-bounded UHP and HP belts. The Qinglongshan area is located at the southern end of the Sulu UHP Terrane, and is 20 km northeast of the Chinese Continental Scientifical Drilling site (Fig. 1). The eclogites from Qinglongshan have acquired celebrity in their unusual oxygen isotope compositions (Yui et al., 1995; Zheng et al., 1996; 1998; Rumble and Yui, 1998; Rumble et al., 2002). They have recorded the lowest $\delta^{18}O$ value, as low as −11‰, for high temperature metamorphic and magmatic rocks.

A new 800-m roadcut section made by a highway construction in the Qinglongshan area has exposed a large quantity of eclogites, which occur as lenses or discontinuous layers, meters to tens of meters wide, in quartzo-feldspathic gneisses. Eclogites formed SE-dipping layers or large lens and the long axes of the eclogite lenses

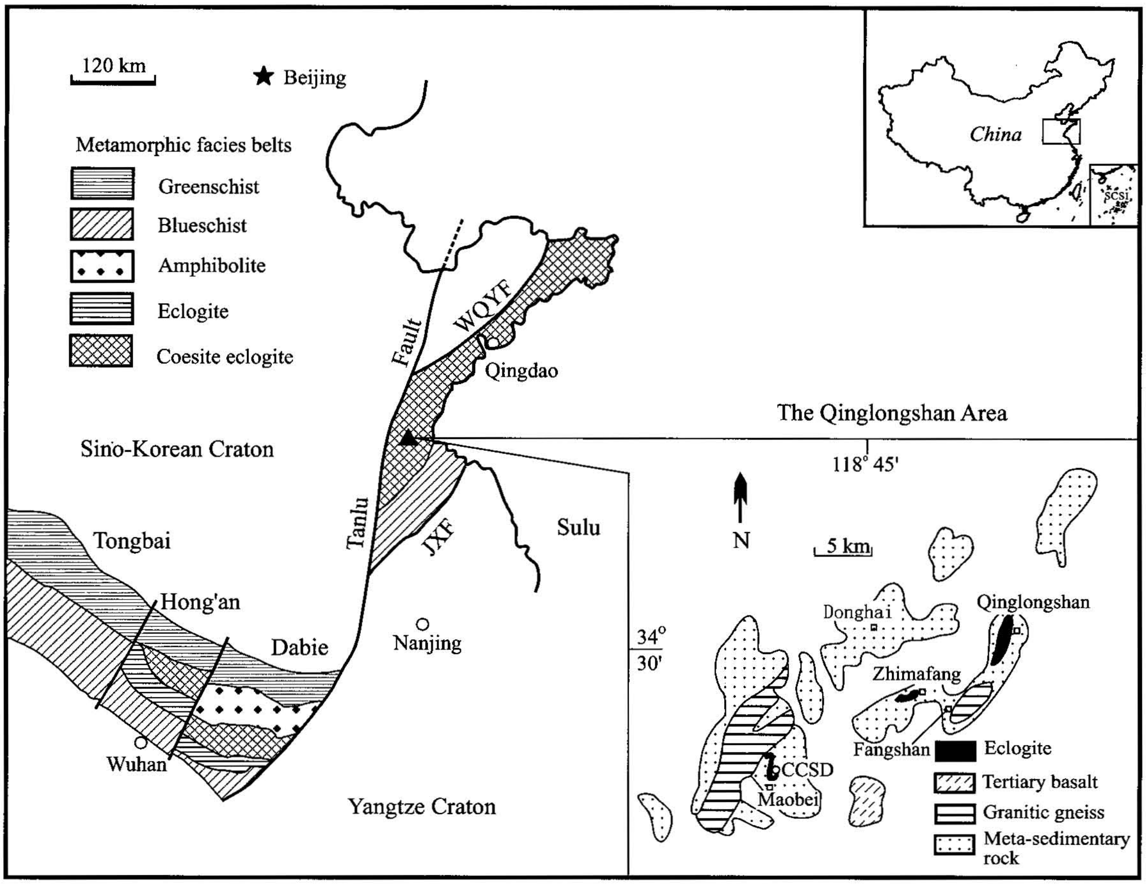

Fig. 1. Simplified geological map of the Sulu UHP Terrane and the Qinglongshan area.
WQYF – Wulian-Qingdao-Yantai Fault; JXF – Jiashan-Xiangshui Fault; CCSD – Chinese Continental Scientifical Drilling

are parallel to the regional schistosity of the gneisses. Except for rare fine-grained pale eclogite, which only records near peak metamorphism, most eclogites also suffered quartz eclogite-facies and amphibolite-facies retrograde metamorphism. The peak metamorphic pressure-temperature condition of these eclogites was estimated as P = 3.0–3.7 GPa and T = 700–770°C (Li, 2003). The quartzo-feldspathic gneisses contain light-colored two mica-two feldspar gneisses and dark-gray-colored biotite-plagioclase gneisses. The two mica-two feldspar gneiss is the main country rock for eclogite, and shows the same geochemical and isotopic characteristics with the regional country granitic gneiss (Li, 2003). In this study, a two mica-two feldspar gneiss sample from the Qinglongshan eclogite-geniess roadcut section was selected for zircon U-Pb dating.

3 Analytical Method

To extract zircons, the granitic gneiss sample was crushed and sieved to less than 250 μm. Light and heavy mineral fractions were separated using a floatation technique in water and alcohol media. Heavy minerals were further separated using a Frantz Isodynamic Magnetic Separator. Non-magnetic fraction, which contains zircons, was then further separated from lighter minerals in a heavy liquid with a density of 3.3 g/cm^3. Zircon grains were finally purified by hand pick under a microscope. The procedure of the preparation of zircon was carried out in Universitė de Rennes 1 of France.

Zircon grains and some chips of standard zircons SL13 and TEM were embedded in epoxy and polished down to half sections. The zircon mount was used for cathodoluminescence (CL) imaging and SHRIMP isotope analyses. The CL imaging was performed on a HITACHI S2250-N scanning electron microscope at the Electron Microscope Unit, Australian National University. The mount was coated with 100 nm of gold before it was set into the sample chamber. The selection of zircons for analyses was done on the basis of the CL images.

Zircons were analyzed for U, Th and Pb using the sensitive high-resolution ion microprobe (SHRIMP II) at the Beijing SHRIMP Center. Using 12 nA as the primary ion beam, zircon surface was first rastered for 2 minutes to remove the Au coating and any surface contamination, then a 25 μm pit in diameter (about 2–3 μm deep) was excavated into the zircon, resulting in a liberation of the minimum sample that was sent as positive secondary ions to the mass spectrometer. Data for each spot were collected in sets of five scans throughout the masses, at a mass resolution of about 5500. The sensitivity was 21 cps per ppm on the standard SL13 (age=572.1 Ma). The measured $^{206}Pb/^{238}U$ ratios of the zircon samples were corrected by SL13 and TEM. Reference zircon TEM (age = 417 Ma) was analyzed after every cycle of two or three sample analyses. The data were treated following SQUID 1.02 (Ludwig, 2001) and plotted on a U-Pb concordia diagram. The errors of the single analytical data are given with 1σ. The mean ages are weighted means at 95% confidence level and 2σ error. The decay constants for ^{238}U is 0.155125 Ga^{-1} and for ^{235}U 0.98485 Ga^{-1}.

4 Morphology and Internal Structure of Zircon

Zircons from the Qinglongshan Granitic Gneiss (CF99-01) show euhedral, subhedral and anhedral shapes, and the first two types are predominant (Fig. 2). They are red, pink, yellow and transparent or translucent. Some twin zircon crystals (e.g. grain No. 8 in Fig. 2) can be found. Their grain sizes range from 150 to 300 μm in length, with length/width ratios of 1–3:1.

Their cathodoluminescence images (Fig. 2) show that the zircons generally consist of a rim with faint oscillatory zoning or no zoning and a core with very complicated internal structures, which display unzoned structure with different chemical composition domains (e.g. grain No. 1, 6 and 8), contorted zoning structure (e.g. grain No. 3, 4) and irregular patch structure (e.g. grain No. 2 and 5). So peculiar internal structures of zircons have not been reported in the Dabie-Sulu Orogen. The thickness of the

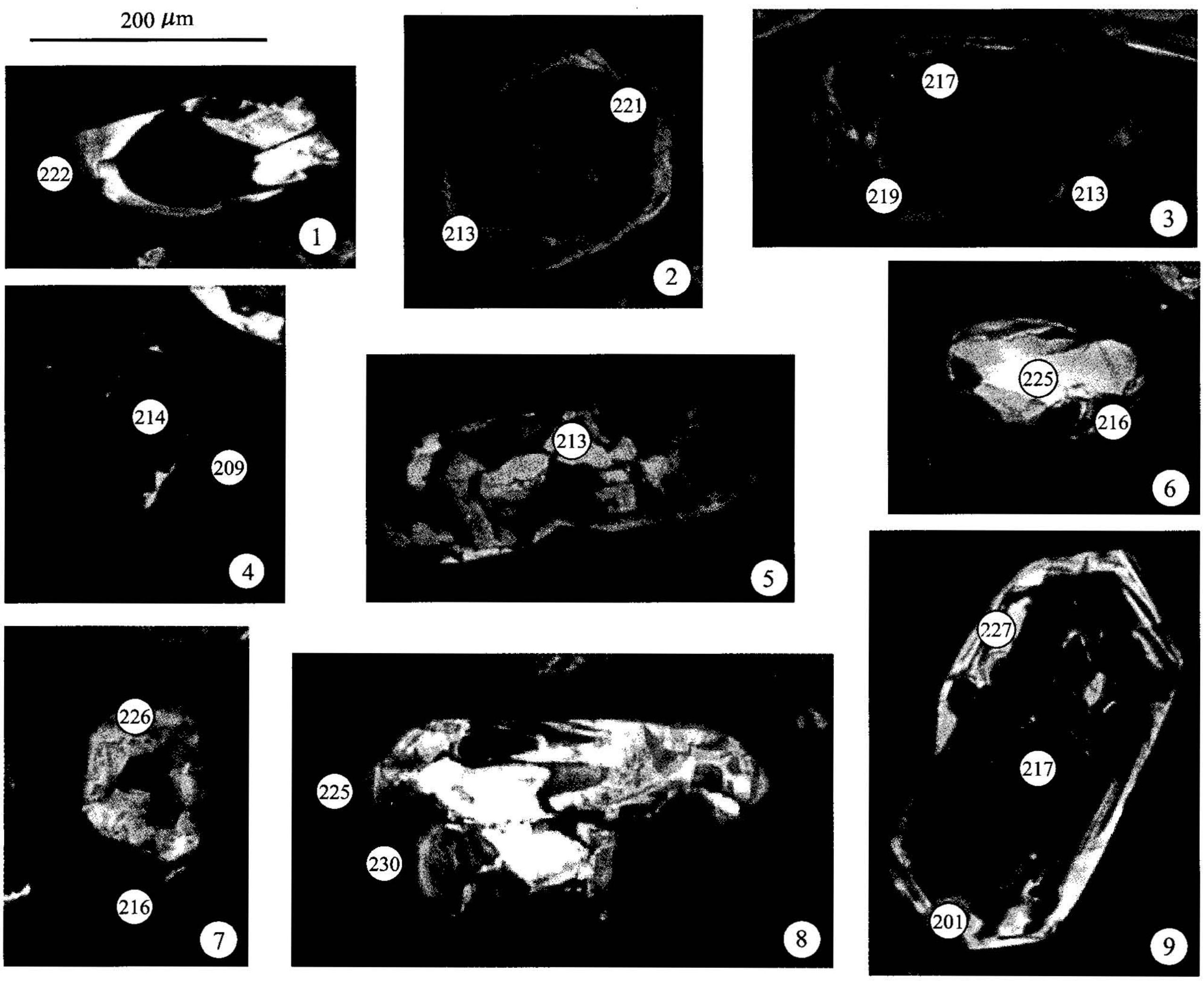

Fig. 2. CL images of zircons from Qinglongshan Granitic Gneiss CF99-01.

rims is less than 50 μm.

Oscillatory zonings, which are represented by growth bands with variable concentrations of trace elements, such as U, Th and REE, are generally considered as typical characteristics of magmatic zircons. Some faint oscillatory zones can be observed in the core and rim of zircon grain No. 9, and they are parallel for each other. Thus, this suggests that these oscillatory zones, either in the core or in the rim, were formed at the same time. However, some unzoned areas can also be found in the core and the rim of this zircon grain, and they interpenetrate into the faint oscillatory zones. In other zircon grains, their original oscillatory zonings are also coarsened and faint, or replaced by unzoned area. These are typical internal structures of zircons formed by metamorphic recrystallization.

The contorted zoning structure and irregular patch structure are peculiar and are different from any primary structures. Similar structures were observed in the zircons from Archean granite from the Darling Range batholith in southwestern Australia. Pidgeon et al. (1998) gave a model to interpret the formation of the peculiar structures. Strong metamorphic recrystallization overprint on primary magmatic zircon is the key of this model. A mechanism that involves reaction between zircon and an external hydrous fluid was emphasized, in which fluid can cause strong recrystallization of original magmatic zircon and loss of some trace elements.

5 SHRIMP Analytical Result

The U/Pb SHRIMP data of zircons from Qinglongshan Granitic Gneiss CF99-01 are listed in Table 1 and are displayed in a U-Pb concordia diagram (Fig. 3). Eighteen analytical spots are located in either rims or cores of 9 zircon grains. The U content of the zircons range from 51 to 974 ppm, and Th abundance from 1 to 26 ppm. Their Th/U ratios are characterized by low values of 0.01–0.08, and no difference can be identified in the Th/U ratios of the rims and the cores.

The Th/U ratio of zircon has been considered as an index for the genesis of zircon (e.g. Williams and Claesson, 1987; Williams et al., 1996; Vavra et al., 1996, 1999; Chen et al., 2001; Liu et al., 2003). Compared with magmatic zircon, metamorphic zircon not only shows no oscillatory zoning but also has lower and relatively dispersed Th/U ratios. In the Dabie-Sulu Orogen, the Th/U ratios of magmatic and metamorphic zircons are generally 0.5–1.5 and < 0.1–0.2, respectively (Harcker et al., 1998; Xue et al., 1997; Rowley et al., 1997). Thus, the Th/U ratios of the zircons from CF99-01 also indicate the zircon genesis of metamorphism.

Eighteen analytical spots gave apparent $^{206}Pb/^{238}U$ ages from 201 to 230 Ma, with a weighted mean age of 218±5

Table 1 SHRIMP analytical data of zircons from Qinglongshan Granitic Gneiss CF99-01

Spot Name	Location	U (ppm)	Th (ppm)	Th/U	Common ^{206}Pb(%)	Apparent age (Ma)			$^{207}Pb/^{206}Pb$	±	$^{207}Pb/^{235}U$	±	$^{206}Pb/^{238}U$	±
						$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{232}Th$						
CF99-01-01A	rim	725	12	0.02	-0.39	222 ± 10	338 ± 64	546 ± 130	.0532	2.8	0.26	5.4	.0350	4.6
CF99-01-02A	rim	250	8	0.03	0.21	213 ± 10	203 ± 92	206 ± 88	.0502	4.0	0.23	6.1	.0336	4.7
CF99-01-03A	rim	437	8	0.02	-0.36	213 ± 10	343 ± 61	481 ± 123	.0533	2.7	0.25	5.3	.0336	4.6
CF99-01-04A	core	225	3	0.01	-0.50	217 ± 10	360 ± 90	780 ± 256	.0537	4.0	0.25	6.1	.0343	4.6
CF99-01-05A	rim	342	6	0.02	-0.34	219 ± 10	353 ± 42	573 ± 67	.0536	1.9	0.26	5.0	.0346	4.6
CF99-01-06A	core	353	26	0.08	0.13	221 ± 10	217 ± 78	216 ± 36	.0505	3.4	0.24	5.7	.0348	4.6
CF99-01-07A	rim	759	12	0.02	-0.02	209 ± 9	156 ± 30	232 ± 19	.0492	1.3	0.22	4.7	.0329	4.6
CF99-01-08A	core	362	6	0.02	0.54	214 ± 10	33 ± 158		.0467	6.6	0.22	8.0	.0337	4.6
CF99-01-09A	core	58	1	0.03	-0.33	213 ± 10	411 ± 96	638 ± 93	.0550	4.3	0.25	6.4	.0335	4.7
CF99-01-10A	rim	170	3	0.02	-0.87	201 ± 9	531 ± 115	979 ± 331	.0580	5.2	0.25	7.0	.0317	4.6
CF99-01-11A	rim	461	8	0.02	-0.22	216 ± 10	385 ± 52	402 ± 71	.0543	2.3	0.26	5.1	.0341	4.6
CF99-01-12A	core	72	7	0.10	-1.19	226 ± 11	606 ± 149	375 ± 77	.0601	6.9	0.30	8.4	.0357	4.9
CF99-01-13A	rim	115	4	0.03	0.85	227 ± 10	656 ± 133	803 ± 184	.0615	6.2	0.30	7.7	.0359	4.6
CF99-01-14A	core	387	9	0.02	-0.37	217 ± 10	468 ± 41	388 ± 45	.0564	1.9	0.27	4.9	.0343	4.6
CF99-01-15A	rim	974	23	0.02	0.01	225 ± 10	227 ± 31	208 ± 27	.0507	1.3	0.25	4.7	.0356	4.5
CF99-01-16A	rim	963	24	0.03	0.04	230 ± 10	216 ± 30	207 ± 21	.0505	1.3	0.25	4.7	.0363	4.6
CF99-01-17A	rim	188	3	0.02	-0.08	216 ± 10	246 ± 59	373 ± 54	.0511	2.6	0.24	5.2	.0340	4.6
CF99-01-18A	core	51	1	0.03	-1.05	225 ± 11	542 ± 100	1006±177	.0583	4.6	0.29	6.6	.0355	4.8

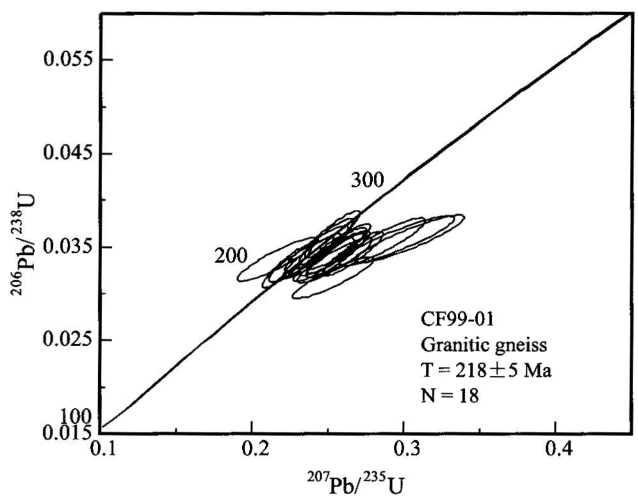

Fig. 3. U-Pb concordia diagram for the zircons from Qinglongshan Granitic Gneiss CF99-01.

Ma (Fig. 3). They are concordant or slightly discordant ages, and the rims and the cores of the zircons gave uniform ages. This is strongly in contrast with previously published zircon U-Pb ages of the Dabie-Sulu UHP metamorphic rocks. The results of geochronological studies in the last decade have shown that zircon U-Pb lower intercept ages are from 202 to 238 Ma, which indicates that the continental collision and UHP metamorphism took place at ~220 Ma; most zircon U-Pb upper intercept ages for both eclogites and granitic gneisses range from 600 to 800 Ma, particularly ~770 Ma, which suggests that most protoliths of the UHP metamorphic rocks were formed in Neoproterozoic (Ames et al., 1993, 1996; Rowley et al., 1997; Xue et al., 1997; Hacker et al., 1998, 2000; Chen et al., 2000; Cheng et al., 2000; Chavagnac et al., 2001). Thus, it is obviously uncommon that only Triassic ages are recorded in this Granitic Gneiss CF99-01.

6 Discussion

6.1 Complete metamorphic recrystallization of the primary magmatic zircon

The scarcity or absence of syn-collisional magmatic rocks has been considered as one of the most remarkable features of the Dabie-Sulu Orogen (e.g. Jahn, 1998; Chen, et al. 2002). However, some syn-collisional or collision-related magmatic rocks were also sporadically reported in this orogen (Liu et al., 2001b; Zhang et al., 2001; Chen et al., 2002). The Shidao K-rich complex in the eastern extremity of the Sulu UHP Terrane is composed of pyroxene syenite, quartz syenite and granite, whose zircon U-Pb ages are 225±2 Ma, 211±3 Ma and 205±5 Ma, respectively (Chen et al., 2002). Two zircon U-Pb ages of 234±4 Ma and 227±5 Ma for two foliated garnet-bearing granites in the western Dabie UHP Terrane were reported by Zhang et al. (2001). The granitic gravels sampled in the Hefei Basin also gave 214 Ma zircon U-Pb age (Liu et al., 2001b). Up to now, it has been controversial whether there exists syn-collisional magmatism in the Dabie-Sulu Orogen. In this study, the analytical spots on the rim with faint oscillatory zoning, or on the core with unzoned structure, or on the core with irregular patch structure, or on the core with contorted zoning structure, all give ~ 220 Ma concordant or slightly discordant ages. What is the geological significance of the age of 218±5 Ma of the Qinglongshan Granitic Gneiss? Does it represent the syn-collisional magmatic event?

The UHP metamorphism in the Donghai area was dated at ~220 Ma by multiple isotope systems. Garnet, omphacite, phengite from a Qinglongshan eclogite and the whole rock defined a Sm-Nd isochron age of 226±5 Ma, and a Rb-Sr isochron age of 219±2 Ma (Li et al., 1994). A zircon U-Pb dating of a Qinglongshan eclogite shows a similar metamorphic age of 217±9 Ma and an inferred protolith age of 762±28 Ma (Ames et al., 1996). Concordant $^{238}U/^{206}Pb$ ages of zircons from Fangshan and Hushan metagranites are 684 to 754 Ma in zircon cores and 221 Ma at zircon rims, whilst the discordant $^{238}U/^{206}Pb$ ages range from 242 to 632 Ma (Xu et al., 2001; Rumble et al., 2002). Five U-Pb analyses of zircons from a UHP granitic gneiss of Qinglongshan give metamorphic age of 218±16 Ma and protolith age of 702±130 Ma (Zheng et al., 2003). These age data suggest that the protoliths of eclogites, granitic gneisses and metagranites in the Donghai area were formed in the Neoproterozoic. The regional geological survey of the Donghai area shows that the Fangshan and Hushan metagranites show gradual contact relationship with regional granitic gneisses (Xu et al., 2001). Except for their different structures, Qinglongshan Granitic Gneiss CF99-01 and the Fangshan metagranite show the same geochemical and isotopic characteristics (Li, 2003). In other words, their protoliths should come from the same magma source. But, why the protoliths age of Neoproterozoic in Granitic Gneiss CF99-01 is absent?

In this study, the peculiar internal structures: contorted zoning and irregular patch structures of the zircons, together with their very low Th/U ratios, strongly suggest that the zircons of Qinglongshan Granitic Gneiss CF99-01 were formed by metamorphic recrystallization. Recrystallization is considered as an important mechanism for the formation of metamorphic zircons (Black et al., 1986; Pidgeon, 1992; Friend and Kinny, 1995; Vavra et al., 1996; Fraser et al., 1997; Pan, 1997; Bowring and Williams, 1999; Hoskin and Black, 2000). Generally, metamorphic recrystallization at low temperatures (≤500°C) can create a disequilibrium in certain isotopic systems, such as Sm-Nd and Rb-Sr, and result in some discordant ages. These phenomena have been well documented for many cases of the Alpine eclogites (Luais et al., 2001) and Hong'an eclogites (Jahn and Liu, 2002).

During recrystallization, the loss of Pb is accompanied by the loss of U, Th, and the recrystallized unzoned zircon is extremely stable with respect to later Pb loss, thus the recrystallized zircons tend to retain a concordant or slightly discordant U-Pb age (Pidgeon, 1992; Nemchin and Pidgeon, 1997; Pidgeon et al., 1998; Hoskin and Black, 2000). This is evidently different from other models for the formation of metamorphic zircons, which mainly involve a leaching of radiogenic Pb rather than mobilization of U and Th and induce discordant ages. Recrystallization includes partial recrystallization and complete recrystallization. Partial recrystallization is frequently observed, and it cannot completely reset the U-Pb isotopic composition of the protolith zircons, so it can partially leave some "memory" of the previous trace element and isotopic features. An isotope analysis on such an area will yield a mixed age, which is older than the recrystallization event and younger than the protolith age. However, in the completely recrystallized zircon, all radiogenic Pb is lost, thus the zircon will show a concordant age that dates the recrystallization event. Therefore, the 18 concordant or near concordant ages of the zircons from Qinglongshan Granitic Gneiss CF99-01 could be interpreted as a complete recrystallization event.

Oscillatory zoning is the feature of magmatic zircon, and is represented by growth bands with variable concentrations of trace elements, such as U, Th and REE (Vavra, 1990; Pidgeon, 1992; Hanchar and Miller, 1993). At the early stage of recrystallization or weak recrystallization process, primary oscillatory zonings are coarsened and faint, and replaced by some unzoned domains. During a strong or complete recrystallization process, trace elements of zircon can migrate from the outer primary oscillatory zones and concentrate as irregular patches, curved bands at the center of the zircon. The irregular patches and curved bands can cut cross primary zoning. The very complicated internal structures, such as irregular patch and contorted zoning structures, are observed in the studied Granitic Gneiss CF99-01, thus they also indicate a complete recrystallization that overprinted on the primary magmatic zircons.

Magmatic zircons have high Th/U ratios, generally > 0.5 (Vavra et al., 1996, 1999). Completely recrystallized zircons have low Th/U ratios of 0.1 or less, while partially recrystallized zircons show medium values between completely recrystallized zircons and magmatic zircons. Th is less compatible than U in the zircon lattice due to its larger radius, so, a different degree of expulsion for Th and U can be found in the recrystallization of protolith zircon. The very low Th/U ratios of 0.01–0.08 of the zircons from CF99-01 are also consistent with the origin of a complete recrystallization.

6.2 Effect of metamorphic fluid on the zircon U-Pb isotope system

Complete recrystallization (complete Pb loss) is rare, and is limited to a few cases involved with fluid activity. Pidgeon et al. (1998) suggested that reaction between zircon and an external hydrous fluid could intensify the recrystallization of zircon. Rubatto et al. (1999) and Liati et al. (2000) also argued that the metamorphic recrystallization of zircon and resetting of its U-Th-Pb systematics may be strongly promoted by fluids and can occur at moderate temperatures of < 600°C.

In the last decade, low H_2O activity during the UHP metamorphism has been considered as one of the most remarkable features of the Dabie-Sulu Orogen. This is supported by many lines of evidence, such as, the occurrence of intergranular coesite and progressive mineral transformation from gabbro to coesite eclogite in the Yangkou eclogite (Liou and Zhang, 1996; Zhang and Liou, 1997), preservation of primary igneous and sedimentary structures in the Ganghe UHP block (Dong et al., 2002; Oberhänsli et al., 2002). However, the occurrence of coesite and/or coesite pseudomorphy in hydrous UHP minerals, such as epidote, zoisite and phengite (Liou and Zhang, 1995; Zhang et al., 1995; Zhang and Liou, 1996), suggests the presence of water in UHP rocks. The occurrence of zoisite-kyanite-paragonite quartz veins of 220 Ma defined by rutile U-Pb dating in the Zhujiachong eclogite block (Castelli et al., 1998; Franz et al., 2001) indicates that fluid activity is inneglectable during the exhumation and retrograde metamorphism in some localities. Up to date, the scale of metamorphic fluid and its effect during the exhumation of subducted crustal rocks have not been well understood.

In the Qinglongshan eclogite-gneiss roadcut section, some muscovite quartz veins and zoisite-kyanite-paragonite quartz veins or nodules were observed in the eclogites and the country gneisses. The muscovite quartz veins are generally several cm in thickness, and the zoisite-kyanite-paragonite quartz nodules are several cm to ~ 20 cm in size. They are characterized by the formation of coarse-grained mineral phases. The recent studies of the author (unpublished data) indicate that the peak metamorphism of the eclogite from the Qinglongshan roadcut section occurred at 223±8 Ma, which is defined by a Sm-Nd isochron age of garnet, omphacite, phengite and whole rock. The zoisite-kyanite-paragonite quartz veins and muscovite quartz veins enclosed in the eclogites were formed at 226–215 Ma, which were defined by Rb-Sr mica-whole rock isochron ages. The petrological, geochemical and isotopic studies for the eclogites and veins argue that the Qinglongshan eclogites suffered a coesite eclogite-facies peak metamorphism, and subsequent quartz eclogite-facies and amphibolite-facies retrograde metamorphism. The zoisite-kyanite-paragonite quartz veins and muscovite quartz veins were formed in the early stage of the retrograde metamorphism, which equilibrated at the quartz eclogite-facies metamorphic condition.

As described above, hydrous fluid activities during the retrograde metamorphism of the UHP rocks in the Qinglongshan area are evident. The complete recrystallization and complete reset of zircon U-Pb isotope system in Granitic Gneiss CF99-01 might be related to the retrograde metamorphic fluid events. In other words, the Triassic age of 218 Ma recorded in Granitic Gneiss CF99-01 should represent the time of a complete Pb loss event, i.e. a retrograde metamorphic fluid event, rather than a syn-collisional magmatic event.

7 Conclusions

(1) Zircons of a granitic gneiss from the Qinglongshan eclogite-gneiss roadcut section show euhedral-subhedral external shapes and very complicated internal structures: faint oscillatory zoning in the rims, whilst unzoned, irregular patch and contorted zoning structures in the cores.

(2) The Th/U ratios of the zircons are very low, of 0.01–0.08. The very low Th/U ratios and very complicated internal structures of the zircons might be interpreted as a complete metamorphic recrystallization that overprinted primary magmatic zircons.

(3) Zircon SHRIMP dating results of 18 analytical spots either in the rims or in the cores show that only a Triassic metamorphic age of 218±5 Ma are recorded in the granitic gneiss. The absence of a Neoproterozoic protolith age in this rock is strongly in contrast with previously published zircon U-Pb ages of the Dabie-Sulu UHP metamorphic rocks.

(4) The complete recrystallization recorded in the granitic gneiss was derived by the Triassic UHP metamorphism, and was strengthened by the early stage of retrograde metamorphic fluid activity. The SHRIMP U-Pb age of 218±5 Ma of the granitic gneiss might represent the time of a complete Pb loss event, i.e. the early stage of the retrograde metamorphic fluid event.

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