FLUIDS RELEASED FROM EXHUMING "DRY" ECLOGITES, DABIE SHAN, CHINA

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Summary

Quartz-veins, ranging from mm to dm in width, developed in eclogites from the Dabie-Shan, China. These veins cut across eclogitic foliation at outcrop-scale and peak pressure metamorphic minerals (garnet, omphacite) at thin-section-scale, implying they formed during exhumation.

The vein compositions depend on their host rocks. Quartz (Qz)-veins with kyanite (Ky) and anthophyllite (Anth) developed in Jinhe coesite-bearing eclogite that contains talc (Tc) in addition to omphacite and pyrope (Py)-rich garnet, and with kyanite and zoisite (Zo) talc in Zhujiachong and Hualiangting eclogites that were lawsonite-bearing. These veins developed at depth of >50 km and T around 800°C according to our P-T calculations.

The similarity in O-isotope between quartz-veins ($\delta^{18}O$ = -2.6-+2.2) and their host eclogite ($\delta^{18}O$ = -2.8 - +1.6) suggests the vein-forming fluids were derived from the host eclogite. Possible reactions to release fluids include: Tc + Ky = Py + 2 Qz + H_2O, 7 Tc = 3 Anth + Qz + 4 H_2O, and 8 Lw + Py = Tc + 3 Ky + 4 Zo + 13 H_2O. A release of H_2O due to P-decrease and additional T-increase is the result of all these reactions.

It is proposed that hydrous fluids are derived in-situ from exhuming "dry" eclogite as an alternative or competitive process to the H_2O influx from external sources. If sufficient water would be released, syn-exhumation partial melts could develop in "dry" roots of a collision orogen such as the Dabie-Shan.

Introdution

Eclogite occurs extensively in the southern section of the Dabie Shan, China. These eclogite has experienced Ultrahigh-pressure (UHP) or high-pressure (HP) metamorphism. The UHP eclogite was called as hot one because its metamorphic temperature is higher than 750°C in addition to its very high pressure (>2.8 GPa). The HP eclogite was called as cold one for its low temperature (<700°C) and low pressure (1.8-2.6 GPa).

Quartz veins, ranging from mm to dm in width, developed in both hot and cold eclogites from the Dabie Shan. Recently, such veins were considered to have formed before the peak pressure metamorphism of eclogite facies (Castelli *et al.*, 1998; Jiang *et al.*, 1998). However, our study supports the alternative possibility, that these veins formed after the peak pressure metamorphism but before the amphibolite facies retrograde metamorphism.

Occurrence of the high-pressure veins

The veins staudied in both hot eclogite and cold eclogite from the southern section of the Dabie Shan cut across eclogitic foliation at outcrop scale and peak pressure metamorphic minerals such as garnet and omphacite at thin-section scale. For examples, quartz veins with anthophyllite and kyanite invaded the coesite-bearing Jinhe eclogite and those with Kyanite and zoisite filled the fractures in the Zhujiachong cold eclogite. Thees occurrences already imply the formation of these veins later than the peak pressure metamorphism.

Composition of veins and their host rocks

The vein compositions depend on their host rocks. For example, the Jinhe hot eclogite, that is cut by quartz veins with anthophyllite and kyanite, is composed of garnet, omphacite, phengite, as well as coesite and talc.

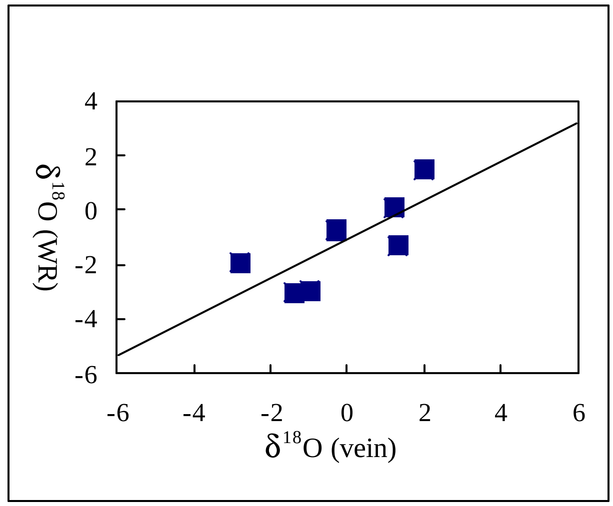

Fig.1 Positive correlation between $\delta^{18}O$ of quartz in veins and that of eclogite whole rock (WR) according to data from Li (1999).

While the Zhujiachong and Hualiangting cold eclogite, that is cut by quartz veins with kyanite + zoisite ± talc, are composed of garnet, omphacite, quartz, paragonite and glaucophane, as well as lawsonite that has been replaced by zoisite.

Oxygen isotope investigations (Li, 1999) indicate that $\delta^{18}O$ of quartz in veins ($\delta^{18}O$= -2.6 – 2.2 ‰) is lower than that of quartz ($\delta^{18}O$= 2.4 – 4.4 ‰) in their host eclogite, and positively correlated to whole rock ($\delta^{18}O$= -2.8 –1.6 ‰) of the host eclogite (Fig. 1). Therefore, it is suggested that the vein-forming fluids were derived from the host eclogite.

P-T conditions of vein formtation

Three generations of mineral assemblage have been recognized in the Jinhe hot eclogite. Stage I is characterized by coesite + garnet + omphacite + phengite + talc. Garnet shows zoning patterns, with pyrope component decreasing from core to rim. Garnet + plagioclase + amphibole + biotite + epidote is typical for stage II. Stage III is characterized by biotite and chlorite.

As mentioned above, fine veins filling fractures that cut the Jinhe eclogite contain quartz, anthophyllite, and kyanite. Anthophyllite is a phase stable in a narrow P-T field that is limited towards high temperatures by 3 Anth + 7 Ky = 7 Pyr +10 Qz + 3 H_2O (curve 9 of Fig. 2), and towards low temperatures by 2 Pyr + 5 Tc = 2 Ky + 3 Anth + 2 H_2O (curve 7 of Fig. 2). In the case of mineral compositions of the Jinhe eclogite, the corresponding two reaction curves intersect near 1.7 GPa and 800 °C (Fig.2) according to our thermodynamic calculations. Therefore, anthophyllite and kyanite in the quartz vein could form either through temperature decrease reaction curve 9 or temperature increase reaction curve 7. In the case of Zhujiachong cold eclogite, kyanite and talc in quartz veins could form through temperature increase reaction: 8 Lw + Py = Tc + 3 Ky + 4 Zo + 13 H_2O (curve 4 of Fig. 2).

In order to determine the temperature change during the vein-forming reactions, mineral compositions were determined with CAMECA SX50 electron microprobe on rocks thin-sections (Table 1). In addition, element distribution maps especially for gartnet (Mg, Fe, Ca) were prepared applying the technique of Bernhardt *et al.* (1995). Based on these studies, the metamorphic P-T paths of the host eclogites were calculated using the Ge0-Calc software package of Brown *et al.* (1988) and the set of thermodynamic data of Berman (1988),augmented by data of Massonne (1995) and Massonne and Spzurka (1997). As a result of these calculations, the P-T path of the Jinhe hot eclogite shows a T-increase section for stage II (Fig. 2), similar to that of the Zhujiachong cold eclogite (Wang *et al.*, 1998), followed by temperature decrease at almost isobaric conditions. Thus, anthophyllite and kyanite in the quartz vein form through the temperature decrease reaction curve 9. On the other hand, the quartz vein with kyanite and talc in the Zhujiachong cold eclogite is believed to have formed through reaction curve 4 either dominated by temperature increase or pressure release.

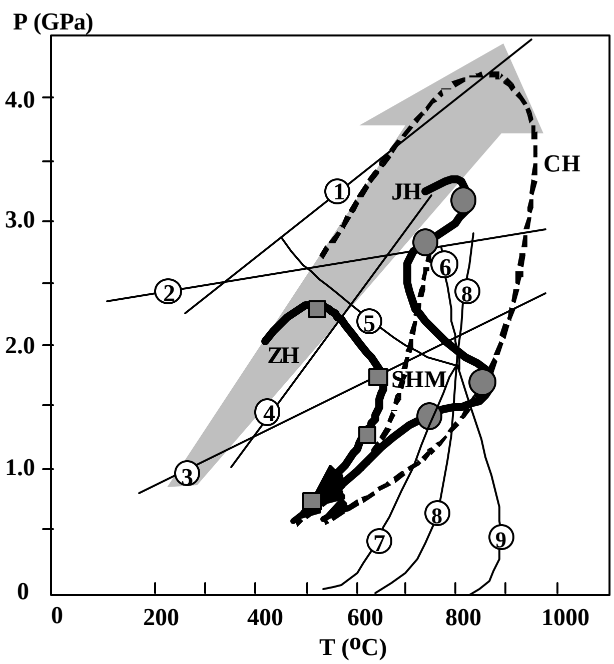

Fig. 2. P-T paths of the Jinhe hot eclogite (JH) and the Zhujiachong cold eclogite (ZH), with filled circles and squares marking the calculated data sets. Previous published P-T paths (Xu *et al.*, 1992; Li *et al.*, 1993) from Changpu (CH) and Shima (SHM) are also shown. Reaction curves are (low pressure side assemblages on the left side in reactions 1, 2, and 3; while low temperature side assemblages on the left side in the other reactions): 1 – graphite = diamond; 2 – quartz = coesite; 3 – albite = jadeite + quartz; 4 – 8 Lw + Pyr = Tc + 3 Ky + 4 Zo +13 H_2O; 5 – 3 Anth + 4 Ky = 3 Tc + 4 Qz + 4 Pyr; 6 - Tc + Ky = Pyr + 2 Qz + H_2O; 7 - 2 Pyr + 5 Tc = 2 Ky + 3 Anth + 2 H_2O; 8 - 7Tc = 3 Anth + 4 Qz/Coe + 4 H_2O; 9 - 3 Anth + 7 Ky = 10 Qz + 7 Pyr + 3 H_2O. Subduction path is shown by the freckled arrow.

Table 1 Mineral compositions of the Jinhe hot eclogite

	Garnet			
	core	mantle	rim	
point No.	11274 /17	11274 /36	11274 /20	11274 /35
SiO_2	38.88	38.30	38.57	38.79
TiO_2	0.05	0.04	0.05	0.05
Al_2O_3	22.64	22.28	22.18	22.39
Cr_2O_3	0.03	0.03	0.04	0.00
MgO	9.86	8.35	8.25	8.36
FeO	20.30	20.89	20.75	20.57
MnO	0.46	0.55	0.57	0.45
CaO	7.76	8.80	9.15	9.10
Na_2O	0.03	0.03	0.04	0.02
K_2O	0.00	0.00	0.00	0.00
Sum	100.01	99.27	99.60	99.73

Minerals	omphacite		phengite	
point No.	11273 /37	11273 /34	11275 /1	11275 /5
SiO_2	56.69	56.12	50.61	49.67
TiO_2	0.06	0.06	0.25	0.26
Al_2O_3	12	12.09	27.39	27.29
Cr_2O_3	0.04	0.01	0.06	0.12
MgO	7.79	8.01	3.56	3.43
FeO	3.61	3.41	1.76	1.79
MnO	0.02	0.04	0.08	0.04
CaO	12.02	12.28	0	0
Na_2O	7.83	7.51	0.75	0.53
K_2O	0	0	10.19	10.44
Sum	100.06	99.53	94.65	93.57

Minerals	biotite	Amphi -bole	Plagioclase	
point No.	11275 /15	11273 /39	11275 /19	11275 /20
SiO_2	34.85	37.87	62.55	64.46
TiO_2	0.36	0.02	0.04	0.01
Al_2O_3	20.86	19.58	22.51	21.23
Cr_2O_3	0	0.05	0.06	0
MgO	14.84	9.72	0	0
FeO	12.31	14.13	0.73	0.3
MnO	0	0.11	0.11	0
CaO	0	11.11	3.74	2.52
Na_2O	0.07	3.40	9.64	10.35
K_2O	9.94	0.67	0.17	0.11
Sum	93.23	96.66	99.55	98.98

An implication of our findings is that the quartz veins formed during the exhumation paths of the eclogite. The vein forming mechanism might be related to the fluids released from the exhuming eclogite. Lawsonite, phengite, and epidote are all hydroxyl-bearing minerals that remain stable under ultrahigh-pressure conditions, under which even nominally anhydrous minerals like clinopyroxene and garnet could contain considerable amounts of water. However, when they are transported upwards from great depths, water could be released from the "dry" eclogite due to mineral reactions. This thus generated fluid phase could act as a medium for multiple cyclical transport of material that is idssolved from eclogites as well as other HP rocks and precipitated in veins and fractures.

Conclusions

1. Both Jinhe hot eclogite and Zhujiachong cold eclogite experienced a pressure decrease and temperature increase metamorphic event, when the quartz veins with garnet, kyanite, and anthophyllite formed.
2. The hydrous fluids are derived in-situ from exhuming "dry" eclogites as an alternative or competitive process to the H_2O influx from external sources. If sufficient water would be released, syn-exhumation partial melts could be developed in "dry" roots of a collision orogen such as the Dabie Shan.

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