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QUARTZ-ECOLGITE IN SHUANGHE AREA OF THE DABIE MOUNTAINS: HOT OR COLD ?

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Abstract

Quartz-eclogite blocks were discovered in Shuanghe area of the Dabie Mountains, which belongs to the so-called hot eclogite terrain. The peak metamorphic assemblage of the eclogites is garnet + omphacite + phengite + kyanite + rutile + quartz. Their *P-T* conditions are estimated as *P*=2.0 GPa and *T*=700°C by using garnet-omphacite-phengite barometer and garnet-omphacite thermometer. Tectonically, the contrast in peak metamorphic temperatures is more significant. Therefore, the quartz-eclogite in Shuanghe could also be considered as "hot" eclogite, although it experienced no UHP metamorphism.

1. Introduction

A southward decrease in peak metamorphic temperature within the Dabie eclogite zone has long been recognized (Wang and Liou, 1991). Okay (1993) subdivided it into a northern "hot" and a southern "cold" eclogite terrain, with boundary running roughly along the south bank of the Hualiangting reservoir. The hot eclogite terrain is characterized by higher-temperature eclogites and marble-eclogite association, while the cold eclogite terrain by coesite-free eclogite and sodic amphibole-bearing eclogite. This subdivision was supported by Carswell et al. (1997), who preferred to term them the Central Dabie UHP eclogite-bearing terrain and the Southern Dabie HP eclogite-bearing terrain. However, during a systematic sampling study, we have found coesite-free quartz-eclogite in Shuanghe area (Fig. 1), which is located in the northern hot eclogite terrain of Okay, or the Central Dabie UHP eclogite-bearing terrain of Carswell et al.. In the present paper, we will describe the petrography and estimate the peak metamorphic P-T condition of the unique eclogite member from Shuanghe.

2. Field Occurrence and Petrography

Shuanghe village is located at the southwest of Qianshan County, Anhui Province (Fig. 1). The sudied area is only hundreds of meters to south of the UHP slab mapped by Cong et al. (1995). Eclogitic blocks of meter-scale occur in the epidote-mica schist, which is surrounded by granitic gneiss. Foliation developed in the schist wraps the mechanically competent eclogite blocks, as showing a block-in-matrix structure. Two kinds of eclogite blocks have been recognized based on the petrological study, with one being UHP eclogite and the other HP eclgoite (Liu, 1998).

The UHP eclogites, represented by sample LXD21, are similar to those in the northern UHP slab described by Cong et al. (1995). They are characterized by peak metamorphic assemblage of Grt + Phen + Omp + Rt $\pm$ Qtz/Coe, as well as retrograde assemblage of Cpx + Hbl + Pl + Ap + Bi + Qtz + Ilm and Pl + Hbl+ Ep + Spn + Bi + Qtz.

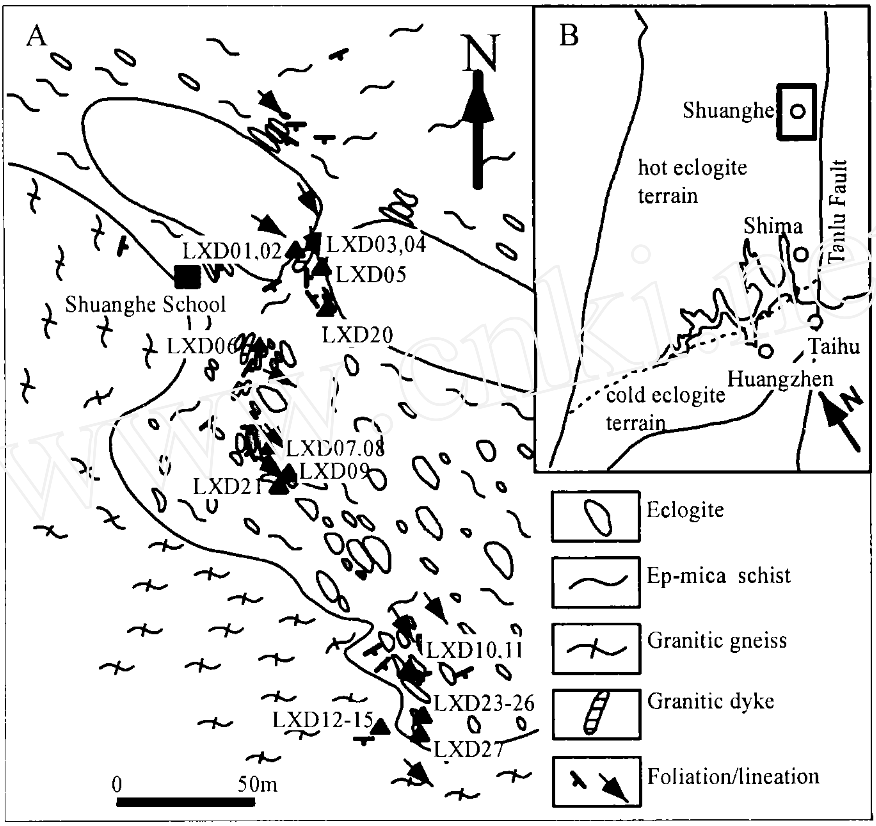

Fig.1 Geological map in Shuanghe area

The HP eclogites, represented by sample LXD23, are medium-grained, and contain garnet, omphacite, phengite, rutile, sphene, kyanite, amphibole, paragonite, and quartz. No coesite or its pseudomorph has been found. Garnet, occurring as large porphyroblast, is the most abundant phase in the eclogite. Most of the garnet grains range from 0.6 to 2.5 mm in diameter and show good zonation (Fig. 2) with pyrope component decreasing from core (X_{Mg}=0.40) to rim (X_{Mg}=0.26). Inclusions of omphacite, paragonite, and apatite in the core bring garnet an atoll shape. The garnet grains are always surrounded by corona composed of green amphibole + epidote + albite. Omphacite is the second abundant phase. It occur either as large grains in matrix, or as inclusions in garnet. Some omphacite grains have partially replaced by symplectite of diopside and albite.

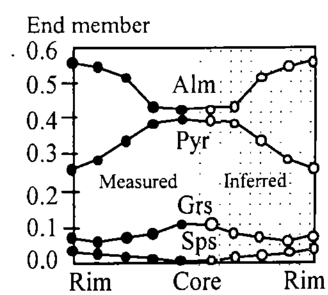

Fig. 2 Compositional profile of garnet (LXD21)

TABLE 1 Representative microprobe analyses of minerals from eclogite LXD23

	Grt (core)	Grt (rim)		Omp (core)		Phen (core)	Phen(rim)		Hbl		Pl
SiO2	38.714	37.391		56.215		51.794	48.625		39.421		63.311
TiO2	0.084	0.081		0.026		0.431	0.446		0.494		0.050
Al2O3	21.888	21.317		8.988		27.353	29.082		19.318		22.447
Cr2O3	0.000	0.000		0.028		0.018	0.043		0.007		0.000
MgO	10.202	6.471		10.415		3.726	3.246		11.617		0.006
FeO	21.645	27.153		3.022		1.292	1.379		10.742		0.012
MnO	0.378	1.425		0.111		0.009	0.000		0.066		0.000
CaO	6.435	5.196		15.055		0.000	0.000		10.262		3.998
BaO	0.000	0.000		0.000		0.001	0.000		0.000		0.000
Na2O	0.008	0.029		5.909		0.354	0.880		4.176		9.186
K2O	0.000	0.012		0.000		10.715	9.323		0.154		0.067
TOTAL	99.354	99.075		99.769		95.693	93.024		96.257		99.077
	8 Ox	8 Ox		4 Cat		11 Ox	11 Ox		23 Ox		8 Ox
Si(T)	2.947	2.939	Si(T)	1.997	Si(T)	3.443	3.296	Si(T)	5.763	Si	2.820
AlIV	0.053	0.061	AlIV(T)	0.003	Al(T)	0.557	0.704	Al(T)	2.237	Al	1.178
AlVI	1.910	1.914	AlVI(M1)	0.374	ΣT	4.000	4.000	ΣT	8.000	Ti	0.002
Ti	0.005	0.005	Ti(M1)	0.007	Fe3+	0.000	0.000	Alo	1.092	Cr	0.000
Cr	0.000	0.000	Cr(M1)	0.008	Fe2+	0.071	0.078	Fe3+	0.609	Mg	0.000
Fe3+	0.135	0.143	Fe3+(M1)	0.034	Alo	1.568	1.612	Cr	0.054	Fe	0.000
Fe2+	1.242	1.642	Mg(M1+M2)	0.552	Ti	0.021	0.023	Ti	0.001	Mn	0.000
Mg	1.158	0.758	Fe(M1+M2)	0.056	Cr	0.001	0.002	Mg	2.532	Ca	0.191
Mn	0.024	0.095	Mn(M2)	0.003	Mn	0.001	0.000	Fe2+	0.704	Ba	0.000
Ca	0.525	0.468	Ca(M2)	0.573	Mg	0.366	0.327	Mn	0.008	Na	0.793
Ba	0.000	0.000	Ba(M2)	0.000	ΣM	2.029	2.042	ΣM1-3	5.000	K	0.004
Na	0.001	0.004	Na(M2)	0.407	Ca	0.000	0.000	Ca	1.607	Sum	4.988
K	0.000	0.001	K(M2)	0.000	Na	0.045	0.115	NaM4	0.393		
Sum	8.000	8.000	Sum	4.014	K	0.901	0.804	ΣM4	2.000		
					Ba	0.000	0.000	NaA	0.791		
					ΣA	0.946	0.919	K	0.029		
								ΣA	0.820		
Grs	0.1096	0.0776	Dio	0.5155	Mus	0.4586	0.5131	X1(-Tr-)	0.8036	An	0.1931
Pyr	0.3925	0.2586	Hed	0.0522	Trioct	0.0287	0.0418	X2(-Gl-)	0.1261	Ab	0.8030
Alm	0.4213	0.5599	Jad	0.3717	Mg-Al-Cel	0.3709	0.2389	X3(-Mri-)	0.0703	Or	0.0039
Sps	0.0083	0.0323	Opx	0.0199	Fe-Al-Cel	0.0721	0.0569				
X(Al)	0.9549	0.9570	Cats	0.0020	Pg	0.0478	0.1255				
			rest	0.0387	rest	0.0219	0.0238				

Phengite, usually showing a composition zone, is concentrated in matrix. Rutile occurs either in matrix or as inclusions in garnet and omphacite. The rutile close to garnet is always rimmed by sphene. Kyanite co-exists with garnet, omphacite, phengite and rutile. Its retrograde products include margarite + quartz and paragonite. Paragonite occurs either as inclusion in garnet, or as large flake mounting omphacite and garnet, as well as retrograde corona surrounding kyanite.

At least three metamorphic stages could be recognized. Their peak metamorphic assemblage is Grt + Phen + Omp + Ky + Rt + Qtz, and retrograde assemblages are Cpx + Pg + Phen + Hbl + Pl + Qtz + Spn/Ilm and Pl + Hbl + Ep + Bi + Mr-g + Qtz.

3. Mineral Chemistry and *P*-*T* Paths

Mineral compositions (Table 1) were analyzed at analytical conditions of 15 KV acceleration voltage and 20 nA current using microprobe (CAMECA SX51) in the Laboratory of Lithosphere Tectonic Evolution, Institute of Geology, Chinese Academy of Sciences.

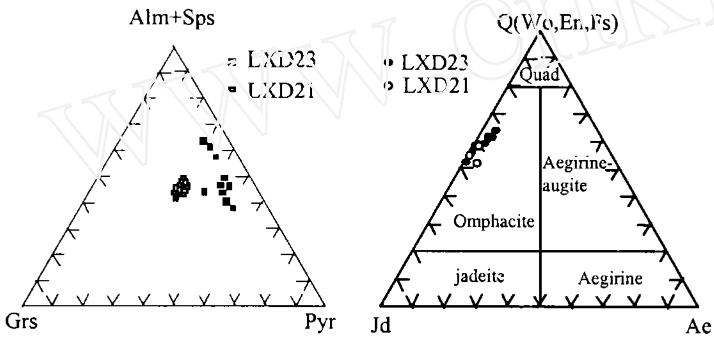

Fig. 3 Compositional variation of garnets (A) and omphacites (B)

The garnet in the LXD23 is characterized by zonation with pyrope end-member decrease from core to rim (Fig. 2) and low content of grossular ranging from 0.07 to 0.17 (Fig. 3). The Jadeite content of omphacite in the studied eclogite (LXD23) is lower than that in the nearby UHP eclogite (LXD21), with the former being 0.31-0.45 and the later being 0.43-0.60 (Fig. 4). The Si content in the phengite is about 3.3-3.5 p.f.u. (O=11). Other representative mineral composites are shown in Table 1.

The peak metamorphism *P*-*T* could be calculated by using garnet-omphacite-phengite barometer and garnet-omphacite thermometer. In the K_2O-CaO-MgO-FeO-Al_2O_3-SiO_2-H_2O system, absolute pressures for stability of the peak assemblage could be calculated through reaction equilibriums (Fig. 4):

3 Al-Cel + 2 Grs + Pyr = 3 Mus + 6 Dio,
Alm + 3 Al-Cel + 2 Grs = 3 Mus + 3 Hed + 3 Dio, and
2 Alm + 3 Al-Cel + 2 Grs = Pyr + 3 Mus + 6 Hed.

The temperatures could be calculated through reaction equilibrium (Fig. 4):

3 Dio + Alm = 3 Hed + Pyr.

The peak metamorphic *P*-*T* conditions are calculated using the Ge0-Calc software package of Brown et al. (1988). The thermodynamic data source for the calculations was given by Massonne (1992, 1997). The calculations yield P = 2.0 GPa and T = 700°C from the quartz-eclogite (LXD23) and P = 3.9 GPa and T = 750°C from one nearby eclogite block (LXD21) (Fig. 5). On the other hand, the peak metamorphic pressure of the epidote-mica

schist as matrix of the eclogitic blocks was estimated as $P > 2.2$ GPa at $T = 700°C$, based on mineral assemblage of Rut + Grs + Coe/Qtz +Sph +Czo (Liu, 1998).
The retrograde *P-T* conditions were estimated as $P = 0.8$ GPa and $T = 650°C$, based on the following reactions in the Na_2O-CaO-MgO- Al_2O_3-SiO_2-H_2O system:

11 Grs +10 Pyr + 27 Qtz + 6 H_2O = 6 Tr + 21 An,
7 Grs + 3 Pg + 5 Pyr +18 Qtz = 3 Tr + 15 An +2 Ab,
2 Grs + 5 Pyr + 7 Ab + 3 Qtz + 10 H_2O = 3 Tr + 7 Pg, and
Grs + 5 Pyr + 3 An + 9 Ab + 12 H_2O = 3 Tr + 9 Pg.

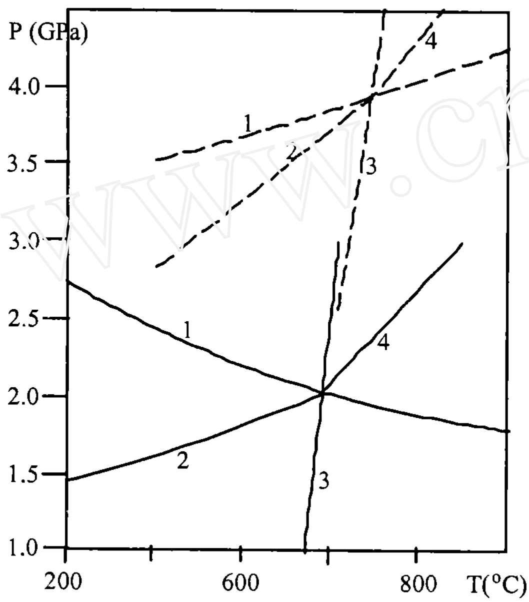

Fig. 4 P-T diagram showing peak metamorphic condition of the eclogites LXD23 (solid lines) and LXD21 (dash lines)

1. 3Al-Cel + 2Gr + Py = 3Ms + 6Di
2. Alm + 3Al-Cel + 2Gr = 3Ms + 3Hed + 3I
3. 3Di + Alm = 3Hed + Py
4. 2Alm + 3Al-Cel + 2Gr = Py + 3Ms + 6H(

On the other hand, the retrograde of kyanite to margarite + quartz and paragonite indicate the following reactions:

5 Ky + 2 Zoi + 3 H_2O = 4 Mrg + 3 Qtz,
2 Ky + 2 Zoi + 3 Pg = 4 Mrg + 2 Ab, and
Ab + Ky + H_2O = Pg + Qtz.

In the Na_2O-CaO-Al_2O_3-SiO_2-H_2O system the calculations of these retrograde *P-T* conditions yield $P = 0.8$ GPa and $T = 670°C$, which are quite close to the estimation in the Na_2O-CaO-MgO- Al_2O_3-SiO_2-H_2O system mentioned above.
The summary of the above *P-T* estimations gives a clockwise and isothermal decompression path for the quartz-eclogite in Shuanghe (Fig. 5).

4. Discussion and Conclusion

The first temperature-based subdivision of eclogite facies was put forward by Banno (1970) and emphasized by Caswell (1990). Their three-fold classification put 550°C as boundary between low temperature (LT) and medium temperature (MT) eclogites, and 900°C between MT and high temperature (HT) eclogites. These subdivisions have an advantage that they broadly correlate with eclogite formation in three fundamentally different geological environments. The LT eclogites are associated to blueschist developed in oceanic subduction zones. The MT eclogites are stable in tectonically thickened continental crust in continent-continent collision zones. The HT eclogites are characterized by xenolithic assemblages in the upper mantle. Obviously, the LT, MT, and HT eclogites have a meaning different from Okay's "hot" and "cold" eclogites mentioned above.

The "cold" eclogites, as a descriptive term appeared first in study of the Dora Maira eclogite terrain (Chopin et al., 1991). It was invented to denote a coesite-free eclogite unit, which yielded peak metamorphic temperature as about 500°C, in contrast to 700°C in the nearby coesite-bearing eclogite unit. Okay (1993) followed the usage in study of the Dabie eclogite terrain, and added another term "hot" eclogites to describe the nearby coesite-bearing unit. In fact, the two units subdivided by Okay (1993) and Carswell et al. (1997) differ not only in their peak metamorphic temperature (800±50°C in the northern unit and 635±40°C in the southern one), but also in their peak metamorphic pressure (>3.8 GPa in the northern unit and 1.8-2.6 GPa in the southern one).

The quartz-eclogite studied in the present paper, however, is characterized by high temperature (700 °C) and low pressure (2.0 GPa) peak metamorphic conditions. It differs either in peak temperature from the coesite-free eclogite to the south, or in peak pressure from the nearby coesite-bearing eclogite on the north. Should we call it as "hot" or "cold" eclogites? No pigeonhole fits it, if considering only the peak metamorphic temperature and pressure. However, we prefer to call it as the "hot" eclogite, when taking into account of the garnet zonation that indicates a homogenization at high peak temperature and modification in the later retrogradation. As shown in another paper in the same volume (Wang et al., 1998), when the deep-subducted "hot" coesite-bearing unit exhumed, the "cold" coesite-free unit could be heated. This indicates that the contrast in their peak metamorphic temperatures might be more tectonically significant.

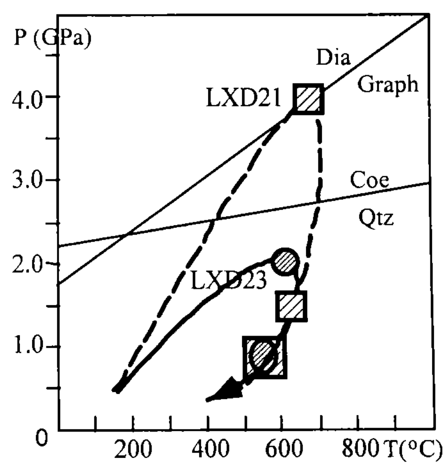

Fig. 5 P-T paths of the eclogites LXD23 and LXD21

The Shuanghe eclogites and other UHP rocks have been considered as the tectonic melange formed when supracrustal rocks subducted down to mantle depth (Cong et al., 1995; Wang et al., 1997, 1998). The special melange is characterized not only by composition variation either in their protolith (Cong et al., 1995) or in their oxygen isotope (Zheng et al., 1997), but also by block-in-matrix structure and peak pressure contrast between different eclogite blocks, as shown by the present study. Such a melange nature implies that not all of the rocks in the coesite-bearing unit were subducted down to the same depth. Some might stumble halfway and join into a upward flow, as a block turning its way in the corner flow (Cloos, 1982). In such a case, the "in situ" contact between eclogites and their UHP or HP country rocks only denotes that they all subducted down to great depth. However, it does not mean that they were metamorphosed side by side. They might be separated far from each other in an extensive UHP environment, and mixed together as "foreign" blocks during exhumation.

Acknowledgments

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