

# Coesite from Mengzhong eclogite at Donghai county, northeastern Jiangsu province, China

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## Abstract

Coesite has been found as an inclusion in garnet from the Mengzhong eclogite in Donghai county, northeastern Jiangsu province, eastern China. The host eclogite occurs closely associated with regionally developed gneiss and was formed under  $P$ - $T$  conditions of about 810°C and more than 28 kbar.

**KEYWORDS:** coesite, eclogite, garnet, gneiss, Jiangsu, China.

## Introduction

COESITE has been found in crustal metamorphic rocks of the eclogite facies in two areas in Europe; garnet-quartzite in the Western Alps (Chopin, 1984) and dolomite-eclogite in Norway (Smith, 1984). Recently, coesite pseudomorphs have been reported from several places in eastern and central China (Yang and Smith, 1989; Enami and Zang, 1990; Zhiqin, 1987) and finally coesite has also been found in deep crustal rocks in central China (Okay *et al.*, 1989; Wang *et al.*, 1989). In this paper, we report the fifth documented occurrence of coesite from a crustal eclogite in eastern China.

## Geological setting and petrography

The coesite eclogite occurs at Mengzhong in Donghai county, Jiangsu province, eastern China (Fig. 1). Donghai county is situated to the east of the Tancheng-Lujiang (Tanlu) fracture zone and north of the Jiashan-Xianshui fracture zone, between the Sino-Korean craton and the Yangtze craton (Tectonic Map Compiling Group, 1974; Ma and Zhang, 1988; Liu *et al.*, 1989). Almost all eclogites in this county were found in the Donghai (or Jiaonan) Group, whose protolith was formed in the early Proterozoic as indicated by the U-Pb concordia age of zircons from the Jiaonan Group (2233 Ma) and a bulk rock Rb-Sr isochron age of diorite intrusion (1855 Ma) (Wang, 1986). The Donghai Group mainly consists of various kinds of migmatitic and gneissic rocks with minor amounts of marble, quartzite,

amphibolite and schist. The coesite-bearing Mengzhong eclogite occurs as lenses ranging from several decimeters to several metres in thickness intercalated with granitic gneiss of the Donghai Group.

The coesite eclogite consists mainly of garnet and omphacite, along with phengite, quartz and rutile. The garnet and omphacite crystals are 1–5 mm in diameter across, and phengite occurs as large flakes, commonly up to 5 mm across. Quartz in the matrix occurs as polygonal crystals (1–2 mm in diameter). The garnet and omphacite include rutile, phengite, paragonite and K-feldspar along with two types of SiO<sub>2</sub> inclusions; one is fine-aggregate quartz, both polycrystalline and multicrystalline quartz in the sense of Smith (1984), and the other, though only one example has been found so far, is a quartz-coesite aggregate in garnet (E88D-1). Both types of SiO<sub>2</sub> inclusions are associated with cracks radiating from them. These microstructures have been considered to be characteristic of coesite inclusions in garnet and omphacite (Smith, 1988). Figs. 3a and b show the radial cracks developed around the multicrystalline quartz after coesite in omphacite and garnet, respectively. Fig. 3c is a photomicrograph of the quartz-coesite aggregate associated with radial cracks in garnet, and Fig. 3d is the corresponding backscattered electron image. Electron-microprobe analysis shows only SiO<sub>2</sub> in the aggregate shown in Figs. 3c and d, and its central part is occupied by a cleaved phase with higher polishing hardness than the surrounding quartz. Under the microscope, the cleaved

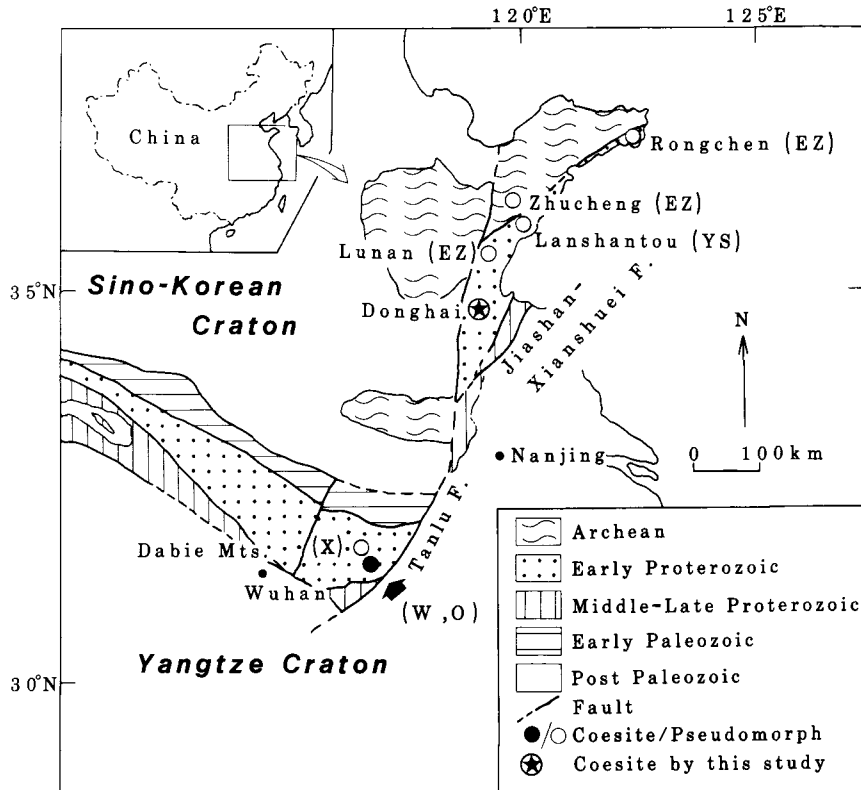


FIG. 1. Tectonic map of central and eastern China with localities of coesite and its pseudomorph. EZ: Enami and Zang (1990), YS: Yang and Smith (1989), O: Okay *et al.* (1989), W: Wang *et al.* (1989).

phase has higher refractive indices than the other, and on a U-stage the optic axial plane is normal to the cleavage with  $2V_Z > 60^\circ$ . According to Smyth and Hatton (1977), coesite has (010) and (012) apparent cleavages and Sclar *et al.* (1962) reported  $b = X$  and  $2V_Z = 64^\circ$  for synthetic coesite. Our observations lead us to conclude that the cleaved phase is coesite.

#### Mineralogy of the coesite-eclogite

Representative chemical analyses of the main constituent minerals of the coesite-bearing eclogite are shown in Table 1. Chemical analyses were done by an electron-probe microanalyser (Hitachi S550) with an energy-dispersive X-ray analytical system (KeveX 8000 + KeveX Quantum detector) at Kyoto University, following the procedures of Mori and Kanehira (1984).

Garnet is only slightly heterogeneous with Fe decreasing and Ca increasing from core ( $grs_{0.30} alm_{0.43} py_{0.27}$ ) to rim ( $grs_{0.33} alm_{0.40} py_{0.27}$ ). Omphacite has a chemical variation between

$jd_{0.58} di_{0.40} acm_{0.02}$  and  $jd_{0.47} di_{0.46} acm_{0.07}$ . Garnet and omphacite are free from Cr. The Fe-Mg partitioning between garnet and omphacite is  $K_D = 8.0-9.3$  around an omphacite inclusion and  $K_D = 7.5-7.7$  for the rim-rim pair. Temperature estimation (Powell, 1985) and the existence of coesite (Mirwald and Massonne, 1980) give temperatures of  $810^\circ\text{C}$  and pressures  $> 28$  kbar at the rim and  $740-780^\circ\text{C}$  and  $> 25$  kbar for the closure of the partitioning at the core. Phengite inclusions in garnet have  $Si = 3.5$ , while in the matrix they have  $Si = 3.6$  on an  $O = 11$  basis. Paragonite + quartz inclusions and K-feldspar + quartz inclusions are found in omphacite and garnet, respectively. They are of almost pure end-member composition. Green amphibole growing along grain boundaries between garnet and clinopyroxene is ferroan-pargasite (Leake, 1978). Chopin (1987) found a paragonite crystal included in garnet of a coesite-bearing metapelite in the Western Alps and concluded that it survived the overstepping pressure at the maximum stage as a prograde relic. Due to the greater relative compressibility

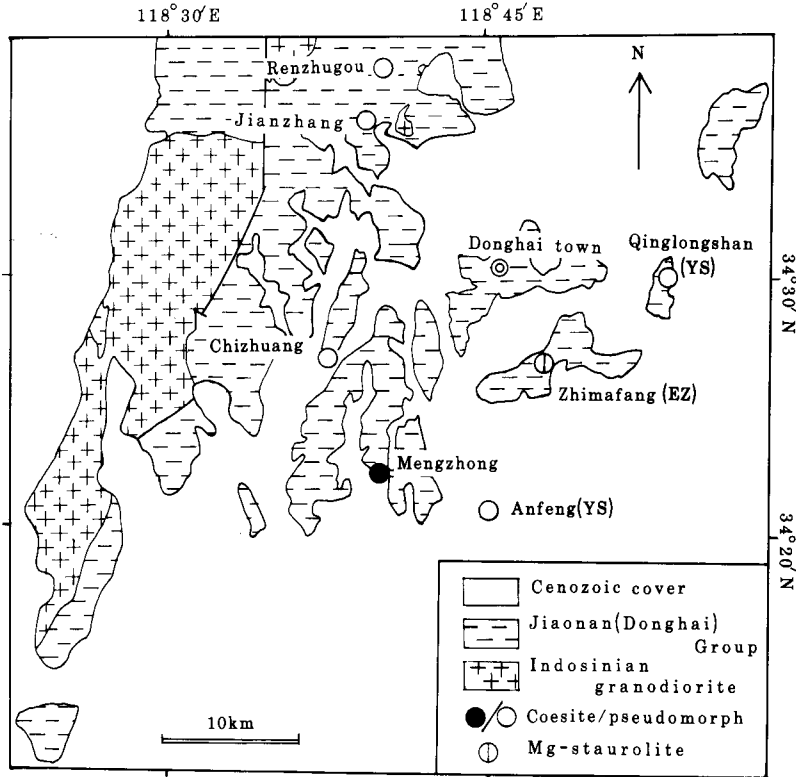


Fig. 2. Geologic sketch map of the Donghai district, Jiangsu province, with localities of coesite and its pseudomorph by Yang and Smith (1989) (YS) and this study. The locality of magnesian staurolite by Enami and Zang (1988) (EZ) is also shown.

of the mica compound compared to garnet, this allows the internal pressure of the inclusion to be less than the pressure applied on the garnet by the matrix. These observations may suggest that the prograde growth of zoned garnet has taken place under a very low geothermal gradient.

### Geological implication

Fig 2. compiles the known localities of coesite pseudomorph (Yang and Smith, 1989) and of magnesian staurolite (Enami and Zang, 1988) in Donghai county, along with the new localities of coesite and its pseudomorph in this study. Although coesite was found in only one sample, its pseudomorph was found at almost all eclogite localities in this county. The temperature estimate for the coesite eclogite in this study is similar to those of Shandong province (Yang and Smith, 1989; Enami and Zang, 1990) (Fig. 1), but slightly higher than that of Dabie Mountains, in Anhui province (750°C, Okay *et al.*, 1989;

600–710°C, Wang *et al.*, 1989). The wide occurrence of coesite or its pseudomorph, and the similar  $P$ – $T$  conditions for coesite eclogite in the Shandong and Jiangsu province may support the ‘Su-Lu coesite–eclogite province’ proposed by Yang and Smith (1989). However, Enami *et al.* (1986) gave 700–760°C and 11–30 kbar as maximum  $P$ – $T$  conditions for eclogites closely associated with serpentinite at Mengzhong, where we found the coesite eclogite intercalated within regional granitic gneiss. They also gave 610–620°C and 10–13 kbar as maximum  $P$ – $T$  conditions for eclogites closely associated with regional gneisses from another outcrop in Donghai county. This suggests that the thermodynamic environment and tectonic history of eclogite may be variable and complicated even in the restricted part of ‘Su-Lu coesite–eclogite province’.

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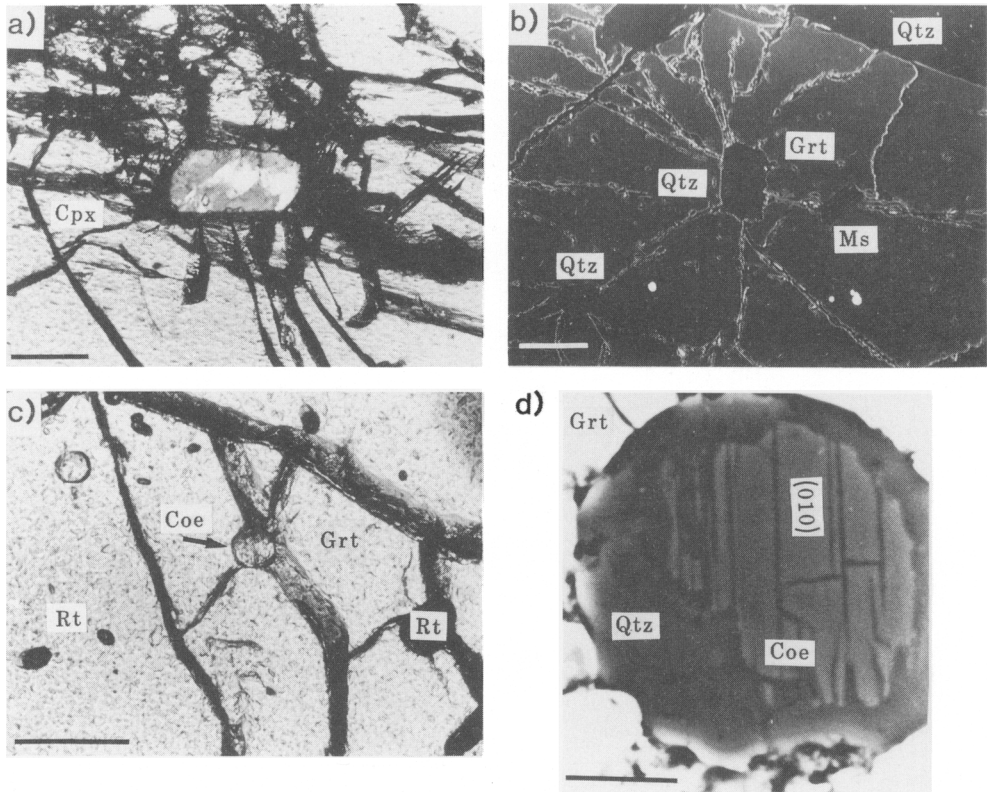


FIG. 3. Photomicrographs (*a* and *c*) and backscattered electron images (*b* and *d*) of coesite and coesite pseudomorph. Scale bars indicate 100  $\mu\text{m}$  for *a*, *b* and *c*, and 10  $\mu\text{m}$  for *d*. (*a*) Multicrystalline quartz aggregate after coesite in clinopyroxene (Cpx). Crossed nicols with test plate. (*b*) Quartz (Qtz) and phengite (Ms) inclusions in garnet (Grt). Radial cracks are developed around the quartz inclusion, but not around the phengite inclusion. (*c*) Coesite-quartz aggregate in garnet. Plane polarized light. (*d*) Close up of the coesite-quartz aggregate of (*c*). Cleaved part occupying the centre of the aggregate is coesite. Coesite inverts to quartz from the margin.

lished information on coesite and its pseudomorph in China. We also thank Dr S. Wallis of Kyoto University and Dr C. Chopin for their comments on this manuscript.

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Table 1. Chemical composition of representative minerals of coesite-bearing eclogite (Rock No.E88D-1)

Point No. Mineral Core/Rim	7 Cpx rim	8 Grt rim	10 Cpx incl	11 Grt core	14 Phen incl	21 Phen mat	17 Pg incl	18 Kfs incl	9 Amp late
SiO <sub>2</sub>	56.79	39.59	57.06	40.12	52.21	54.36	47.67	65.07	39.24
TiO <sub>2</sub>	-	-	-	-	.41	.28	.12	0.18	-
Al <sub>2</sub> O <sub>3</sub>	13.48	22.13	12.84	22.29	25.06	22.64	39.13	18.15	18.05
Fe <sub>2</sub> O <sub>3</sub> *	-	-	-	-	-	-	-	0.25	-
FeO*	2.96	18.04	3.07	19.10	1.20	1.53	.47	-	15.88
MnO	-	.42	-	.45	-	-	-	-	-
MgO	7.22	7.24	7.66	7.03	4.78	5.29	.31	-	8.48
CaO	10.64	11.58	11.22	11.37	-	-	.19	-	9.76
Na <sub>2</sub> O	8.44	-	8.01	-	.58	.18	8.14	.11	4.15
K <sub>2</sub> O	-	-	-	-	10.39	11.15	.22	16.78	.06
Total	99.54	99.00	99.84	100.36	94.62	95.03	96.25	100.54	95.62
O=	12	12	12	12	22	22	22	8	23
Si	4.003	3.027	4.014	3.035	6.976	7.221	6.035	2.999	5.984
Ti	-	-	-	-	.041	.028	.011	.006	-
Al	1.120	1.994	1.064	1.987	3.947	3.545	5.838	.986	3.244
Fe <sub>3</sub>	-	-	-	-	-	-	-	.009	-
Fe <sub>2</sub>	.174	1.154	.180	1.208	.134	.170	.049	-	2.025
Mn	-	.028	-	.029	-	-	-	-	-
Mg	.759	.825	.803	.793	.951	1.048	.058	-	1.927
Ca	.804	.949	.846	.921	-	-	.062	-	1.595
Na	1.154	-	1.093	-	.151	.046	1.998	.010	1.226
K	-	-	-	-	1.770	1.890	.036	.986	.012
Total	8.014	7.977	8.000	7.973	13.970	13.946	14.057	4.996	16.013
Fe <sub>2</sub> /Mg	0.185	1.398	0.189	1.524	-	-	-	-	-
X(Jd)	0.570	-	0.549	-	-	-	-	-	-
X(Acm)	0.019	-	0.015	-	-	-	-	-	-
X(Di)	0.471	-	0.436	-	-	-	-	-	-

Abbreviations of minerals mainly follow Kretz (1983). \*:Total iron as FeO for all minerals, except for paragonite. incl:inclusion, mat:matrix. late:retrograde origin.

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