Discovery of eclogite at northern margin of Qaidam Basin, NW China

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Abstract Eclogite was first discovered at the northern margin of the Qaidam Basin in this study. It occurs as pods in the gneiss sequence of Middle to Upper Proterozoic age and is mainly composed of garnet, omphacite, phengite and rutile. The garnets contain 44%—62% of almandine, 15%—33% of grossular and 12%—30% of pyrope molecules, and the omphacites contain 40%—46% of jadeite. Applying garnet-clinopyroxene thermometry and jadeite geobarometry, the peak conditions of eclogite facies metamorphism occurred at about (722 ± 123)℃ and at the pressure of up to c. 22 $\times 10^8$ Pa.

Keywords: eclogite, high-pressure metamorphism, Da Qaidam, Qinghai-Xizang Plateau.

THE coecite-bearing eclogite and ultra-high pressure metamorphism in the Dabie and Sulu areas in East China have been attracting great attention of the geoscientists in the world since they were recognized in 1987[1,2]. Eclogite and high-pressure metamorphism have also been reported from the Altyn Tagh and Tianshan Mountains[3,4], NW China in recent years. During the field season of Sino-French collaboration of 1996 we found that eclogites occur at the northern margin of the Qaidam Basin. All these discoveries make us reconsider the tectonic framework of NW China as well as of East China.

1 Field occurrence

The eclogite crops out about 40 km northwest of the Da Qaidam Town (fig. 1). It occurs as pods in the plagioclase-gneiss sequence, and the latter belongs to the lower group of the Dakendaban Formation of Middle-Upper Proterozoic age according to the geological maps of 1 : 200 000 of Da Qaidam and neighboring regions[5—7]. The isotopic dating work for the eclogite is undergoing.

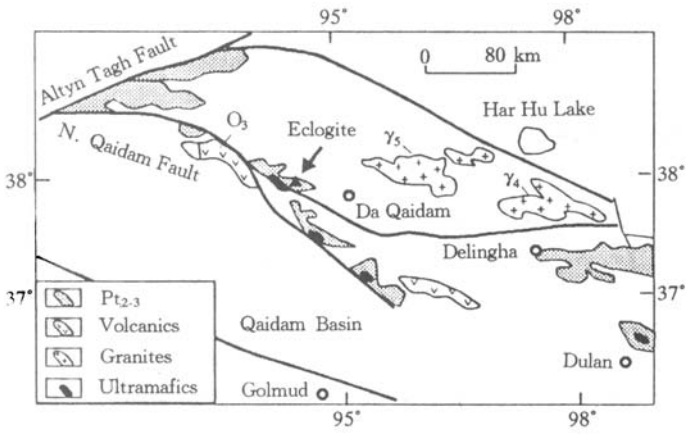

Fig. 1. Location of the eclogite and simplified geological map of the Da Qaidam region. The eclogite is located about 40 km NW of the Da Qaidam Town. Pt_{2-3}, Dakendaban Group of Middle-Upper Protorozoic age.

In a 3-km-long section in the gneiss sequence 14 pods of eclogite were observed, which occur in a varied size, with the largest one up to 40 m × 20 m, but most less than 20 m × 10 m. Some of them are oriented parallel to the gneissosity and regional structure line, dipping to NE20° at a mean angle of 60°. The eclogite is gray-green in color, dense and hard, seen apparently on the ground or at the top of hill (fig. 2(a)). There are some garnet-amphibolite pods, which were probably formed by retrograde metamorphism of eclogite. In addition, some diabase and pyroxenite pods are seen in gneiss and they are supposed to have formed in the same tectonic event as the eclogite.

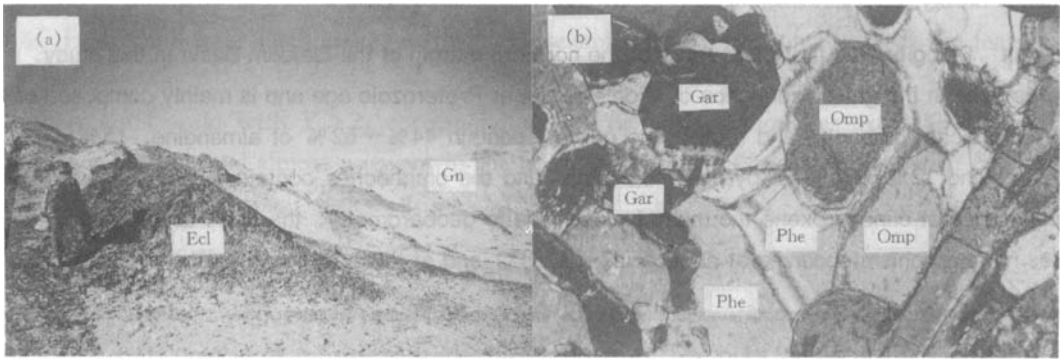

Fig. 2. (a) Eclogites occur as pods in the gneiss of Middle-Upper Proterozoic age, easily distinguished from its country rocks in the field. (b) Photomicrograph of granular texture of eclogite: Gar, garnet; Omp, omphacite; Phe, phengite (crossed Nicols, long side of photomicrograph: 2 mm).

2 Petrologic features

The eclogite shows mainly a medium-fine grained texture and massive structure. Under a mi-

croscope some fresh samples consist of 40%—50% of garnet, 40%—50% of omphacite, and small amounts of amphibole, phengite, quartz, sphene and rutile (figure 2(b)).

Garnets are euhedral and even granular, mostly 1—2 mm in diameter. In some thin sections garnets occur as tadpole in shape with the width/length ratio up to 1:10 due to the post-deformation, while the omphacites in the sections have mostly been replaced by amphiboles. Microprobe analysis shows that the garnets consist of almandine (al) (44%—62%), grossular (gr)(15%—33%) and pyrope molecules (py)(12%—30%) (fig. 3, table 1). In fig. 3, the pyrope contents of garnets are plotted within Groups C and B areas[8], away from those of the eclogitic garnets within glaucophane schists in the SW Tianshan Mts.[4], but are compatible with the eclogitic garnets in the gneisses in the Altyn Tagh Mts.[3]. Inclusions are less abundant in the garnets in general, except in fewer amounts of garnets, where the inclusions are high in percentage and the garnets appear to be sieves. The inclusions are generally composed of quartz, omphacite and mica.

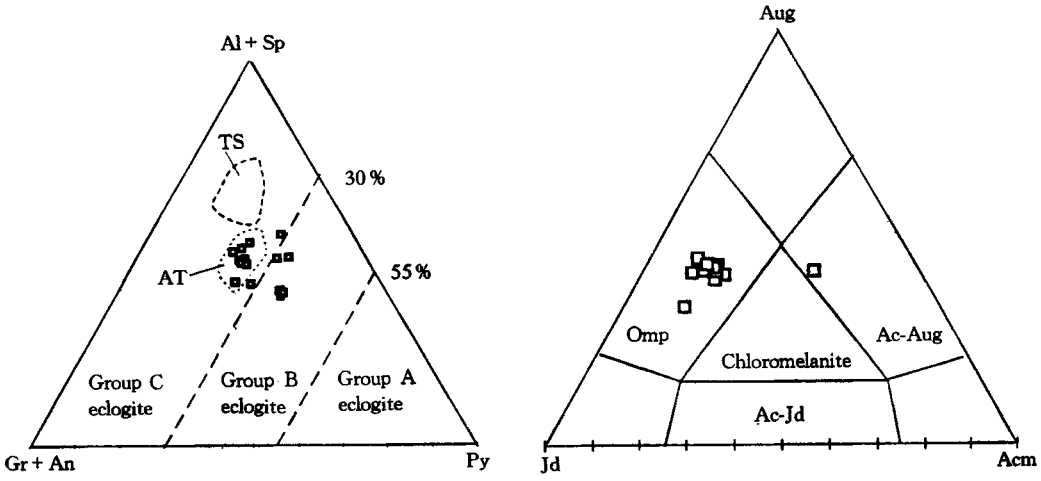

Fig. 3. (a) Garnets from the Da Qaidam eclogites are plotted in the regions of Group C and Group B eclogites[8], away from the region of the SW Tianshan Mts., but partly overlapping that of the Altyn Tagh; (b) jadeite molecules of the clinopyroxenes are plotted within the area of omphacite. TS, SW Tianshan Mts.; AT, Altyn Tagh; Al, almandine; Sp, spessartine; Gr, grossular; An, andradite; Py, pyrope; Aug, augite; Jd, jadeite; Acm, aegirine.

The omphacites are largely prismatic and granular, in a size normally less than 1 mm, but some up to over 2 mm. Omphacites in some sections display weak orientation and intergrowth with garnets. Alteration, during retrograde metamorphism, in some omphacites leads to the formation of a border zone of hornblende and the development of homoaxial fiber of amphibole. Microprobe analysis indicates that the omphacites contain 37%—46% of jadeite (Jd) and 50%—57% of augite (Aug) molecules, and are plotted within the omphacite region (Omp) (fig. 3). Along with the characteristic of garnets, the eclogites are considered to have formed in a higher pressure environment.

Table 1 Microprobe analyses of minerals in eclogites from the Da Qaidam region

	Garnet					Omphacite					Phengite		Rutile	
SiO_2	37.71	38.18	38.69	39.46	37.76	56.37	55.90	55.93	54.85	54.98	51.16	51.35	0.05	0.08
TiO_2	0.43	0.08	0.07	0.03	0.10	0.03	0.13	0.18	0.30	0.34	0.70	0.76	99.39	99.24
Al_2O_3	21.22	21.56	21.85	22.13	21.49	10.63	10.41	11.17	9.93	10.20	26.78	25.80	0.00	0.03
Cr_2O_3	0.00	0.07	0.03	0.06	0.00	0.00	0.00	0.01	0.04	0.02	0.05	0.04	0.04	0.00
Fe_2O_3	0.29	0.43	0.41	0.29	0.29	1.30	0.00	0.48	1.77	2.72				
MgO	3.70	5.25	6.81	8.03	4.16	8.42	8.67	7.60	8.12	7.11	3.57	3.93	0.00	0.00
CaO	9.06	6.24	6.68	9.24	10.83	13.25	14.35	12.88	13.47	12.32	0.01	0.02	0.06	0.17
MnO	0.64	0.49	0.41	0.32	0.33	0.00	0.05	0.03	0.02	0.00	0.02	0.05	0.00	0.00
FeO	27.04	29.12	26.25	20.88	25.13	3.77	4.20	5.09	4.32	4.76	1.91	2.11	0.29	0.34
NiO	0.06	0.03	0.04	0.00	0.00	0.12	0.00	0.02	0.04	0.05	0.00	0.00	0.00	0.00
Na_2O	0.23	0.03	0.03	0.02	0.00	6.80	6.14	6.87	6.42	7.07	0.58	0.40	0.00	0.04
K_2O	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	10.27	10.14	0.01	0.00
H_2O											4.49	4.47		
Total	100.43	101.47	101.26	100.45	100.08	100.70	99.85	100.25	99.27	99.58	99.54	99.06	99.84	99.90
Si	5.93	5.93	5.94	5.99	5.92	1.99	1.99	1.99	1.98	1.98	6.83	6.89	0.00	0.00
Ti	0.05	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.07	0.08	1.00	1.00
Al	3.93	3.95	3.95	3.96	3.97	0.44	0.44	0.47	0.42	0.43	4.21	4.08	0.00	0.00
Cr	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fe	0.03	0.05	0.05	0.03	0.03	0.03	0.00	0.01	0.05	0.07				
Mg	0.87	1.22	1.56	1.82	0.97	0.44	0.46	0.40	0.44	0.38	0.71	0.78	0.00	0.00
Ca	1.53	1.04	1.10	1.50	1.82	0.50	0.55	0.49	0.52	0.48	0.00	0.00	0.00	0.00
Mn	0.09	0.06	0.05	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Fe	3.56	3.78	3.37	2.65	3.30	0.11	0.13	0.15	0.13	0.14	0.21	0.24	0.00	0.00
Ni	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.07	0.01	0.01	0.01	0.00	0.47	0.42	0.47	0.45	0.49	0.15	0.10	0.00	0.00
K	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	1.73	0.00	0.00
and	1.61	1.37	1.28	0.88	1.01	XAug 0.53	0.57	0.52	0.54	0.50				
gro	23.29	15.35	26.64	23.91	28.58	XAc 0.03	0.00	0.01	0.05	0.07				
pyr	14.46	19.95	25.64	30.25	15.87	XJd 0.44	0.43	0.46	0.40	0.42				
spe	1.43	1.05	0.89	0.69	0.71									
alm	59.21	62.07	55.47	44.10	53.83									

Probe analyses were done in the Open Laboratory of Lithosphere Research, Beijing Institute of Geology, CAS. and, Andradite; gro, grossular; pyr, pyrope; spe, spessartine; alm, almandine; Aug, augite; Ac, aegirine; Jd, jadeite.

The eclogite has a relatively low abundance of amphiboles, normally 5%—10%. Some fine-to medium-grained euhedral amphiboles, along with the amphibole inclusions within garnets, were most likely formed during the crystallization of garnet and omphacite, or partly produced by retrograde metamorphism of omphacites. The occurrence of some coarse-grained amphiboles, which may contain small garnet and omphacite crystals, as well as the amphiboles along garnet fractures in some samples, suggest more than one generation of amphiboles crystallized at different stages of evolution of these rocks. Compositional study indicates that the fine- to medium-grained forms are sodic-calcic amphiboles.

Phengite is common and normally less than 5% in abundance. It occurs as small oriented laths (0.2—1 mm) in textural equilibrium with omphacite and garnet, or as fine-grained inclusions in garnet. Some large tabular, unorientated crystals are up to 2—5 mm, which formed probably relatively late. The Si cation of phengite varies from 6.6 to 6.9, whereas Mg ranges from 0.6 to 0.8 and Fe from 0.21 to 0.25 based on a stoichiometry of 22 oxygen atoms. Thus, it belongs to a typical high-pressure mineral assemblage.

Applying garnet-clinopyroxene thermometry[9] and jadeite geobarometry[10], the peak conditions of eclogite metamorphism occurred at about (722 ± 123)℃ (table 2) and at the pressure of up to c. 22 $\times 10^8$ Pa. Therefore, the eclogites most likely formed in a relatively high-pressure environment according to their mineral assemblage and chemical composition.

Table 2 Results of garnet-clinopyroxene geothermometry

Sample		3-3a	3-3b	1-1d	1-1c	1-1b	1-1a
Garnet	Fe	0.09	0.10	0.05	0.05	0.05	0.03
	Mg	1.41	1.05	0.74	1.56	1.22	0.87
	Ca	1.28	1.73	1.81	1.10	1.04	1.53
Pyroxene	Fe	0.031	0.052	0.048	0.035	0.054	0.057
	Mg	0.450	0.444	0.445	0.444	0.465	0.434
	Ca	0.519	0.520	0.498	0.502	0.521	0.498
K_D		8.545	12.24	22.170	8.613	13.888	17.336
T/℃		792	700	544	769	661	615
Sample		4-4d	4-4c	4-4b	4-4a	2-2a	2-2b
Garnet	Fe	0.03	0.06	0.09	0.05	0.02	0.05
	Mg	0.97	0.98	0.91	0.83	1.09	1.74
	Ca	1.82	1.71	1.80	1.66	2.02	1.47
Pyroxene	Fe	0.062	0.032	0.074	0.048	0.000	0.013
	Mg	0.443	0.449	0.382	0.437	0.461	0.403
	Ca	0.506	0.514	0.476	0.521	0.548	0.491
K_D		14.594	11.255	9.634	13.827	9.961	4.144
T/℃		648	717	753	657	743	1063

Calculation using the method of Krogh (1988).

3 Significance

To now, our knowledge to the tectonic framework of the region along the northern margin of

the Qaidam Basin is poor. For instance, although a suite of mafic rocks were observed in the area, it is still unclear whether it belongs to an ophiolitic association. Besides, we do not know whether the meta-peridotite reported from the east end of the Qaidam Basin[11] has been extended to the west, i. e. the Da Qaidam region. Since some garnet-lherzolite bodies in previous[12] and this study have been found in the Dakendaban Formation in the Da Qaidam region, not far from the location of eclogite, we need to know whether this is merely a coincidence without genetic relationship between them, or there is some genetic relationship between them as seen in the Sulu-Dabie UHP belt. Furthermore, it would be an interesting topic to compare the eclogites from Da Qaidam in genesis and significance with those from the neighboring regions, such as Altyn Tagh, Qilian Mts., and Tianshan Mts. Evidently, the discovery of the eclogite at the northern margin of the Qaidam Basin is of significance in approach of the regional tectonic framework in NW China, as well as in comparison between the eclogite belts of East China and West China.

References

1 Xu Zhiqin, *Etude Tectonique et Microtectonique de la Chine Paleozoique et Trasique des Qinglings (Chine)*, These, Universite des Sciences et Techniques du Lanquedoc, Montpellier, France, 1987.

2 Lious, J. G., Wang, Q., Zhai, M. *et al.*, Ultrahigh-*P* metamorphic rocks and their associated lithologies from the Dabie Mountains, central China: a field trip guide to the 3rd International Eclogite Field Symposium, *Chinese Science Bulletin*, 1995, 40(Suppl.): 1.

3 Liu, L., Che, Z. C., Lou, J. H. *et al.*, Determination of eclogite in western Altun Mts. and its geological significance, *Chinese Science Bulletin* (in Chinese), 1996, 41(16): 1485.

4 Gao, J., Discovery of eclogite in southwestern Tianshan Mts. and its tectonic implications, *Chinese Science Bulletin* (in Chinese), 1997, 42(7): 737.

5 Geological Bureau of Qinghai Province, *Geological Map of Da Qaidam* (scale 1:200 000), Beijing: Geological Publishing House, 1980a.

6 Geological Bureau of Qinghai Province, *Geological Map of Mahai* (scale 1:200 000), Beijing: Geological Publishing House, 1980b.

7 Geological Bureau of Qinghai Province, *Geological Map of Yuka* (scale 1:200 000) Beijing: Geological Publishing House, 1985.

8 Deer, W. A., Howie, R. A., Zussman, J., *An Introduction to the Rock Forming Minerals* (2nd ed.), Hong Kong: Longman Scientific & Technical, 1992, 31—46.

9 Krogh, E. J., The garnet-clinopyroxene Fe-Mg geothermometer——a reinterpretation of existing experimental data, *Contribution to Mineralogy and Petrology*, 1988, 99: 44.

10 Carswell, D. A., Harley, S. L., Mineral barometry and thermometry, *Eclogite Facies Rocks* (ed. Carswell, D. A.), New York: Chapman and Hall, 1990, 83—110.

11 Yang, J. S, Robiuson, P. T., Jiang, C. F., Ophiolites of the Kunlun Mountains, China and their tectonic implications, *Tectonophysics*, 1996, 258: 215.

12 Yang, J. J., Discovery of garnet peridotite at northern margin of the Qaidan Basin and its significance, *Acta Petrologica et Mineralogica* (in Chinese), 1994, 13: 97.

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