HIGH-PRESSURE MELT AND FLUID INCLUSIONS IN MINERALS OF GARNET GRANULITES/ECLOGITES (EASTERN PAMIR)

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Introduction

South-Eastern Pamir belongs to the largest Pamir-Himalayan collisional orogen (Fig. 1) and is characterized by abnormally thick (to 70-75 km) continental crust. The only source of information on the composition of the lower crust and upper mantle under this region are deep-seated xenoliths in Neogene alkaline basaltoid diatremes. Xenoliths consist of mantle and lower-crustal rocks. The latter are represented by various granulites (Grt-Ky, Grt-Opx-Cpx, Grt-Bt-Opx,) and Pl-eclogites (Grt-Cpx-Pl granulites). The mantle xenoliths are dominated by eclogites (bimineralic, or kyanite, sanidine, and biotite-bearing) and garnet clinopyroxenites.

Minerals in these xenoliths contain primary melt and fluid inclusions, which provide a wealth of data on the origin and evolution of these lower-crustal and mantle rocks.

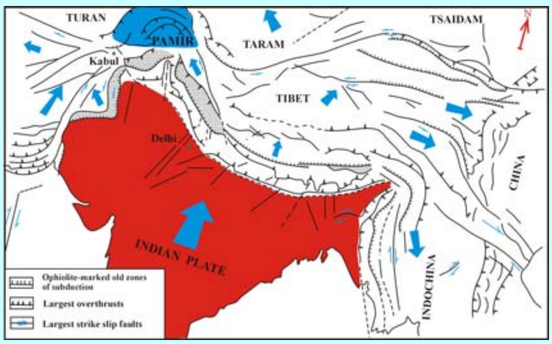


Fig. 1.
The Pamir-Himalayas collisionnal orogen in thetectonic structure of Central Asia (according to K.S. Valdiya, 1984)

Results

Primary melt inclusions have been found in garnet, orthopyroxene, kyanite and some other minerals from all lower-crustal granulites and Pl-eclogites, and mantle eclogites (Fig. 2). Almost all inclusions in garnet are partly decrepitated, but not in other minerals. These inclusions contain glass+heterogeneous fluid bubble±several microcrystallites. According to freezing data and Raman analysis, the fluid phase of melt inclusions in garnet and other minerals from all studied rocks is represented mainly by high density CO_2.

Some grains of garnet from eclogite, Grt-Cpx-Pl granulite, and Ky- and Opx-bearing granulites contain primary inclusions of high density CO_2 (>0,8 g/cm³) and syngenetic melt inclusions, that imply the early stages of granulite and eclogite crystallization in the presence of both CO_2-saturated melts and free CO_2-rich fluid.

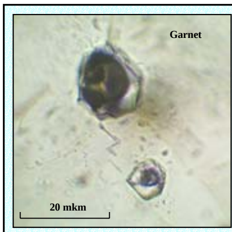
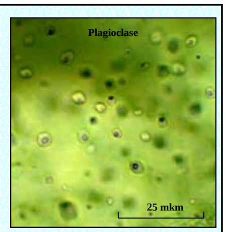
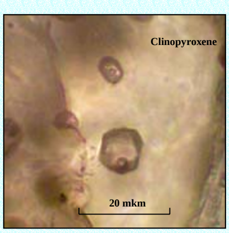
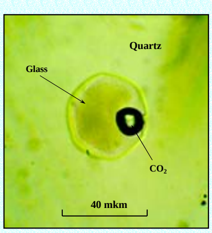
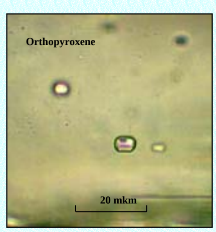


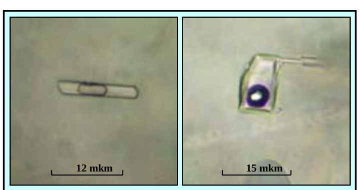
Fig. 2
Primary melt inclusions in minerals from Grt-Opx-Cpx granulite (sample 1324)



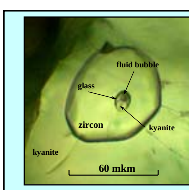




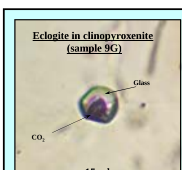


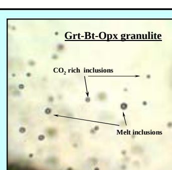


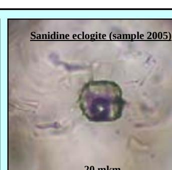
Primary melt inclusions in kyanite from Grt-Ky granulite (sample P-1-2)



Combine primary melt inclusion in zircon from Grt-Ky granulite (sample D-1175)







Primary melt and fluid inclusions in garnet from various xenoliths

High external trapping pressure of melt inclusions in quartz and other minerals is suggested by the formation (segregation) of additional bubbles of very dense CO_2 during heating runs. Melt inclusions in garnet from Cpx-Pl granulite homogenized at 1020°C and in quartz from massive Grt-Ky granulites homogenized at 1000°C during heating experiments in an apparatus with a high (12 kbar) external pressure. These data are in good agreement with mineral estimates, about 940°C for temperature and above 12 kbar for pressure.

The chemical composition of trapped melts in garnet and apatite from Cpx-Pl granulite correspond to a peraluminous K-Na dacite and a strongly peraluminous K-Na rhyodacite respectively (Table 1). Inclusions in garnet and other minerals from massive and gneissic Ky-granulites correspond mainly to a strongly peraluminous subalkaline K-rich rhyodacites (Table 1). Inclusion glass in minerals from Grt-Cpx-Pl granulite and from massive Ky-granulites is enriched in chlorine, whereas inclusion glass in gneissic Ky-granulites does not contain detectable chlorine (Table 1 and Fig. 2). In inclusions occuring in quartz from massive Grt-Ky granulites, the CO_2 content of trapped melt was estimated to be roughly 1,5-1,8 wt.%. Water and trace element contents are given in the Table 2 and in the Fig. 3 (data of ionic microprobe analyses). The low HREE contents seem to be due to the crystallization of early garnet.

Table 1. Representative chemical composition of glasses of melt inclusions in minerals from Grt-Ky and Grt-Cpx-Pl granulites, wt.%

#	Host mineral	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	Cl	Total	T of heat.,°C
					massive Grt-Ky granulites							
1	Grt	69,51	0,16	14,62	0,91	0,33	1,44	1,67	5,69	0,21	94,54	unheated
2	Ky	71,56	0,14	16,50	0,82	0,16	0,51	1,42	5,24	-	95,83	1050
3	Ky	68,78	0,05	17,74	0,18	0,02	1,24	1,61	6,61	0,02	96,25	unheated
4	Zircon in Ky	68,38	0,39	17,59	2,16	0,23	0,76	1,55	5,24	-	96,51	1050
5	Ap in Grt	72,91	0,19	14,80	0,85	0,22	0,68	0,82	5,28	0,35	96,10	unheated
6	Qtz	72,64	0,23	15,02	0,79	0,15	0,62	1,82	6,95	0,33	98,55	1050
7	Qtz	70,67	0,30	14,55	0,74	0,06	1,63	1,92	6,42	0,40	96,69	unheated
					gneissic Grt-Ky granulites							
8	Grt	70,09	0,09	16,73	3,5	0,77	1,76	1,74	5,47	0,01	100,16	1060
9	Grt	72,07	0,18	14,85	0,95	0,09	1,21	2,13	5,25	0,02	96,75	unheated
10	Ky	70,76	0,07	15,17	0,23	0,07	0,43	3,14	4,34	-	94,36	1050
11	Ky	70,4	0,13	15,67	0,1	0	0,82	1,89	4,29	0,01	93,31	unheated
12	Ap in Ky	68,32	0,08	16,05	0,53	0,24	0,83	2,27	7,58	0,01	98,74	1050
13	Ap in Ky	70,17	0,08	15,5	0,43	0,11	0,63	1,58	6,1	0,01	94,61	unheated
14	Monazite	66,91	0,07	14,09	0,3	0,01	0,48	2,08	4,77	-	89,4	1050
					Grt-Cpx-Pl granulite							
15	Grt	65,84	0,24	16,57	3,98	1,35	3,6	1,93	3,63	0,24	97,38	1050
16	Grt	65,63	0,19	15,72	4,68	1,25	2,99	1,72	3,89	0,21	96,28	1020
17	Grt	67,16	0,14	15,32	2,88	0,53	2,65	2,04	4,57	0,22	95,49	1020
18	Grt	66	0,2	15,41	2,16	0,83	3,29	1,49	3,91	0,24	93,53	1000
19	Grt	68,08	0,06	15,35	1,44	0,19	2,38	1,85	5,17	0,26	94,78	880
20	Grt	69,63	0,1	15,48	0,71	0,02	2,19	2,2	4,62	0,3	95,25	700
21	Grt	69,24	0,17	15,42	0,34	0,03	2,28	2,45	4,36	0,27	94,56	unheated
22	Ap in Pl	68,98	0,33	14,65	3,88	0,78	0,99	2,18	3,29	0,22	95,3	unheated

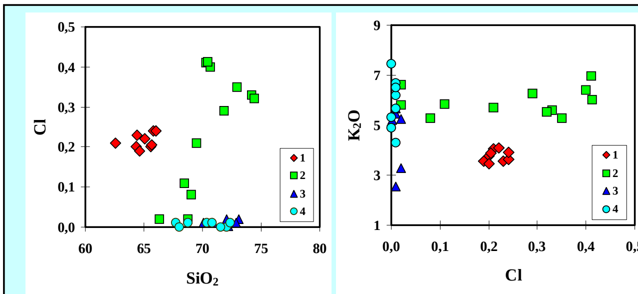


Fig. 2 **Diagrams of Cl - SiO_2 and K_2O-Cl for melt inclusions**

1 - in garnet from Grt-Cpx-Pl granulite; 2 - in kyanite, garnet, apatite, zircon and quartz from massive Ky-granulites; 3, 4 - in garnet (3), kyanite, apatite and monazite (4) from gneissic Ky-granulites

Table 2.
Trase element composition (SIMS) of glasses in unheated melt inclusions and amphibole from Estern Pamir xenoliths

	Grt-Cpx-Pl granulite MI in Grt	Grt-Cpx-Pl granulite Amph	Grt-Ky granulite MI in Qtz		
ppm					
Cr	236,31	386,05	3,51	1,40	2,95
Sr	111,58	107,06	79,20	343,66	250,90
Zr	121,09	44,27	140,82	128,42	134,40
Ba	341,13	184,36	229,64	530,78	433,00
Ce	38,67	57,24	218,39	214,21	164,30
Sm	1,69	5,94	10,06	9,24	5,40
Er	2,48	0,76	0,62	0,74	0,44
Th	22,26	0,28	40,59	59,67	21,23
Yb	2,98	0,53	0,35	0,44	0,31
Dy	3,98	1,66	1,19	1,32	1,05
Eu	0,68	1,30	0,91	1,46	1,50
Nd	6,73	31,74	74,88	68,76	60,70
La	29,58	19,31	96,86	107,47	110,80
Nb	0,47	0,31	2,33	3,30	1,74
Y	24,63	4,12	3,02	2,08	1,53
Ti	1764,68	16039,92	1645,18	1405,44	1235,00
B	11,46	0,80	12,69	14,03	7,80
Li	150,86	6,13	2,86	2,88	6,30
Be	1,26	1,17	8,61	6,73	3,80
H_2O wt.%	2,38	0,45	3,96	3,01	0,83
H_2O*	2,14		3,56	2,70	0,75

H_2O* - estimation for the possible 10% melting of the host mineral during homogenization

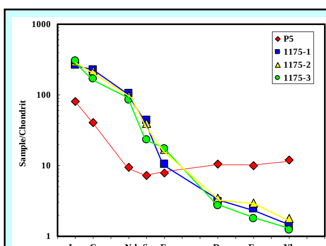


Fig. 4. Chondrite-normalized REE pattern for glasses of unheated melt inclusions from the Estern Pamir xenoliths (sample 1175, P5)

Conclusion

- **The occurrence of melt inclusions in garnet and other minerals from major types of deep-seated xenoliths in Eastern Pamir indicates the importance of magmatic processes during the formation of the lower crust and upper mantle in this region.**

- **CO_2 took an active part in these processes.**

- **All minerals (including subliquidus garnet) of lower-crustal Grt-Cpx-Pl and Grt-Ky granulites crystallized from (or with the participation of) high-temperature K-Na dacite and K-rich strongly peraluminous rhyodacite melts, characterized by a low HREE content. This fact suggests that incongruent melting of K-bearing basic and more acid high-alumina rocks took place in the lower crust, at pressure above 12 kbar, with the formation of acid magmas and crystallization of dense eclogite or granulite paragenesis (garnet±clinopyroxene).**