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Qusongite (WC): A new mineral

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Abstract

An unusual group of mantle minerals including about 70–80 species has been recovered from podiform chromitites of the Luobusa ophiolite, Qusong County, Tibet, China. All of the minerals were hand picked from heavy mineral separates of the chromitite. The minerals include diamond, coesite, moissanite, wüstite, intermetallic compounds, Os-Ir alloys with diamond inclusions, Fe-silicides, and a new mineral, qusongite. Qusongite is associated with chromian chlorite, calcite, (W,Ti)C and (Ti,W)C alloys, and chromite. It occurs as angular grains generally 4–8 μm in diameter, but some are as large as 0.2 × 0.3 × 0.25 mm. The grains are opaque and steel-gray with a metallic luster and grayish-yellow reflection. The empirical formula (based on 2 atoms) is $W_{1.006}Cr_{0.02}C_{0.992}$, and the simplified formula is WC. Qusongite has a hexagonal structure and belongs to space group $P\bar{6}m2$, with $a = 2.902(1)$ Å, $c = 2.831(1)$ Å, $c{:}a = 0.9775$, $V = 20.05\ (1)$ Å^3, $Z = 1$.

Keywords: Qusongite, new mineral, chromite, ophiolite, Qusong county, Tibet

Introduction

Qusongite is tungsten carbide (Nickel-Strunz classification 1.BA.25) and was approved by IMA CNMNC in October 2007. The mineral grain has been deposited in the Geological Museum of China (GMC), registration no. 2007-034. The new mineral was named after its locality, Qusong County, Tibet, in which the Luobusa ophiolite is located.

Native metals, intermetallic grains (Fe-Ni, Cr-Ni, Fe-Co), and corresponding carbides have been discovered previously in several localities around the world (Melville 1892; Bird and Weathers 1975; Rudashevsky et al. 1983; Melcher et al. 1997; Bai et al. 2000; Robinson et al. 2004; Shi et al. 2005). Natural WC was previously reported from an occurrence in Shangdong Province, China (Zhang et al. 1986) and was reported to the IMA-CNMNC as a new mineral but was not approved. Some data on WC in unnamed material were also published by Glavatskikh et al. (1997).

Chromitite orebody 31 of the Luobusa ophiolite is unique in its abundance of native metals and intermetallic grains, indicating a highly reducing environment. Because the melting point of qusongite is much higher than that of other common metal carbides (Rudashevky et al. 1983), a high-temperature environment of formation is also indicated.

Because the minerals reported here were hand-picked from a heavy mineral separate of chromitite, the possibility of natural or anthropogenic contamination cannot be completely eliminated. However, both the samples and crushing equipment were carefully cleaned before processing (Bai et al. 2000), and a 200 kg sample of granite was processed first to test for contamination. Only quartz, feldspar, garnet, mica, apatite, and zircon were recovered from the granite, and any dark or metallic minerals would have been readily recognized.

Using the same procedures with which the granite sample was processed, we recovered a wide variety of metallic minerals and alloys from the Luobusa chromitite. The recovered minerals include numerous native elements, WC, Fe-Si, Fe-Mn, diamond, Os-Ir alloy with diamond inclusions (Yang et al. 2004, 2007), silicon carbide, $Fe_{0.84}Si_2$ (luobusaite) (Bai et al. 2006), Cr_3C_2 (tongbaite) (Tian et al. 1983), various kinds of platinoid minerals, and coesite (Yang et al.2007). (See also Fang et al. 1981; Bai et al. 2000, 2001, 2002, 2003, 2004; Robinson et al. 2004.) None of these minerals occur in the granite sample, but many of them have been recovered from chromitites of other ophiolites, processed in completely different laboratories (Robinson and Yang 2008). Thus, we are confident that the Luobusa sample is free of contamination and that the mantle chromitite origin of qusongite is well established. Some native metals and carbides similar to WC have been reported from the Koryak highlands of Russia and in Alpine metamorphic rocks (Rudashevsky et al. 1983).

Occurrence and analytical techniques

The new mineral, qusongite, was separated from a heavy mineral separate prepared from a 1500 kg sample of chromitite collected from orebody 31 of orebody group II of the Luobusa mining district, in Qusong county, Tibet, about 200 km ESE of Lhasa (29°5′N, 92°5′E). The chromitite is hosted in harzburgite of the Luobusa ophiolite, which lies in the Indus-Yarlung Zangbo suture zone. The ophiolite extends along the Yarlung Zangbo River for about 42 km from east to west and has a width of 1–4 km, with an exposed area of about 70 km^2. It consists chiefly of harzburgite, with lesser amounts of dunite, cumulate mafic rocks, pillow lava, and ophiolitic mélange (Fig. 1) (Zhou et al. 1996; Bai et al. 2000). Numerous podiform chromitite bodies

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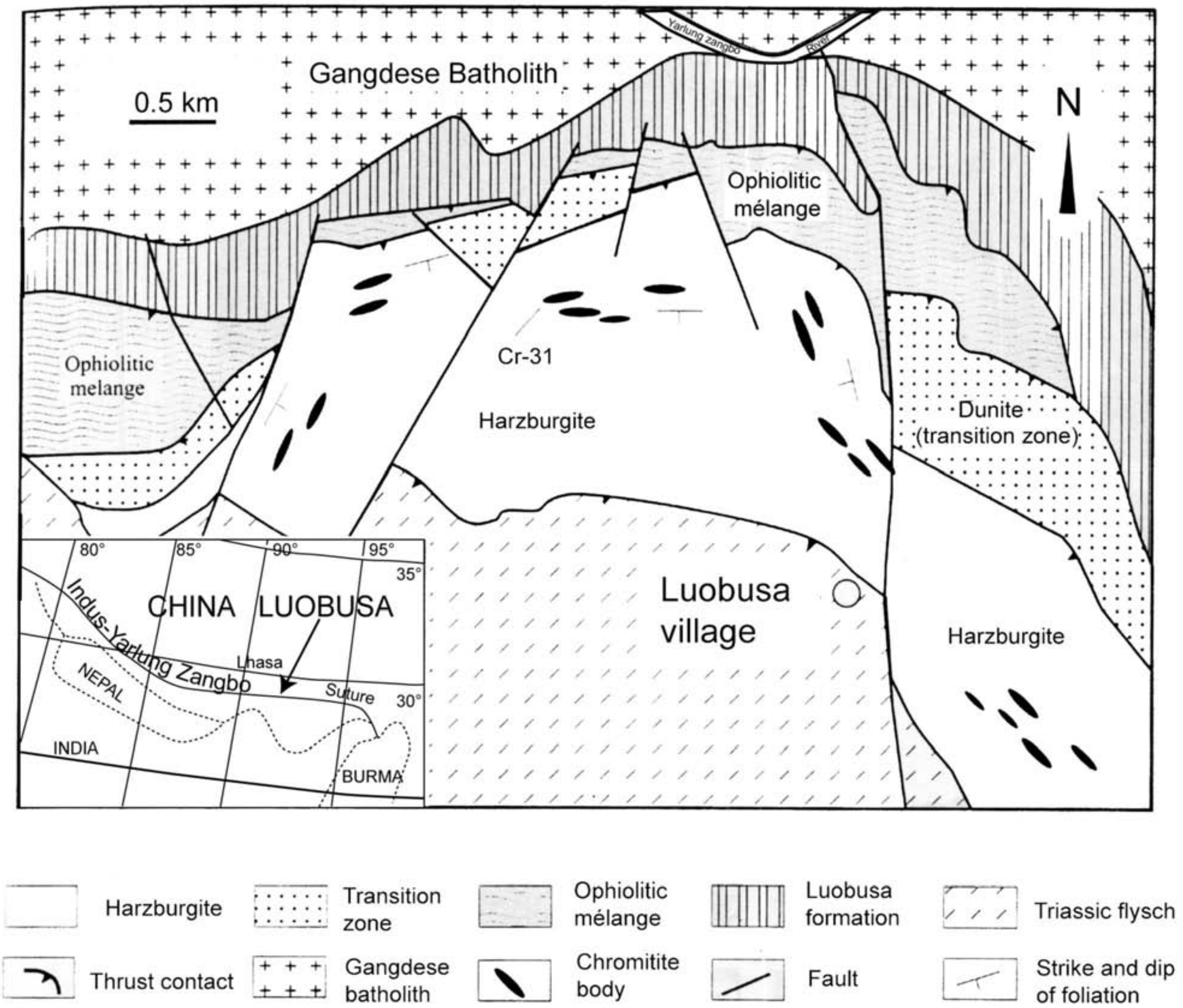

FIGURE 1. Geologic map of the Luobusa ophiolite showing the distribution of chromitite orebodies (after Zhou et al. 1996 and Bai et al. 2000).

are hosted in the mantle rocks, with an aggregate total of about 5 million tons of ore.

Because the mantle minerals are present in very small quantities, they were hand picked from heavy-mineral concentrates of the chromitite. The samples were hand-washed, air-dried, and crushed carefully to minimize any possible native or anthropogenic contamination. Mineral separation was carried using gravity, magnetic, and electric techniques in the Zhengzhou Institute of Multipurpose Utilization of Mineral Resources, Chinese Academy of Geological Sciences.

After hand picking, the minerals were mounted in epoxy, polished, and analyzed on an S-3500 N scanning electron microscope with an INCA energy dispersive spectrometer. The operating conditions were voltage 20 kV, beam current 15 nA, takeoff angle 15°, counting time 30–50 s, and working distance 15 mm. The SW-9100 NOST multiple element standards, fine metals, and native minerals were used for calibration. An EPMA-1600 microprobe and X-ray diffractometer were used for detailed analysis and identification of the minerals.

Chemical analyses of qusongite were carried out by Tao Shufeng (Beijing General Research Institute of Mining and Metallurgy) and Yin Jingwu (China University of Geosciences, Beijing).

CHEMICAL COMPOSITION

The relationship between qusongite and other minerals has been revealed by backscatter images (Fig. 2). The electron microprobe analyses of associated chromian chlorite and calcite are given in Table 1 with the analyses corresponding to the numbers in Figure 2 (e.g., 13 = chromian chlorite and 15 = calcite). Qusongite forms small, subhedral grains intergrown with (W,Ti)C and (Ti,W)C, whose chemical compositions are listed in Table 2. The relationship of qusongite and Cr_2O_3 is shown in Figure 3, and the chemical compositions of these minerals are presented in Table 3.

Chemical analyses of qusongite are given in Table 4. Most

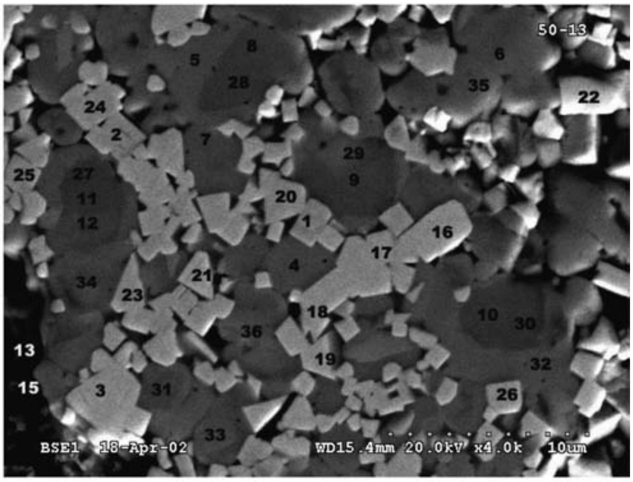

FIGURE 2. BSE image of qusongite (1–3 and 16–26), (W, Ti)C (4–7), and (Ti,W)C (32–35, 8–12, and 27–31), chromian chlorite (13) and calcite (15).

of the grains consist solely of W and C, although some contain small amounts of Cr, Ni, and Ti. The weight percentages of W range from 92.07 to 94.48, with a mean of 93.44. Carbon varies from 6.01 to 6.16 wt% with a mean of 6.07%. The small amounts of Cr (mean 0.04 wt%) are compatible with chromitite being the host rock of the WC.

Based on the chemical analyses qusongite has an empirical formula of $W_{1.0016}C_{0.9984}$, which yields a simplified formula of WC.

Physical and optical properties

Qusongite occurs as irregular, granular, or platy grains, generally 4–8 μm in diameter, but ranging up 0.2 × 0.3 × 0.25 mm. It is steel-gray in color, opaque, with a metallic luster, and black streak. It lacks cleavage and has a conchoidal fracture. The density could not be measured because of the small grain size, but should be 15.84 g/cm^3 based on the empirical formula. The hardness VHN200 is 1553 kg/cm^2 (mean) (1543.6–1563.8 kg/cm^2) measured with a LEOZ ORTHOLUX-BX instrument. It has medium anisotropy, ranging from deep gray to light brown, and internal reflection. Reflectance measurements of qusongite were made from 400 to 700 nm using a Leitz MPV-3 spectrometer and a SiC reflectance standard on a freshly polished grain (Table 5).

X-ray diffraction

Due to the very fine (4–8 μm in diameter) aggregates of qusongite, it is difficult to obtain good single-crystal X-ray measurements. However, we used a Smart APEX instrument with a CCD detector, and Mo*K*α radiation at 45 kv and 30 mA to obtain the X-ray powder-diffraction data listed in Table 6. The computational results are as follows: the mineral is hexagonal; space group $P\overline{6}m2$, $a = 2.902$ (1) Å, $c = 2.831(1)$ Å, $c{:}a = 0.9775$, $V = 20.05$ (1) Å, $Z = 1$.

DISCUSSION

Because the qusongite was collected from podiform chromitite hosted in ophiolitic harzburgite, it is considered to be of

TABLE 1. Chemical compositions of chromian chlorite and calcite intergrowths associated with qusongite

Sample	Content (wt%)						
	MgO	Al_2O_3	SiO_2	Cr_2O_3	H_2O	CaO	CO_2
50-13-13-1	28.54	9.56	46.79	6.31	8.73		
50-13-13-2	29.45	8.98	45.99	6.31	9.07		
Mean of 2 chromian chlorite	29	9.27	46.38	6.31	9		
50-13-15-1						55	45
50-13-15-2						54.9	45.1
Mean of 2 calcite						54.95	45.01

TABLE 2. Chemical compositions of (W,Ti)C and (Ti,W)C intergrowths associated with qusongite

Sample	Content (wt%)						Content (at%)		
	W	Ti	C	Cr	Ni	Total	W	Ti	C
50-13-1	93.87	0.01	6.13	0.04	0.01	100.06	50.01	–	49.99
50-13-4	72.3	17.17	9.17	0.04	0.01	98.69	25.2	23.96	50.8
50-13-2	93.66	–	6.1	0.04	0.01	98.2	49.98	–	49.98
50-13-11	61.33	28.38	11.2	0.04	0.01	100.96	17.72	32.23	50.05
50-13-27	61.26	26.61	10.45	0.04	0.01	98.37	18.78	31.22	50

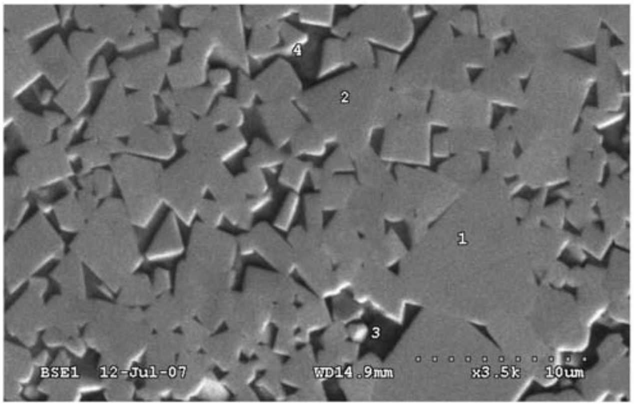

FIGURE 3. BSE image of qusongite (1, 2) and Cr_2O_3(3, 4).

TABLE 3. Chemical compositions of qusongite and associated Cr_2O_3 intergrowths

Sample	Content (wt%)					Content (at%)			
	W	C	Cr	O	Total	W	C	Cr	O
1951-6-1	93.14	6.07	0.04	–	99.26	50.21	49.89		
1951-6-2	93.16	6.06	0.04	–	99.28	50.17	49.83		
Mean of 2 WC	93.15	6.06	0.04	–	99.27	50.19	49.81		
1951-6-3			68.42	31.58	100			40	60
1951-6-4			68.43	31.58	100.01			40	60
Mean of 2 Cr_2O_3			68.43	31.58	100.01			40	60

TABLE 4. Chemical composition of qusongite

Sample	Content (wt%)						Content (at%)	
	W	C	Cr	Ni	Ti	Total	W	C
50-13-1	93.19	6.13	0.04	0.01	0.01	99.38	50.01	49.99
50-13-2	93.63	6.1	0.04	0.01	0	98.82	50.049	49.951
50-13-3	93.601	6.055	0.051	0.011	0	99.738	50.2	49.8
50-13-16	93.222	6.11	0.031	0.012	0.01	99.483	50.004	49.996
50-13-17	93.741	6.16	0.03	0.013	0.01	99.951	49.815	50.185
50-13-18	93.452	6.092	0.04	0.011	0.012	99.615	50.009	49.991
50-13-19	93.373	6.081	0.031	0.014	0.01	99.503	50.079	49.921
50-13-20	93.502	6.074	0.041	0.011	0.009	99.636	50.009	49.991
50-13-21	93.3	6.084	0.04	0.011	0.008	99.395	50.002	49.998
50-13-22	93.074	6.034	0.04	0.012	0.007	99.188	50.103	49.897
50-13-23	93.433	6.062	0.05	0.013	0.006	99.565	50.033	49.967
50-13-24	94.48	6.011	0.04	0.011	0.007	101.549	50.58	49.42
50-13-25	92.731	6.011	0.031	0.011	0.005	99.801	49.895	50.105
50-13-26	93.361	6.013	0.04	0.012	0.004	99.971	50.304	49.696
Mean of 14	93.435	6.073	0.039	0.012	0.007	99.685	50.078	49.922

TABLE 5. Reflectance values (R%) of qusongite

R (%)	Wavelength (nm)	*R* (%)	Wavelength (nm)
36	400 nm	40.54	560 nm
36.55	420 nm	42.21	580 nm
35.19	440 nm	42.47	589 nm (COM)
38.28	460 nm	42.79	600 nm
36.41	470 nm (COM)	42.9	620 nm
38.95	480 nm	43.26	640 nm
39.39	500 nm	45.16	650 nm (COM)
41.42	520 nm	45.17	660 nm
38.61	540 nm	45.04	680 nm
38.1	546 nm (COM)	43.86	700 nm

TABLE 6. X-ray powder-diffraction data for qusongite

I_{obs}	d_{meas}	d_{calc}	*hkl*
44	2.833	2.831	1
94	2.511	2.513	10
90	1.8778	1.88	11
25	1.449	1.451	110
8	1.415	1.416	2
36	1.291	1.292	111
11	1.257	1.257	200
22	1.233	1.233	102
23	1.149	1.149	201
16	1.014	1.013	112
23	0.9008	0.9006	211

mantle origin. It is associated with several other metallic carbides, such as FeC, CrC, NiC, TiC, (W,Co)C, and $(Fe,Cr,Ni)_9C_4$.

These metallic carbides are believed to have been transported from the deep mantle by a plume and incorporated in the ophiolite during seafloor spreading. Blocks of the mantle containing the minerals were presumably picked up by later boninitic melts from which the chromitites precipitated, transported to shallow depth and incorporated into the chromitite (Robinson et al. 2004). It is also possible that some of the chromitite formed originally at depth in the mantle and was carried upward by mantle convection. A mantle origin for the metallic carbides is supported by the presence of numerous UHP minerals in the Luobusa chromitite, including diamond, moissanite, silicon spinel, MgO, FeO, SiO_2 (and coesite) [$(Ti,Si)O_2$, Fe-silicides, Cr_2O_3, Al_2O_3, CaO, and (Mg,Fe)] (Bai et al. 2000).

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