

## A STUDY ON DANBAITE FROM A COPPER-NICKEL SULFIDE DEPOSIT, SOUTHWEST CHINA

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The mineral is discovered from the heavy non-magnetic fraction of a concentrate of Cu-Ni sulfide deposit in SW China. By electron probe analysis, it is found to consist purely of Zn and Cu. The close association with native chromium and its X-ray characteristics indicate that both danbaite and native chromium are all of natural new-mineral species.

The mineral and its name have already been approved before publication by the Commission on New Minerals and Mineral Names, IMA.

### I. OCCURRENCE AND MINERAL ASSEMBLAGE

Danbaite was found in a platinum-bearing Cu-Ni sulphide deposit occurring in a sheet ultramafic intrusion in Carboniferous Daxue Group along the axis of a plunged anticline. The intrusion consists mainly of serpentized, steatitized and uralitized lherzolite, harzburgite and gabbro. Its upper country rock comprises carbonaceous slate, sericite-quartz-schist and thin marble, while the lower one, quartzite and marble.

The ore bodies, occurring in strongly serpentized and steatitized harzburgite of the middle-lower part of the ultramafic intrusion, are mainly of the disseminated, compact massive and taxitic types, the former two of which occur in the ultrabasic body, the latter one along the contact zone of ultrabasic body and marble. Danbaite occurs in the massive ore along the contact zone stated above, predominantly as botryoidal (Figs. 1 and 2) and spherulitic aggregates, up to a size 0.15 mm in diameter, and also in thin film 10  $\mu$  thick around the native chromium (Figs. 4—6).

**Table 1**  
Values ( $R$  %) of Reflectance of Danbaite

$\lambda$ (nm)	405	436	482	526	546	589	644	656	664	700
$R$ (%)	71.3	71	71	68.3	68.5	67.9	66.8	66.6	66.6	65.8

Determined by Zhou Xing

Probably due to the replacement effect, small amounts of Zn (1.12%) and Cu(0.28%) are noticed in the native chromium.

The associated metallic minerals are: pyrrhotite, pentlandite, chalcopyrite, pyrite, magnetite, ilmenite, cobaltite, safflorite, violarite, cubanite, bornite, galena and sphalerite. Besides, there are also some michenerite, sudburyite, omeite sperrylite, gold and electrum.

## II. PHYSICAL AND OPTICAL PROPERTIES

Under binoculars, the mineral is silverish-white and grayish-white in colour with strong metallic luster and without cleavage. VHN ranges from 238 kg/mm<sup>2</sup> (10 g load) to 234—286 kg/mm<sup>2</sup> (20 g load), average 267 kg/mm<sup>2</sup>, corresponding to Mohs hardness 4.2. The density is 3.760 g/cm<sup>3</sup> when  $Z=32$  (Zn, Cu).

Under reflected microscope, danbaite is white with weakly bluish tint, brighter than michenerite and somewhat pale yellowish as compared with the associated native chromium. Isotropic, without internal reflections and twinning. Taking WC as a standard, the values of reflectivity measured by means of MPV-1 are given in Table 1. From the values listed, it is evident that reflectivity decreases as the wavelength increases.

Quantitative colour values of danbaite obtained by means of the equivalent value ordinate method and according to light source ( $S_E$ ) suggested by Chen Zheng are: colour indices ( $S_E$ ), visible colour reflection,  $R_{vis}$  68.3, chromaticity coordinates of the colour,  $X = 0.3364$ ,  $Y = 0.3261$ , dominant wavelength of the colour  $\lambda_d = -519$ , purity of the colour,  $P_c = 0.0304$ . It shows that danbaite belongs basically to white mineral.

## III. CHEMICAL COMPOSITION

Quantitative analyses of danbaite were made on 2 samples with pure Cu and Zn as standards, using a JSM-35 Model scanning electron microprobe, at an accelerating voltage of 25 kV, absorption current of  $2 \times 10^{-8}$  A and fixed at brass stage, ZAF method for correction. The results are listed in Table 2, corresponding to  $CuZn_{1.9574}$ ,  $CuZn_{2.0164}$  on the basis of total atom=3, respectively. The ideal formula is  $CuZn_2$  and this corresponds to the natural Cu-Zn synthesis in  $\gamma$ -brass phase.

Table 2  
Micro-probe Analysis of Danbaite (wt%)

Sample	Cu	Zn	Total	Note
1	33.12	66.70	99.82	spherulitic aggregate
2	32.52	67.47	99.99	intergrowth with native chromium

## IV. X-RAY POWDER DATA

The danbaite grains were selected from the artificial heavy-mineral concentrates. The powder pattern was recorded on the following conditions: camera  $\phi = 57.3$  mm;



Fig. 1. Second electron image of botryoidal danbaite. ( $\times 264$ )

Fig. 2. Second electron image of botryoidal danbaite. ( $\times 264$ )

Fig. 3. Back-scattered electron micrograph of danbaite (a) and native chromium (b). ( $\times 960$ )

Fig. 4. X-ray distribution image for  $\text{CuK}\alpha$  radiation (a). ( $\times 960$ )

Fig. 5. X-ray distribution image for  $\text{ZnK}\alpha$  radiation. ( $\times 960$ )

Fig. 6. X-ray distribution image for  $\text{CrK}\alpha$  radiation. ( $\times 960$ )

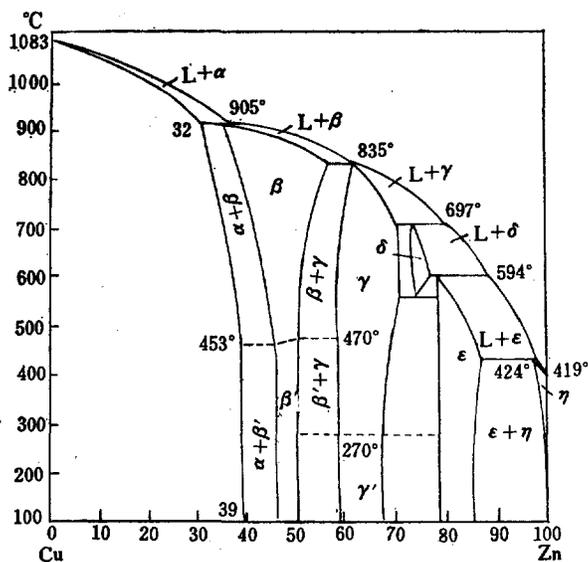


Fig. 7. The equilibrium diagram of copper-zinc alloys.

Ni-filtered,  $\text{CuK}\alpha$  radiation; 30 kV, 20 mA, 15 hr. The X-ray powder diffraction lines of danbaite can all be indexed on a cubic cell. Utilizing the variable scale method, the unit cell dimensions of the cubic lattice are determined to be  $a = 7.7615 \text{ \AA}$ , and cell volume  $V = 467.55 \text{ \AA}^3$ ,  $Z = 32$  (Zn, Cu). The unit cell parameters and both the observed and calculated  $d$ -spacings are listed in Table 3. The results are compared with the data for synthetic  $\gamma$ -brass.

## V. DISCUSSION

The alloys of copper-zinc system have six phases<sup>[1]</sup>,  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ ,  $\epsilon$  and  $\eta$ , which

**Table 3**  
Powder Data for Danbaite and Synthetic  $\gamma$ -brass

Danbaite				Synthetic $\gamma$ -brass (A. S. T. M25-1228)		
<i>hkl</i>	<i>I/I<sub>0</sub></i>	<i>d<sub>obs</sub></i> , Å	<i>d<sub>calc</sub></i> , Å	<i>hkl</i>	<i>I/I<sub>0</sub></i>	<i>d</i>
300,221	1	2.5815	2.5871	222	7	2.558
311	5	2.3552	2.3402	321	5	2.368
320	4	2.1574	2.1527			
321	10	2.0803	2.0743	330,411	100	2.088
410,322	1	1.8915	1.8824	332	5	1.8890
				422	3	1.8085
				510,431	3	1.7376
422	3	1.5901	1.5843			
511,333	1	1.4858	1.4937	600,442	6	1.4767
440	4	1.3732	1.3720			
600,442	1	1.2925	1.2936	631	2	1.3063
				444	3	1.2788
620	3	1.2256	1.2272	550,543	2	1.2530
621,540,443	3	1.2154	1.2121	633,721	10	1.2057
630,642	3	1.1603	1.1570			
631	2	1.1451	1.1444			
710,550,543	1	1.0959	1.0976	741	4	1.0906

<p>Danbaite Cubic: <math>a = 7.7615 \text{ \AA}</math>, <math>V = 467.56 \text{ \AA}^3</math> <math>Z = 32(\text{Zn,Cu})</math> <math>D_{\text{calc}} = 7.36 \text{ g/cm}^3</math></p>	<p>Synthetic <math>\gamma</math>-brass Cubic: <math>a = 8.860 \text{ \AA}</math>, <math>V = 695.51 \text{ \AA}^3</math> <math>Z = 4</math> <math>D_x = 8.027</math></p>
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fall into two classes: one is homogeneous primary solid solution, for example,  $\alpha$ -phase. The second one is electronic compounds<sup>(2)</sup>. The equilibrium diagram is shown in Fig. 7.

$\alpha$ -phase: Zinc atoms replace copper atoms in the Cu lattice, forming a substitutional type of primary solid solution. It possesses a texture of copper type and belongs to face-centered cubic lattice.

The ratio of electron number to atomic number (electron concentration) is called electron compound when it reaches a particular number, e.g.  $3/2$  ( $\beta$ -phase),  $21/13$  ( $\gamma$ -phase) and  $7/4$  ( $\epsilon$ -phase). Each phase has a distinct new lattice totally different from that possessed by the original element. This is the characteristics of the chemical compound which is made up of metals. Atoms in the compound do not display an ordered distribution. At higher temperature, these two elements no longer crystallographically occupy distinct sites, i.e., statistical distribution. Ordering takes place when temperature decreases to a certain value. Therefore, these electron compounds may be treated as intermediate members between chemical compounds and solid solutions.

$\beta$ -phase: The  $\beta$ -phase of Cu-Zn alloys comprises 36.5 to 46% of zinc. In equilibrium the  $\alpha$ - and  $\beta$ -solid solutions are formed. The ratio of electron valence number to atomic one is  $3/2$  or  $21/14$ , zinc atom takes up body-centered position while copper occupies corner position of the lattice or in the reverse. Below 453—470° the atomic

arrangement remains in order.

$\gamma$ -phase: Electron concentration of  $\gamma$ -phase of Cu-Zn alloy is 21/13, corresponding to  $\text{Cu}_5\text{Zn}_3$  solid solution. During crystallization, the compound forms a unit cell composed of 52 atoms, which makes up a complex cubic lattice. The unit-crystal texture of  $\gamma$ -phase is built up by 27 units of body-centered crystal lattice, which forms the complex structure (a lattice number less than 3-fold of lattice constant of  $\gamma$ -phase). At 270°C ordering occurs in this phase.

$\varepsilon$ -phase: the  $\varepsilon$ -phase occurs as  $\text{CuZn}_3$  solid solution with an electron atom ratio of 7: 4, hexagonal close-packed zinc crystal lattices are formed during crystallization.

The ratio of valence electron of danbaite to atom is 5/3, corresponding to  $\gamma$ -phase. Thus far,  $\alpha$ -phase of native Zn, Cu were discovered in South Ural<sup>[3]</sup>.

$\alpha$ -phase brass was also found at the porphyritic copper ore in China, its composition and characteristic lines of X-ray powder are analogous to those of  $\alpha$ -phase brass found in South Ural.

The zinc-bearing brass was found from Apollo-11 and -12<sup>[4]</sup>, which is also analogous to the terrestrial ones.

Native Cu-Zn alloy-danbaite, as an accessory mineral in ultrabasic Cu-Ni sulfide deposit, associates not only with sulfide and platinum group mineral, but also with several kinds of metallic minerals in a native state such as native chromium, native zinc, etc., which have higher melting point and show strong reduction properties.

The temperature (at constant pressure) at which the native element will melt is assumed to mark the upper limit of stability for that mineral<sup>[5]</sup>. Actually, the melting point is helpful in establishing the maximum temperature of mineral genesis. Again, the presence of small amount of extraneous material in crystal may alter the melting point of natural crystals. The melting temperature for intermediate metal compounds is lower than that for individual metal element. As mentioned above, it is observed that danbaite can only be formed under special circumstances and it is much more likely that formation of danbaite was related to the action of mantle magmatic fluids under the lowest oxygen fugacity conditions and at higher temperature. Thus, it is obvious that the discovery of this kind of mineral may provide valuable data for further studies of the composition and behaviour of the upper mantle.

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