Intergrowth texture in Au-Ag-Te minerals from Sandaowanzi gold deposit, Heilongjiang Province: Implications for ore-forming environment

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Sandaowanzi gold deposit, Heilongjiang Province, is the only single telluride type gold deposit so far documented in the world, in which 90% of gold is hosted in gold-silver telluride minerals. Optical microscope observation, scanning electron microscope, electron probe and X-ray diffraction analysis identified abundant intergrowth textures in the Au-Ag-Te minerals, typified by sylvanite-hosting hessite crystals and hessite-hosting petzite crystals. The intergrown minerals and their chemistry are consistent, and the hosted minerals are mostly worm-like or as oriented stripes, evenly distributed in the hosting minerals, with clear and smooth interfaces. These suggest an exsolution origin for the intergrowth texture. With reference to the phase-transformation temperature derived from synthesis experiments of tellurides, the exsolution texture of Au-Ag-Te minerals implies that the veined tellurides formed at 150–220°C. The early stage disseminated tellurides formed at $\log f(\text{Te}_2)$ from -13.6 to -7.8 , $\log f(\text{S}_2)$ from -11.7 to -7.6 , whereas the late stage veined tellurides formed at $\log f(\text{Te}_2)$ ranging from -11.2 to -9.7 and $\log f(\text{S}_2)$ from -16.8 to -12.2 .

Sandaowanzi gold deposit, Au-Ag tellurides, intergrowth texture, mineralization environment

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The Sandaowanzi gold deposit is a newly discovered epithermal-mesothermal telluride deposit, in which more than 90% of gold occur as telluride minerals, with gold grade up to 20000×10^{-6} . It is the only single telluride gold deposit ever documented in the world [1–3]. Tellurides are abundant in the Sandaowanzi gold deposit [1–4], including calaverite (AuTe_2), krennerite ($(\text{Au}, \text{Ag})\text{Te}_2$), petzite (Ag_3AuTe_2), hessite (Ag_2Te), coloradoite (HgTe) and altaite (PbTe), and possibly Au_2Te compound as suggested by the research [5]. Intergrowth textures are commonly seen in the Au-Ag-Te tellurides, mostly as sylvanite-hessite and petzite-hessite.

Au-Ag-Te system is a very common intermetallic compound group. Previous authors have carried out extensive synthetic experiment research, which revealed the rel-

ationship among Au-Ag-Te mineral crystal chemistry, paragenetic association and the temperature under which the minerals were formed: (1) transformation temperature of the synthetic minerals: in the Ag-Te binary system the transition of hessite from lower crystal category into higher class takes place at $145 \pm 3^\circ\text{C}$ [6–9]; for petzite in cubic system, the transition from low-temperature phase to high-temperature phase takes place at $210 \pm 10^\circ\text{C}$ [8,10]. (2) Under heating, petzite-hessite begins to form solid solution at 250°C [10]. Cabri [8], Markham [11,12] and Legendre [13] carried out respectively synthesis experiment of Au-Ag-Te system, of which Cabri's experiment was more successful, and he discussed the temperature for crystallization of the sythetic minerals and the phase-transformation. (3) Crystal chemistry: study of the crystal sturcture of natural Au-Ag-Te mineral series indentified incommensurate modulated texture and unique superspace texture [14–16]. Meanwhile,

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the crystal texture of telluride mineral are related to Au and Ag content [17,18], for example, crystal cell parameters a_0 and c_0 of calaverite increase with the increasing of Ag content [18]. Complex exsolution [19,20] and micrographic texture [21] of tsumoite were also reported in the Dashiugou Te deposit, Sichuan Province. By means of optical microscope, scanning electron microscope, electron probe and X-ray diffraction analysis, we conducted detailed study on the intergrowth textures, and looked into the ore-forming environment of the telluride gold deposit.

1 Ore deposit geology

The Sandaowanzi telluride gold deposit is located at the northeastern edge of the Da Hinggan Mountains. Gold mineralization is hosted primarily by the early Cretaceous trachyte and trachytic andesite of Tamulangou Formation. The mining area is regionally controlled by NWW- and EW-striking faults, and the NWW-striking extensional faulting is the major ore-hosting structure [22,23].

Gold telluride ore bodies are primarily hosted in quartz veins intruding the Cretaceous trachyte andesite and trachytic andesitic breccias, secondly in silicified trachytic andesite. There are 40 ore bodies in three ore belts. Amongst them, the ore body II is the only ore body mined to date (Figure 1). The length of the lenticular ore body is 212.6 m at the surface and its thickness varies from 0.81 to 14.3 m with an average of about 6 m. The transformation ratio of thickness is 59%. The ore body strikes 20° – 40° and dips 58° – 77° northwestward (the angle becomes smaller in the deep, and the minimum is only 30°), plunging to 520 m in the dip direction. There are two horizons of high

grade ores from 240 to 50 m, ranging from 1×10^{-6} to 20000×10^{-6} , and the highest grade is found at the 130 m horizon.

2 Tellurides

2.1 The ore occurrences and mineralogy

The tellurides mainly occur at the level from 90 to 130 m, within the ore body of Sandaowanzi gold deposit, and are rare at other levels. The quantity of tellurides in the ore body exhibits a positive correlation with the gold grade that averages 99.38×10^{-6} at the level from 90 to 130 m, with the highest grade up to 20000×10^{-6} . There are two major occurrence modes for the telluride gold ores in the deposit, veins and disseminations. Tellurides in the dissemination ores are dominated by hessite, petzite and sylvanite, frequently associated with sulfides, i.e. pyrite, chalcopyrite, tetrahedrite, galena and sphalerite. The tellurides in the vein-type ores mainly occur in 23 and 25 cross cuts at 130 m level of ore body, and the mineralogy is dominated by petzite, sylvanite, calaverite, native gold, and accidentally a new compound Au_2Te [5].

2.2 The ore-forming stages

Field observation and microscope study suggest that the ore-forming process may include three stages: (1) The early stage paragenesis include pyrite-quartz and polymetallic sulphides-quartz phases, hessite-dominated tellurides are rare in these assemblages. These ores are found at the level from 50 to 240 m. (2) The second stage, dominated by

Figure 1 (a) The geological map of Sandaowanzi gold ore district (after Tran et al. [1]); (b) tectonic map of Sandaowanzi gold deposit (after Tran et al. [1]). 1, Trachyandesite of Tamulangou Formation; 2, andesite breccia of Tamulangou Formation; 3, adamellite of Sandaowanzi Unit; 4, Early Cretaceous rhyolite porphyry; 5, diabase porphyrite; 6, Au-bearing quartz vein; 7, geological boundary; 8, unconformity boundary; 9, fault.

gold and silver tellurides, is the principal stage for gold mineralization, the ores from this stage are located at the level from 90 to 130 m. Paragenetic and structural evidences further subdivided this stage into two phases: 1) the earlier phase is expressed by quartz-hosted tellurides disseminations and the mineralogy is dominated by hessite, petzite and sylvanite, in which tellurides occur in the form of clump aggregate, and hessite commonly intergrows with sylvanite (Figure 2(a)); and 2) the later phase is expressed by telluride veins cross cutting telluride disseminations. The mineralogy is dominated by petzite and sylvanite, and intergrowth of petzite with hessite (occasionally with coloradoite or calaverite). Minor native gold is found in the second stage ores, which occur in two modes: 1) round grains coexisting with calaverite and 2) round grains in the cracks of petzite, occasionally associated with round grains

of the new compound Au_2Te . The late stage is expressed by carbonate-quartz veins with poor gold mineralization.

3 The intergrowth among tellurides

3.1 Mineralogy

Ore petrographic observation and Scanning Electron Microscope analysis (equipped with energy spectrum) have identified two types of intergrowth texture formed in the Au-Ag tellurides mineralization. Type I is characterized by intergrowth of hessite with sylvanite, in which hessite is the host, and sylvanite occurs as drips and stripes dispersed in hessite (Figure 2(a)); type II, petzite intergrows with hessite that occurs mostly as worm-like or strips in hessite (Figure 2(b)), occasionally hosting calaverite and coloradoite (Figure 2(c)).

Figure 2 Typical intergrowth textures in tellurides in Sandaowanzi gold deposit. (a) Sylvanite intergrown with hessite; (b) hessite intergrown with petzite; (c) hessite, calaverite and coloradoite intergrown with petzite; (d) typical spectrum characteristics of tellurides. Arrows show the orientation of the exsolution. Syl, sylvanite; Hes, hessite; Cav, calaverite; Ptz, petzite; col, coloradoite; Au, native gold.

3.2 Morphology of the intergrowth

In hessite-sylvanite intergrowth texture, sylvanite occurs as arrays of drips (2–20 μm in size) or stripes (10–35 μm in length and 2–5 μm in width) drip-like within hessite (Figures 2(a),3(a)). No sylvanite has been found outside hessite. The borders between the hosting and hosted minerals are smooth but show no evidence of replacement relationship. Hessite by volume accounts for about 2/3 of the intergrowth minerals, whereas sylvanite accounts for nearly 1/3, suggesting Ag_5AuTe_6 for chemical formula of this intergrowth.

In petzite-hessite intergrowth texture, petzite hosts hessite, and the latter occurs only within the former, as stripes, 10–50 μm long and 2–10 μm wide, never goes out of the host (Figures 2(b),3(b) and (c)). Also in the host include minor calaverite, as drips 50–150 μm long and about 3 μm wide, and coloradoite, mineral grains as drips from 3 to 5 μm across (Figures 2(c),3(d)). Petzite by volume accounts for nearly 2/3 of the intergrown minerals and hessite accounts for nearly 1/3, based on which we infer that the chemical formula of this intergrowth is approximately $\text{Ag}_8\text{Au}_2\text{Te}_3$.

In both intergrowth textures, the hosted minerals are

aligned and evenly dispersed in the hosting minerals. The shapes of the margins between the hosting and hosted minerals do not support a metasomatism origin.

Hessite in the intergrowth texture shows strong heterogeneity, varying from dark orange to dark bluish grey-colored under ore microscope. This suggests that the hessite is monoclinic [24]. Hessite's structure varies between isometric and monoclinic in response to temperature change, and the transition point is $145\pm 3^\circ\text{C}$ [6–8].

3.3 Chemistry of the intergrown minerals

The chemistry of the intergrown minerals were analyzed with scanning electron microscope equipped with energy spectrum and electron probe (Table 1). In type I of intergrowth texture, hosting and hosted minerals are hessite and sylvanite respectively. Based on the experiment data (Table 1), the content of Ag and Te in hessite are 60.63 wt% to 64.57 wt%, averaging 62.09 wt% and 35.37 wt% to 39.37 wt%, averaging 37.89 wt%, respectively. The content of Ag, Te and Au in sylvanite are 12.44 wt% to 12.44 wt% (with an average of 14.19 wt%), 57.39 wt% to 61.44 wt% (with an average of 59.75 wt%) and 23.09 wt% to 29.32 wt% (with an average of 26.07 wt%), respectively.

Figure 3 Typical intergrowth textures in telluride minerals. (a) Sylvanite intergrown with hessite; (b), (c) hessite intergrown with petzite; (d) hessite and calaverite intergrown with petzite. Hes, Hessite; Cav, calaverite; Ptz, petzite; col, coloradoite; Au, native gold.

Table 1 Chemical composition of the minerals in intergrowth textures (wt%)^{a)}

Intergrowth type		Number	Se	Au	S	Fe	Cu	Zn	Co	Ni	Ag	Te	Bi	Total	Chemical formula	Mineral species
Hessite-sylvanite intergrowth (by SEM)	Hosting crystal	1	—	—	—	—	—	—	—	—	60.63	39.37	—	100.00	Ag ₂ Te	hessite
		2	—	—	—	—	—	—	—	—	61.08	38.92	—	100.00	Ag ₂ Te	
		3	—	0.06	—	—	—	—	—	—	64.57	35.37	—	100.00	Ag ₂ Te	
	Hosted crystal	4	—	24.31	—	—	—	—	—	—	15.54	60.15	—	100.00	AuAg ₃ Te ₄	sylvanite
		5	—	29.32	—	—	—	—	—	—	13.30	57.39	—	100.00	AuAg ₃ Te ₄	
		6	—	27.56	—	—	—	—	—	—	12.44	60.00	—	100.00	AuAg ₃ Te ₄	
		7	—	23.09	—	—	—	—	—	—	15.47	61.44	—	100.00	AuAg ₃ Te ₄	
Petzite-hessite intergrowth (by EPMA)	Hosting crystal	1	0.15	25.27	—	—	—	—	—	0.00	41.43	32.58	0.19	99.63	AuAg ₃ Te ₂	petzite
		2	0.01	24.57	—	—	—	0.08	—	—	40.72	32.68	0.38	98.43	AuAg ₃ Te ₂	
		3	0.07	25.02	0.00	—	—	0.02	0.01	—	41.49	32.66	0.38	99.66	AuAg ₃ Te ₂	
		4	0.15	24.93	—	—	0.01	0.05	—	—	41.14	32.77	0.47	99.51	AuAg ₃ Te ₂	
		5	0.13	24.88	—	—	0.03	—	0.02	—	41.28	32.41	0.10	98.84	AuAg ₃ Te ₂	
		6	0.04	25.00	0.01	—	—	—	0.00	—	40.70	32.56	0.15	98.46	AuAg ₃ Te ₂	
		7	0.12	24.89	—	0.01	—	—	0.02	—	41.19	32.34	0.33	98.90	AuAg ₃ Te ₂	
	Hosted crystal	8	0.20	1.64	0.01	—	0.02	0.05	—	0.02	57.44	40.40	0.06	99.82	Ag ₂ Te	hessite
		9	0.09	0.45	0.02	—	0.00	0.02	—	0.00	57.84	40.57	0.01	99.00	Ag ₂ Te	
		10	0.18	0.36	0.01	0.01	0.03	—	—	0.03	58.54	40.56	0.06	99.77	Ag ₂ Te	
		11	0.18	0.24	0.03	0.03	0.02	0.03	0.02	0.02	58.96	40.54	0.01	100.08	Ag ₂ Te	
		12	0.15	0.43	0.01	0.07	—	—	0.03	—	58.21	40.64	0.00	99.54	Ag ₂ Te	
		13	0.26	0.92	0.01	0.01	—	—	—	—	57.68	40.48	0.04	99.40	Ag ₂ Te	calaverite
		14	0.18	0.67	0.01	0.01	—	—	—	—	58.39	40.03	0.04	99.32	Ag ₂ Te	
		15	0.16	0.63	0.02	0.04	0.01	0.05	—	0.01	58.68	40.85	0.02	100.46	Ag ₂ Te	
		16	0.19	40.48	—	—	—	—	—	0.02	1.48	55.86	0.76	98.78	AuTe ₂	
		17	0.20	41.88	—	0.02	—	0.04	—	0.01	1.28	54.72	0.66	98.79	AuTe ₂	
		18	0.06	41.38	—	0.03	0.01	—	0.00	0.01	1.30	55.01	0.67	98.46	AuTe ₂	

a) Testing units: Scanning electron microscope: University of Science and Technology Beijing. Electron probe: Mineral Resources Geology in Chinese Academy of Geosciences. Instrument types: JXA-8230; acceleration voltage: 20 kV; beam current: 20 nA; beam diameter: 1 or 5 μm ; the standards used for calibration: Pd/Au alloy for Au; AgS for Ag; HgTe for Te; CuFeS₂ for Fe, Cu and S; FeAsS, Sb₂S₃, PbS and ZnS for As, Sb, Pb and Zn, respectively. —, Below the inspecting line.

In type II intergrowth texture, petzite hosts in most cases hessite, occasionally calaverite and coloradoite. The petzite contains 40.70 wt% to 41.49 wt% Ag (averaging 41.14 wt%), 32.34 wt% to 32.77 wt% Te (averaging 32.57 wt%) and 24.57 wt% to 25.27 wt% Au (averaging 24.94 wt%). The content of Ag, Te and Au in hessite are 57.44 wt% to 58.96 wt% (averaging 58.21 wt%), 40.03 wt% to 40.85 wt% (averaging 40.51 wt%) and 0.24 wt% to 1.64 wt% (averaging 0.67 wt%), respectively. The content of Ag, Te and Au in calaverite are 1.28 wt% to 1.48 wt% (averaging 1.35 wt%), 54.72 wt% to 55.86 wt% (averaging 55.20 wt%) and 40.48 wt% to 41.88 wt% (averaging 41.25 wt%), respectively.

The atomic ratio of Au, Ag and Te in the intergrowth minerals are plotted in Au-Ag-Te diagram (Figure 4), which indicates that the chemistry of the hosting and hosted mineral are stable. For hessite, only a few analysis are compatible with the theoretical stoichiometry (Ag/Te=2/1), in most cases the content of tellurium is higher than theoretical stoichiometry. And the sylvanite has higher gold content than theoretical stoichiometry.

3.4 X-ray diffraction analysis

In order to determine the phases and cell parameters of the intergrown minerals, micro-zone X-ray diffraction and single-crystal X-ray diffraction were used on the basis of ore microscope observation, electron probe and scanning electron microscope analysis.

Micro-zone X-ray diffraction. The data of micro-zone X-ray diffraction was collected by a Rigaku D/max Rapid IIR 18KW Rotating anode micro-zone diffraction at the research center of X-ray diffraction of Central South University. The working condition was 45 kV and 35 mA with an X-ray beam diameter of 30 μm . The data was collected after 2 h and the 2θ ranged from 20° to 160°. The accuracy rating of d -values is higher than 0.001 Å.

With the consideration that the powder samples for X-ray diffraction analysis may contain impurities, micro-zone X-ray diffraction was applied. Sample 130CM23-13, derived from the vein type telluride ores has intergrowth texture. The detect zones are presented in Figure 5 and the micro-zone X-ray diffraction data are listed in Table 2. The

Figure 4 Ternary diagram of the intergrown minerals.

Figure 5 Micro-zone X-ray diffraction pattern of the intergrown minerals.

results indicate that the intergrown minerals are mostly petzite and hessite (Figure 5), which is consistent with the chemistry of the minerals determined by scanning electron microscope and electron probe.

Four crystals (also derived from sample 130CM23-13) were detected with single-crystal X-ray diffraction, on Bruker AXS SMART APEX diffractometer equipped with a CCD detector, working at 45 kV and 35 mA, at the State

Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Beijing). A hemisphere of data was collected with graphite-monochromatized MoK α ($\lambda=0.71073$ Å) radiation and frame widths of 0.3° in ω , 10 s per frame exposure time, at room temperature.

Petzite transforms from low-temperature phase ($a_0=10.38$ Å) of isometric system to high-temperature phase ($a_0=5.20$ Å) of isometric system at $210\pm10^\circ\text{C}$ [8,10], so the cell parameter of petzite can serve as an indicator of the crystallization temperature. The analysis of the four crystals yielded 10.39 Å, 10.38 Å, 103.9 Å and 10.41 Å, respectively, averaging 10.39 Å (Table 3). The results indicate that the petzite belongs to the low-temperature phase [9], and its crystallization temperature is lower than phase transition point $210\pm10^\circ\text{C}$.

4 Discussion and conclusions

4.1 Discussion

(1) Genesis of the intergrowth textures in tellurides. In the above intergrowth textures, the hosted mineral exhibit alignment and are evenly distributed within the host minerals. The chemistry and mineralogy are persistent in the intergrowth textures. The morphology of the hosted crystal does not support a metasomatic origin. From the above evidence, the authors suggest an exsolution origin for the intergrowth textures. Hence the exsolution intergrowth texture can serve as an indicator for ore-forming environment, such as temperature, tellurium and sulfur fugacity.

(2) Constraints of mineralization temperature. (i) Evidence from paragenetic association. The petzite-hessite

intergrowth paragenesis includes tellurides of petzite, hessite and calaverite and rarely native gold that is stable with calaverite (Figures 2(b),3(d)). Native silver was not discovered. With reference to the stability diagram of Au-Ag-Te-minerals (Figure 6) [25], the petzite-hessite-native gold and calaverite-native gold parageneses are stable at $150\text{--}280^\circ\text{C}$.

(ii) Evidence from exsolution. Heating experiments of petzite-hessite stock have revealed that the minerals begin to form solid solution at 250°C [10]. Therefore we infer that the petzite-hessite intergrowth formed below 250°C . Hessite shows strong heterogeneity (varying from dark orange to dark bluish grey) under a microscope, which suggests that the hessite is monoclinic rather than isometric. Synthesis experiments suggest that hessite transforms from isometric to monoclinic system at $145\pm3^\circ\text{C}$ [6–9], therefore we infer that the crystallization temperature of hessite is below 145°C . Combinations of the above arguments support the interpretation that the petzite-hessite intergrowth was formed below 250°C , as the hessite might have transformed from isometric system to monoclinic system after exsolution.

(iii) Significance of cell parameters of petzite for temperature indicating. The cell parameter of petzite is 10.38 Å, which indicates that the petzite belongs to the low temperature form of isometric system [8,10]. We can infer that the crystallization temperature of petzite is below $210\pm10^\circ\text{C}$, the transition point for petzite from low temperature form of isometric system to high-temperature form of isometric system.

All the above analysis suggest that the petzite-hessite intergrowth texture formed at $150\text{--}220^\circ\text{C}$, and the monoclinic hessite might have been formed below 145°C . The texture is always observed in vein ores that represents the late phase

Table 2 The micro-zone X-ray diffraction data of petzite

130CM23-13-1		130CM23-13-2		130CM23-13-3		JCPDS12-424 (petzite)	
d (Å)	I/I'	d (Å)	I/I'	d (Å)	I/I'	d (Å)	I/I'
2.77	100	2.77	100	2.78	100	2.77	100
2.12	49	2.03	63	2.12	49	2.12	80
2.03	22	2.12	58	2.45	38	2.03	70
2.32	20	2.32	44	2.03	27	2.32	60
2.44	15	2.45	42	2.32	26	2.44	60
1.89	13	1.89	29	1.89	13	1.89	50
3.00	8	1.32	20	1.32	13	7.50	50
1.32	8	1.38	11	3.00	11	1.31	50

Table 3 Cell parameters of petzite in sandaowanzi gold deposit

Samples		130CM23-13-a	130CM23-13-b	130CM23-13-c	130CM23-13-d
Sandaowanzi gold deposit	Formulas	AuAg ₃ Te	AuAg ₃ Te	AuAg ₃ Te	AuAg ₃ Te
		$a_0=10.39$ Å	$a_0=10.38$ Å	$a_0=10.39$ Å	$a_0=10.41$ Å
	Cell parameters	$b_0=10.39$ Å	$b_0=10.38$ Å	$b_0=10.39$ Å	$b_0=10.41$ Å
		$c_0=10.39$ Å	$c_0=10.38$ Å	$c_0=10.39$ Å	$c_0=10.41$ Å
Synthetic petzite [8,10]	High-temperature form	Isometric system $a_0=5.20$ Å			
	Low-temperature form	Isometric system $a_0=10.38$ Å

Figure 6 Stability diagram of Au-Ag-Te-minerals (after Bortnikov et al. [25]).

in the stage of Au-Ag telluride mineralization. The crystallization temperature of the intergrown minerals may represent the ore-forming temperature of the late phase of the Au-Ag tellurides stage. Previous fluid inclusion study of quartz from the Au-Ag tellurides yielded homogeneous temperature ranging from 220–320°C [2]. The lower limit temperature from the fluid inclusion study may correlate with the upper limit temperature of this study.

(3) Tellurium fugacity. With reference to the crystallization temperature data, we can discuss the tellurium fugacity in the ore forming process. The Au-Ag telluride mineralization process could be divided into two phases, i.e. the early dissemination ores and the late vein ores. The dissemination ores mainly contain tellurides, mostly hessite, sylvanite, petzite and minor altaite. The tellurides from this stage may coexist with sulfides, but native silver and calaverite have not been discovered. The hessite-sylvanite intergrowth texture is observed in minerals from this phase. On the basis of the homogeneous temperature (220–320°C) [2] and the stabilities of sulfides and tellurides as a function of $f(\text{Te}_2)$ and $f(\text{S}_2)$ (Figure 7) [26], we infer $\log f(\text{Te}_2)$ –13.6 to –7.8 and $\log f(\text{S}_2)$ –11.7 to –7.6 for the early phase dissemination ores (at 300°C). Petzite-hessite intergrowth texture discussed in this paper is found in the late phase vein type ores of the Au-Ag telluride mineralization. It formed below 220°C, dominated in mineralogy by petzite, hessite and calaverite. With reference to the stabilities of sulfides and tellurides as a function of $f(\text{Te}_2)$ and $f(\text{S}_2)$ at 200°C (Figure 8) [27], we infer $\log f(\text{Te}_2)$ –11.2 to –9.7, and $\log f(\text{S}_2)$ –16.8 to –12.2 for the later phase dissemination ores. All the evidence suggests that tellurium fugacity increased in

Figure 7 The stabilities of sulfides and tellurides as a function of $f(\text{S}_2)$ and $f(\text{Te}_2)$ at 300°C (after Afifi et al. [26]).

the mineralization, matched with decline of sulfur fugacity.

4.2 Conclusions

(1) The intergrowth textures are common in the Au-Ag tellurides in Sandaowanzi gold deposit. The intergrown minerals could be divided into two groups: sylvanite-hessite and petzite-hessite (coloradoite-calaverite). We propose an exsolution interpretation for the genesis of the intergrowth textures, which is supported by the morphologies of the textures, distribution patterns of the chadacryst mineral and mineral chemistry. Significantly, the intergrowth textures could provide ore-forming information of the Au-Ag telluride deposit.

(2) The petzite-hessite (or calaverite and coloradoite) in

Figure 8 The stabilities of sulfides and tellurides as a function of $f(S_2)$ and $f(Te_2)$ at 200°C (after Afifi et al. [27]).

tergrowth texture may have formed below 220°C, as evidenced by experimental exsolution temperature and crystal structure of the intergrown minerals.

(3) Disseminated tellurides were formed under $\log f(Te_2)$ from -13.6 to -7.8 and $\log f(S_2)$ from -11.7 to -7.6 in the earlier phase gold-silver tellurides. Veined tellurides formed under $\log f(Te_2)$ from -11.2 to -9.7 and $\log f(S_2)$ from -16.8 to -12.2 in the later phase gold-silver tellurides.

The study of exsolution in Au-Ag-Te minerals from Sandaowanzi gold deposit can provide direct mineralization information, especially the physicochemical conditions of ore-forming processes. The research results have significance for understanding ore genesis and providing guidance to mineral exploration.

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