

# 鋅赤鐵矾和鋅葉綠矾——兩種新的 硫酸鹽變種礦物

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作者在柴達木北緣某鉛鋅礦床氧化帶中找到兩種含鋅高的硫酸鹽礦物。經過詳細的礦物學研究，定名鋅赤鐵矾 (zincobotryogen) 和鋅葉綠矾 (zincocopiapite)。前者是赤鐵矾的變種礦物，後者是葉綠矾的變種礦物。

鋅赤鐵矾產於氧化帶偏上部位，其分布不廣泛，含量亦較少，但有時能局部富集，它與鎂明矾的共生關係密切。礦物集合體呈放射狀或聚集呈錐狀，塊狀者亦常見。單個礦物呈柱狀，常見有結晶完整的晶體。顏色呈鮮艷橘紅色，有時過渡到栗褐色。玻璃光澤到油脂光澤。條痕淺黃色。半透明。硬度約 2.5。比重 2.201。多色性顯著。近乎平行消光。負延長。二軸晶正光性。 $2V = 54^\circ$  (計算值)。 $r > v$ 。折光率  $N_g = 1.587$ ,  $N_m = 1.551$ ,  $N_p = 1.542$ ,  $N_g - N_p = 0.045$ 。晶體測角確定有  $b\{010\}$ ,  $o\{\bar{1}01\}$ ,  $l\{120\}$ ,  $m\{110\}$ ,  $n\{\bar{1}11\}$  和  $d\{101\}$  六種單形，其中前四種單形均很發育，後兩種則發育較差。化學成分：Fe<sub>2</sub>O<sub>3</sub> 18.34, Al<sub>2</sub>O<sub>3</sub> 0.01, MgO 2.50, MnO 1.75, FeO 0.85, CaO 痕量, ZnO 11.77, K<sub>2</sub>O 0.00, Na<sub>2</sub>O 0.05, H<sub>2</sub>O<sup>+</sup> 29.13, H<sub>2</sub>O<sup>-</sup> 0.22, SO<sub>3</sub> 36.03, 共計 100.65。計算分子式 (Zn<sub>0.64</sub>, Mg<sub>0.27</sub>, Mn<sub>0.11</sub>, Fe<sub>0.05</sub>)<sub>1.07</sub>Fe<sub>1.00</sub>(SO<sub>4</sub>)<sub>1.96</sub>(OH)<sub>1.00</sub> · 6.61H<sub>2</sub>O。理論分子式為 ZnFe<sup>'''</sup>(SO<sub>4</sub>)<sub>2</sub>(OH) · 7H<sub>2</sub>O。本區所產的鋅赤鐵矾，Mg、Mn 和 Fe<sup>''</sup> 置換了部分 Zn。粉晶分析主要晶面間距是 9.01(10), 5.24(8), 4.11(5), 3.24(6)。單晶分析確定為單斜晶系，晶胞常數  $a_0 = 10.488 \text{ \AA}$ ,  $b_0 = 17.819 \pm 0.057 \text{ \AA}$ ,  $c_0 = 7.185 \pm 0.006 \text{ \AA}$ ,  $\beta = 100^\circ 50'$ ，空間羣為 NO. 14.  $C_{2h}^5 - P2_1/n$ ,  $Z = 4$ 。差熱分析曲線全是吸熱效應，加熱至 247°C 有強吸熱谷出現，525°C 有弱吸熱谷出現，二者分別是脫失結晶水和結構水所引起的；750°C 和 855°C 又出現兩個較強的吸熱谷，它們是分兩次脫失 SO<sub>3</sub> 所引起的。

鋅葉綠矾產於氧化帶偏下部位，分布廣泛，為主要硫酸鹽礦物之一。共生礦物有葉綠矾和鐵明矾，伴生礦物有針綠矾、粒鐵矾、鈣鈉鐵矾和水綠矾等。礦物呈致密塊狀，顆粒大小均一，結晶細小，顯微鏡下所見晶形十分完整。顏色呈黃綠色。玻璃光澤。微透明至半透明。條痕灰白色發淡黃。硬度約為 2。比重 2.181。多色性顯著。斜消光。二軸晶正光性。 $2V = 78^\circ$  (計算值)。 $r > v$ 。折光率  $N_g = 1.586$ ,  $N_m = 1.554$ ,  $N_p = 1.534$ ,  $N_g - N_p = 0.052$ 。晶體測角確定有  $b\{010\}$ ,  $a\{100\}$ ,  $e\{0\bar{1}1\}$ ,  $M2\{1\bar{2}0\}$  和  $c\{001\}$  等五種單形，其中前三種均很發育，後兩種只在一個晶體上出現。化學成分：Fe<sub>2</sub>O<sub>3</sub> 25.35, Al<sub>2</sub>O<sub>3</sub> 0.00, ZnO 5.22, FeO 0.42, CaO 0.20, MgO 0.00, MnO 0.39, K<sub>2</sub>O 0.15, Na<sub>2</sub>O 0.05, H<sub>2</sub>O<sup>+</sup> 22.03, H<sub>2</sub>O<sup>-</sup> 5.58, SO<sub>3</sub> 41.23, 共計 100.62。計算分子式 (Zn<sub>0.41</sub>, Fe<sub>0.04</sub>, Ca<sub>0.02</sub>, Mn<sub>0.03</sub>)<sub>0.50</sub>Fe<sub>2.00</sub>(SO<sub>4</sub>)<sub>3.25</sub>(OH) · 9.18H<sub>2</sub>O。理論分子式為 ZnFe<sup>'''</sup>(SO<sub>4</sub>)<sub>6</sub>(OH)<sub>2</sub> · 20H<sub>2</sub>O。本區所產的鋅葉綠矾中之鋅很少被其他二價元素置換。粉晶分析主要晶面間

距是 9.25 (10), 6.12 (8), 5.66 (5), 3.56 (6)。单晶分析确定为三斜晶系, 晶胞常数  $a_0 = 7.35 \pm 0.04 \text{ \AA}$ ,  $b_0 = 18.16 \pm 0.03 \text{ \AA}$ ,  $c_0 = 7.28 \pm 0.03 \text{ \AA}$ ,  $\alpha = 93^\circ 50'$ ,  $\beta = 101^\circ 30'$ ,  $\gamma = 99^\circ 22'$ 。根据晶体的对称型, 确定空间群为  $NO. 2. C_2^1 - P\bar{1}$ 。  $Z = 1$ 。差热分析曲线全为吸热效应, 加热至  $205^\circ\text{C}$  出现了强吸热谷,  $350^\circ\text{C}$  出现了微弱吸热谷, 二者是分别脱失结晶水和结构水所致;  $540^\circ\text{C}$  和  $875^\circ\text{C}$  分别出现的弱吸热谷和  $815^\circ\text{C}$  出现的强吸热谷均属脱失  $\text{SO}_3$  所引起的。

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## ZINCOBOTRYOGEN AND ZINCOCOPIAPITE—TWO NEW VARIETIES OF SULPHATE MINERALS

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### (Summary)

Two new varieties of sulphate minerals, zincobotryogen and zincocopiapite, belonging to the botryogen group and the copiapite group respectively, were found in the oxidation zone of a lead-zinc deposit, situated on the northern border of the extremely arid Tsadam Basin.

Zincobotryogen is only locally well developed. It is in close association with pickeringite. It usually forms radiated crystalline aggregates, while single crystal is prismatic in shape. Zincobotryogen is bright orange red, translucent with glassy to greasy luster. It has a hardness of about 2.5, specific gravity 2.201. Optically zincobotryogen is biaxial positive, with negative elongation and strong pleochroism. Refractive indices are  $N_g = 1.587$ ,  $N_m = 1.551$ ,  $N_p = 1.542$ ,  $N_g - N_p = 0.045$ ,  $r > v$ ,  $2V = 54^\circ$  (calculated).

Crystal forms of zincobotryogen are  $b\{010\}$ ,  $o\{\bar{1}01\}$ ,  $l\{120\}$ ,  $m\{110\}$  and less frequently,  $n\{\bar{1}11\}$  and  $d\{101\}$ . Single crystal studies by the Weissenberg method show monoclinic symmetry, with space group No. 14.  $C_{2h}^5 - P2_1/n$ , cell constants  $a_0 = 10.488 \text{ \AA}$ ,  $b_0 = 17.819 \pm 0.057 \text{ \AA}$ ,  $c_0 = 7.185 \pm 0.006 \text{ \AA}$ ,  $\beta = 100^\circ 50'$ , and  $Z = 4$ . Strongest lines of the X-ray powder pattern are 9.01(10), 5.24(8), 4.11(5), 3.24(6).

Differential thermal analysis of zincobotryogen shows strong endothermal peak at  $247^\circ\text{C}$  due to loss of water of crystallization, weak endothermal peak at  $525^\circ\text{C}$  due to loss of structural water, and two relatively strong endothermal peaks at  $750^\circ\text{C}$  and  $855^\circ\text{C}$  due to loss of  $\text{SO}_3$ .

Chemical analysis of zincobotryogen gives  $\text{Fe}_2\text{O}_3$  18.34,  $\text{Al}_2\text{O}_3$  0.01,  $\text{MgO}$  2.50,  $\text{MnO}$  1.75,  $\text{FeO}$  0.85,  $\text{CaO}$  trace,  $\text{ZnO}$  11.77,  $\text{K}_2\text{O}$  0.00,  $\text{Na}_2\text{O}$  0.05,  $\text{H}_2\text{O}^+$  29.13,  $\text{H}_2\text{O}^-$  0.22,  $\text{SO}_3$  36.03, total 100.65. The calculated formula is  $(\text{Zn}_{0.64}, \text{Mg}_{0.27}, \text{Mn}_{0.11}, \text{Fe}'_{0.05})_{1.07} \text{Fe}''_{1.00}(\text{SO}_4)_{1.96}(\text{OH})_{1.00} \cdot 6.61\text{H}_2\text{O}$ . The theoretical formula of zincobotryogen would be  $\text{ZnFe}''(\text{SO}_4)_2(\text{OH}) \cdot 7\text{H}_2\text{O}$ , with Mg,  $\text{Fe}''$  & Mn replacing part of Zn.

Zincocopiapite is widely distributed, forming an essential sulphate mineral of the deposit referred to. It is in close association with copiapite, halotrichite, coquimbite, roemerite, sideronatrite and melanterite.

Zincocopiapite forms compact, massive aggregates. It is yellowish green, weakly transparent to translucent, with glassy luster. It has a hardness of about 2, specific gravity 2.181.

Microscopically, zincocopiapite displays well-formed outlines. It is biaxial positive, with strong pleochroism. The indices of refraction are  $N_g = 1.586$ ,  $N_m = 1.554$ ,  $N_p = 1.534$ ,  $N_g - N_p = 0.052$ ,  $r > v$ ,  $2V = 78^\circ$  (calculated).

Crystal forms of zincocopiapite are  $b\{010\}$ ,  $a\{100\}$ ,  $e\{0\bar{1}1\}$ , and rarely  $M2\{1\bar{2}0\}$  and  $c\{001\}$ . Single crystal studies by the Weissenberg method show triclinic symmetry, with space group No. 2.  $C_1^1 - P\bar{1}$ ,  $Z = 1$ , cell constants  $a_0 = 7.35 \pm 0.04 \text{ \AA}$ ,  $b_0 = 18.16 \pm 0.03 \text{ \AA}$ ,  $c_0 = 7.28 \pm 0.03 \text{ \AA}$ ,  $\alpha = 93^\circ 50'$ ,  $\beta = 101^\circ 30'$ ,  $\gamma = 99^\circ 22'$ . Strongest lines of the X-ray powder pattern are 9.25(10), 6.12(8), 5.66(5), 3.56(6).

Differential thermal analysis of zincocopiapite shows endothermal peaks at 205°C, 350°C, 540°C, 815°C and 875°C, the former two peaks being due to loss of water, the latter three — loss of  $\text{SO}_3$ .

Chemical analysis of zincocopiapite gives  $\text{Fe}_2\text{O}_3$  25.35,  $\text{Al}_2\text{O}_3$  0.00,  $\text{ZnO}$  5.22,  $\text{FeO}$  0.42,  $\text{CaO}$  0.20,  $\text{MgO}$  0.00,  $\text{MnO}$  0.39,  $\text{K}_2\text{O}$  0.15,  $\text{Na}_2\text{O}$  0.05,  $\text{H}_2\text{O}^+$  22.03,  $\text{H}_2\text{O}^-$  5.58,  $\text{SO}_3$  41.23, total 100.62. The calculated formula is  $(\text{Zn}_{0.41}, \text{Fe}''_{0.04}, \text{Ca}_{0.02}, \text{Mn}_{0.03})_{0.50} \text{Fe}'''_{2.00} (\text{SO}_4)_{3.25} (\text{OH}) \cdot 9.18 \text{H}_2\text{O}$ . The theoretical formula of zincocopiapite would be  $\text{ZnFe}'''_4 (\text{SO}_4)_6 (\text{OH})_2 \cdot 20 \text{H}_2\text{O}$ . The replacement of Zn by  $\text{Fe}''$ , Mn and Ca in our case is very negligible.