Betpakdalite $Ca_2MgFe_3^{3+}As_2^{5+}Mo_8^{6+}O_{36}(OH)\cdot 23H_2O$

Crystal Data: Monoclinic. *Point Group:* $2/m$. Crystals are short prismatic, with $\{hk0\}$ and $\{h0l\}$, or pseudo-octahedra, to 0.2 mm; in crystalline aggregates, powdery, as thin coatings, massive. *Twinning:* Many crystals are "oriented intergrowths of two or three individuals."

Physical Properties: *Cleavage:* {001}, very good. Hardness = ∼3 D(meas.) = 2.98–3.05 D(calc.) = 2.90

Optical Properties: Transparent. *Color:* Bright lemon-yellow with a pale greenish, rarely brownish, tint; greenish yellow in transmitted light. *Luster:* Dull to waxy. *Optical Class:* Biaxial (+). *Pleochroism:* Distinct; X = pale yellow; Y = greenish yellow; Z = bluish green. *Orientation:* $Y = b$; $X \wedge c = 12°$. *Dispersion:* Inclined, extreme. *Absorption:* $Z > Y > X$. α = 1.782–1.809 β = 1.797–1.821 γ = 1.850–1.857 2V(meas.) = n.d. 2V(calc.) = 53°–88°

Cell Data: *Space Group:* $C2/m$. a = 19.531(2) b = 11.061(1) c = 15.257(2) β = 131.57(1)° Z = 2

X-ray Powder Pattern: Kara-Oba deposit, Kazakhstan.
8.75 (10), 3.63 (9), 1.532 (8), 1.480 (8), 2.95 (7), 1.732 (7), 1.191 (7)

Chemistry:	(1)	(2)	(3)		(1)	(2)	(3)
MoO_3	50.26	52.9	52.42	H_2O^+	3.20		
As_2O_5	13.94	10.0	10.46	H_2O^-	15.80		
Fe_2O_3	12.30	11.2	10.90	H_2O		[19.4]	19.27
MgO		1.8	1.84	insol.	0.80		
CaO	4.18	5.3	5.11	Total	100.48	[100.6]	100.00

(1) Kara-Oba deposit, Kazakhstan. (2) Tsumeb, Namibia; by electron microprobe, total Fe as Fe_2O_3, H_2O calculated for stoichiometry; corresponds to $Ca_{2.1}Mg_{1.0}Fe_{3.1}Mo_{8.00}As_{1.9}O_{36}(OH)\cdot 23H_2O$. (3) $Ca_2MgFe_3Mo_8As_2O_{36}(OH)\cdot 23H_2O$.

Occurrence: Filling cracks in leached pyrite in the oxidized zone of a mineral deposit (Kara-Oba deposit, Kazakhstan); on vein quartz (Krupka, Czech Republic); in a deep oxidation zone of a dolostone-hosted hydrothermal polymetallic ore deposit (Tsumeb, Namibia).

Association: Ferrimolybdite, gypsum, jarosite, hydromica, "limonite", "opal" (Kara-Oba deposit, Kazakhstan); molybdenite, molybdite, quartz (Krupka, Czech Republic); scorodite, powellite, adamite, gerdtremmelite, wulfenite, hidalgoite, chalcocite, digenite, kaolinite, quartz, hematite (Tsumeb, Namibia).

Distribution: In the Kara-Oba Mo–W deposit, Bet-Pak-Dal Desert, central Kazakhstan. At Krupka, Krušné hory Mountains, Czech Republic. From Vaulry, Haute-Vienne, France. At Tsumeb, Namibia. From Elsmore, New South Wales, Australia.

Name: For the original occurrence in the Bet-Pak-Dal Desert, Kazakhstan.

Type Material: A.E. Fersman Mineralogical Museum, Academy of Sciences, Moscow, Russia, 62532, 62533.

References: (1) Yermilova, L.P. and V.M. Senderova (1961) Betpakdalite – a new mineral from the oxidation zone of the Karaoba wolframite deposit. Zap. Vses. Mineral. Obshch., 90, 425–430 (in Russian). (2) (1962) Amer. Mineral., 47, 172–173 (abs. ref. 1). (3) Čech, F. (1962) The yellow molybdic ochre from Krupka in the Krusne Mountains. Casopis Mineral. Geol. 7, 195–197. (4) (1962) Chem. Abs., 57, 3093–3094 (abs. ref. 3). (5) Schmetzer, K., B. Nuber, and G. Tremmel (1984) Betpakdalit aus Tsumeb, Namibia: Mineralogie, Kristallchemie und Struktur. Neues Jahrb. Mineral., Monatsh., 393–403 (in German with English abs.). (6) Moore, P.B. (1992) Betpakdalite unmasked, and a comment on bond valences. Aust. J. Chem., 45, 1335–1354. (7) (1993) Amer. Mineral., 78, 849 (abs. ref. 6). (8) Cooper, M.A. and F.C. Hawthorne (1999) The crystal structure of betpakdalite and a new chemical formula $Mg(H_2O)_6Ca_2(H_2O)_{13}[Mo_8^{6+}As_2^{5+}Fe_3^{3+}O_{36}(OH)](H_2O)_4$. Can. Mineral., 37, 61–66.