TABLE 2. Chemical composition (average ppmw) of 84 emerald samples by LA-ICP-MS.[a]

Element	Musakashi, Zambia	Kafubu, Zambia	Panjshir, Afghanistan	Davdar, China	Coscuez, Colombia	Muzo, Colombia	Peñas Blancas, Colombia	La Pita, Colombia	Chivor, Colombia	Detection limit
	11 samples, 55 spots	10 samples, 165 spots	15 samples, 205 spots	13 samples, 103 spots	12 samples, 100 spots	12 samples, 89 spots	2 samples, 10 spots	3 samples, 15 spots	6 samples, 35 spots	
^{7}Li	55–97 (73)	360–872 (576)	78–254 (113)	72–332 (109)	52–139 (83)	28–92 (45)	30–65 (48)	24–80 (44)	40–113 (67)	0.2
^{9}Be	40,700–55,6000 (47,260)	40,600–59,000 (49,630)	44,500–57,900 (51,578)	45,800–71,400 (54,515)	45,200–57,100 (50,448)	43,400–56,800 (51,053)	49,900–54,700 (52,480)	52,900–70,700 (58,666)	46,900–56,000 (50,365)	2.3
^{23}Na	1,150–5,900 (4,109)	14,200–20,100 (17,204)	2,470–15,600 (9,822)	4,200–12,500 (8,356)	2,530–6,500 (4,885)	1,890–9,860 (4,527)	2,390–4,100 (3,226)	1,980–7,000 (4,677)	1,340–6,090 (3,448)	8.8
^{24}Mg	928–5,740 (3,652)	12,600–17,400 (15,004)	1,790–15,700 (9,197)	3,420–11,700 (7,366)	2,100–5,840 (4,176)	1,720–6,590 (3,869)	2,280–3,740 (2,888)	1,840–6,830 (4,475)	1,100–5,280 (2,859)	0.4
^{27}Al	75,6000–108,000 (90,895)	64,100–92,400 (77,865)	71,900–110,000 (90,390)	81,200–153,000 (101,220)	83,400–112,000 (94,655)	81,300–109,000 (97,888)	96,600–109,000 (102,750)	92,300–129,000 (105,493)	84,600–110,000 (97,188)	3.6
^{39}K	25–102 (59)	305–890 (506)	52–1,590 (670)	102–609 (340)	6–46 (14)	7–49 (26)	8–11 (10)	bdl–40 (24)	bdl–30 (14)	3.0
^{45}Sc	40–240 (119)	12–75 (31)	49–2,290 (580)	54–916 (372)	2–258 (41)	34–706 (224)	36–82 (57)	94–344 (248)	6–173 (87)	0.8
^{51}V	588–2,100 (1,165)	71–180 (109)	255–3,680 (1,444)	657–6,960 (2,867)	656–6,210 (2,204)	673–6,920 (2,062)	317–3,960 (2,000)	6,000–10,100 (8,004)	218–2,020 (846)	0.3
^{53}Cr	1,340–6,170 (4,211)	733–4,330 (2,287)	118–4,730 (1,832)	146–5,630 (1,333)	172–6,330 (1,156)	208–4,890 (1,620)	1,810–2,540 (2,183)	2,940–10,700 (5,645)	671–2,880 (1,334)	2.5
^{57}Fe	680–1,490 (1,224)	5,900–11,600 (8,621)	1,010–9,820 (3,890)	1,230–4,350 (2,440)	285–1,130 (650)	188–2,030 (588)	164–656 (400)	200–383 (280)	117–862 (366)	18.4
^{69}Ga	13–29 (20)	9–19 (15)	12–38 (24)	10–43 (23)	13–54 (28)	17–44 (30)	12–30 (20)	32–36 (34)	7–40 (19)	0.1
^{85}Rb	1–5 (3)	17–105 (65)	4–110 (50)	3–29 (15)	0.7–3 (2)	0.8–5 (3)	0.6–1	bdl–4 (3)	0.5–3 (2)	0.1
^{133}Cs	3–10 (6)	527–2,210 (1,391)	11–97 (49)	6–41 (15)	7–19 (12)	4–19 (11)	3–10	5–12	6–16 (11)	0.1
^{47}Ti	bdl–30 (6)	6–25 (12)	bdl–67 (14)	bdl–63 (7)	bdl–27 (6)	bdl–14 (4)	4–7 (4)	bdl–5 (4)	bdl–7 (4)	2.1
^{60}Ni	bdl–12 (6)	7–38 (20)	bdl–14 (2)	bdl	bdl–3 (2)	bdl–3 (1)	bdl	bdl	bdl	0.5
^{66}Zn	bdl–2 (1)	12–44 (29)	bdl–5 (1)	bdl–8 (2)	bdl–2 (1)	bdl–5 (1)	bdl	bdl	bdl	0.4

[a]*Data reported in minimum and maximum values, with average concentration in parentheses; ppmw = parts per million by weight; bdl = below detection limit.*

TABLE 3. Summary of physical properties, UV-Vis-NIR absorption data, and trace-element chemistry of emeralds from five different localities.

Locality	Refractive index	Color filter reaction	Microscopic characteristics	UV-Vis spectroscopy (cations in addition to Cr^{3+})	Trace-element analysis (84 samples)
Musakashi, Zambia	1.572–1.582	Strong pink	Multiphase inclusions tend to be more irregular than those in Colombian gems; multiphase inclusions with at least two crystals associated with a gas bubble may indicate Zambian rather than Colombian origin	No significant Fe^{2+}-related absorption features in the NIR region, and no Fe^{3+} observed	Low alkali metal concentrations (1,530–6,060 ppmw) Cr > V; Cr/V ratio 1.7–5.3 Fe concentration: 680–1,490 ppmw Li vs. Cs log-log plot can help separate Musakashi from Kafubu and slightly separate from Colombia Fe vs. K log-log plot can help separate Musakashi from Colombia
Kafubu, Zambia	1.582–1.593 (RI values typically higher than other localities)	Inert	Multiphase inclusions are usually rectangular in shape, but may be irregular in outline; solid crystals of pyrolusite, chlorite, mica, amphibole, and tourmaline	Strong broad Fe^{2+} band at approximately 810 nm O-ray: narrow Fe^{3+} band at approximately 372 nm	High alkali metal concentrations (15,834–23,294 ppmw) Cr >> V; Cr/V ratio 8–40 Fe concentration: 5,900–11,600 ppmw Li vs. Cs log-log plot can help separate Kafubu from others
Panjshir Valley, Afghanistan	1.572–1.590	Inert to pink	Multiphase inclusions tend to be more elongated or needle-shaped than other localities; each may host several cubic to rounded transparent crystals, and sometimes small, dark opaque crystals	Medium broad Fe^{2+} band at approximately 810 nm O-ray: Fe^{3+} peak at 372 nm in some samples	Moderate to high alkali metal concentrations (3,946–17,505 ppmw) Cr and V concentrations may be similar: Cr/V ratio 0.3–3.3 Fe concentration: 1,010–9,820 ppmw Li vs. Cs log-log plot can help separate Panjshir from Kafubu, Musakashi, and Colombia (and Davdar, to a lesser extent)
Davdar, China	1.577–1.588	Pink	Multiphase inclusions are usually jagged or irregular in outline, and some are needle-like	Similar to Musakashi: Small broad Fe^{2+} band at approximately 810 nm Similar to Colombia: Strong V^{3+} bands at approximately 400 and 654 nm	Low to moderate alkali metal concentrations (5,190–12,620 ppmw) Slightly more V than Cr; Cr/V ratio 0.1–1.0 Fe concentration: 1,230–4,350 ppmw Fe vs. K log-log plot can help separate Davdar from Musakashi and Colombia Li vs. Cs log-log plot can help separate Davdar from Panjshir, to a lesser extent
Colombia (Muzo, Coscuez, La Pita, Peñas Blancas, and Chivor)	1.570–1.580 (typically lower than other localities)	Pink to strong pink	Classic jagged multiphase inclusions host a gas bubble and one or more cubic crystals; gas bubbles are usually smaller than the whole inclusion, and also smaller or about the same size as the associated cubic crystal	No Fe^{2+} or Fe^{3+} observed Weak to medium V^{3+} bands at approximately 400 and 654 nm	Low alkali metal concentrations (1,515–8,115 ppmw) Cr and V concentrations may be similar: Cr/V ratio 0.04 and 3.5 Fe concentration: 117–2,030 ppmw Fe vs. Ga and Fe vs. K log-log plot can help separate Colombia from others