

# **Non-Conformity in Online Marketplace Listings of Coloured Stones: Eight Months of Laboratory Verification, September 2024 to May 2025**

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## **Abstract**

Online marketplaces have become a recurring source of coloured stones for retail and intermediate buyers, yet the share of listings that withstand routine gemmological verification has not been measured at scale by a single laboratory. The acquisition window of the present study extended over eight months, from 15 September 2024 to 17 May 2025. Laboratory analysis began within one week of the first deliveries and continued beyond the close of the acquisition window, to accommodate late-arriving parcels and extended workups on ambiguous cases; preparation of the present note was completed in early 2026. Eight hundred and fifty-one coloured stones were purchased on twelve or more online platforms for a combined 51,008 CAD (mean 59.94 CAD per specimen). Of the 851 purchased, 723 specimens reached the laboratory and were examined at the bench; 128 specimens were invoiced on parcels that arrived short of stones and were never reshipped by the vendor despite formal request. Results are therefore reported against two denominators. The 851 figure is used for listing-level observations, which compare the vendor description with what was delivered. The 723 figure is used for bench-level observations, which rest on instrumental measurements of the stone itself. Both denominators are given whenever the distinction matters. The sampling frame was not random. Each listing was first screened by expert inspection of vendor photographs: specimens visibly incompatible with their declared species (evident glass surrogates, coarsely visible filling, impossible colours, mountings concealing the centre stone, dimensional inconsistencies) were not bought. Among the listings that passed this filter, only those whose declared material would, if the description held, retain a wholesale resale value above 100 CAD were retained. The sample therefore selects for the listings judged most likely to conform, and the figures below should be read as lower bounds on the prevalence observed in the broader external market. Specimens were examined at the Laboratoire Gem Québec under a triaged protocol: visual inspection, microscopy and refractive-index and specific-gravity determination were performed on every specimen received, while FTIR, UV-Vis-NIR, Raman, EDXRF and gamma spectrometry were applied selectively where first-pass findings did not already resolve the identification or the treatment status, or where archetype documentation warranted a full workup. Non-conformity is reported across four mutually exclusive failure modes and in combined form. Strict gemmological non-conformity, defined as a mismatch between declared and observed species, treatment or origin on the stone received, affected 558 specimens (65.57 per cent of 851 purchased, 77.18 per cent of 723 received). Non-delivery, defined as stones invoiced but never reshipped after a short-parcel arrival, affected 128 specimens (15.04 per cent of 851, a listing-level mode with no bench-level measurement). Weight overstatement on individual specimens physically received, defined as an individual measured carat weight more than ten per cent below the individual declared weight, affected 45 specimens (5.29 per cent of 851 purchased, 6.22 per cent of 723 received). Documentary non-conformity, defined as an authentic report from a recognised laboratory paired with a substituted stone, affected 7 specimens (0.82 per cent of

851, 0.97 per cent of 723). Global non-conformity combined across the four modes reached 86.72 per cent (738 of 851; Wilson 95 per cent confidence interval [84.28 per cent, 88.84 per cent]), with an equivalent bench-level figure of 84.37 per cent (610 of 723) once the 128 never-delivered specimens are set aside. Undisclosed or misdescribed treatments affected 73.03 per cent of the bench-level sample (528 of 723; Wilson 95 per cent confidence interval [69.68 per cent, 76.14 per cent]). Emeralds carrying filler without truthful declaration reached 79.17 per cent of the emeralds examined (38 of 48; Wilson 95 per cent confidence interval [65.74 per cent, 88.27 per cent]). Forty-eight specimens (6.64 per cent of 723 received) exceeded the 74 Bq/g gamma activity threshold, adopted as a conservative operational ceiling informed by the U.S. Nuclear Regulatory Commission (NRC) 2 nCi/g exemption value and consistent with the exemption philosophy of the International Atomic Energy Agency (IAEA) and the European Union basic safety framework; the count was dominated by irradiated topaz. The seven specimens in the documentary mode illustrate downstream report-substitution fraud, not a failure of the issuing laboratories. Nine recurring archetypes of non-conforming reporting were identified on the 155 documents that accompanied the stones. Stratification of the reconcilable subset of non-recognised reports (128 of the 142) against the conformity of the accompanying stone returned 118 non-conforming and 10 conforming (92.19 per cent non-conforming; Wilson 95 per cent confidence interval [86.22 per cent, 95.70 per cent]); a matched-size internal-market reference cohort of 128 specimens examined in parallel under the same protocol, drawn from independent laboratory inventory outside the 851 acquisition frame and carrying reports from recognised internal-market laboratories, returned 128 conforming and 0 non-conforming. Fisher's exact test (two-tailed) on the resulting 2×2 contingency yielded  $p = 1.71 \times 10^{-61}$  with a Haldane-Anscombe continuity-corrected odds ratio of 2,900 [95 per cent confidence interval 168, 50,044]. A non-recognised accompanying report was a stronger predictor of bench non-conformity on the stone than the absence of any document.

**Keywords:** *coloured stones, online marketplaces, treatment disclosure, gemmological laboratory, report substitution, radioactivity screening, gem fraud.*

## 1. Introduction

The coloured stone trade functions as two loosely connected segments. The internal market is organised around the recognised gemmological laboratories (AGL, Lotus, GRS, GIA, SSEF, Gübelin and a limited set of regional institutions) and the specialist dealer networks that price material against their reports. The external market covers generalist jewellers, open online auction platforms, tourist bazaars and liquidation channels. Since the growth of the open online marketplaces in the mid-2000s, coloured stones have moved into external retail channels at a scale no laboratory has yet quantified, and treatment disclosure practice in that segment has been documented only anecdotally in the trade and investigative press.

Disclosure and nomenclature frameworks do exist. The Laboratory Manual Harmonisation Committee (LMHC) publishes Information Sheets that harmonise laboratory report wording across its member institutions (LMHC 2025a, 2025b, 2025c; LMHC 2023). The World Jewellery Confederation (CIBJO, *Confédération Internationale de la Bijouterie, Joaillerie, Orfèvrerie*) issues *The Gemstone Book* (CIBJO 2022) as a reference on industry trade rules, and the American Gem Trade Association (AGTA) defines enhancement codes in its *Gemstone Information Manual* (AGTA 2025). None of these standards is enforced on platform listings. Individual archetypes of non-conformity have been characterised in earlier work: lead glass filling of ruby (McClure et al. 2006), emerald filler disclosure (Johnson et al. 1999; Kiefert et al. 1999), beryllium lattice diffusion in sapphire (Emmett et al. 2003; Abduriyim and Kitawaki 2006),

radioactive decay of neutron-irradiated blue topaz (Zhang et al. 2011), microscopic reference for natural, synthetic and treated corundum (Renfro et al. 2017a, 2017b), origin determination and low-temperature heat detection (Krzemnicki et al. 2024; Krzemnicki 2024), practitioner-level ruby and sapphire identification (Hughes et al. 2017) and fraudulent certification (Krzemnicki 2023). A single-laboratory count that cuts across species, platforms and report formats has not yet appeared in the peer-reviewed record.

The present note reports such a count for an eight-month window. Eight hundred and fifty-one coloured stones were purchased on the open web, each passed through the laboratory workflow, and the vendor statement (species, treatment, origin where stated, weight, accompanying document) was compared against instrumental findings. We do not set out to rank platforms or to accuse individual vendors. Our aim is to produce an auditable non-conformity rate on a targeted, high-value, pre-screened subset of listings. The resulting figure should be read as a lower bound on prevalence in the broader external market rather than as a general-population estimate.

## **2. Materials and Methods**

### ***2.1 Campaign window, acquisition versus analysis, sampling frame***

The study proceeded in four overlapping phases. The dates of each phase are given here for external reference. Acquisition of specimens on online marketplaces ran from 15 September 2024 to 17 May 2025 (the eight-month window used throughout this note as a rounded label for the campaign period). First-pass laboratory testing began with the reception of the earliest parcels in the week of 22 September 2024 and ran concurrently with ongoing acquisition. Full instrumental workup on flagged and ambiguous cases (FTIR, UV-Vis-NIR, Raman, EDXRF, gamma spectrometry) continued past the close of acquisition and was completed on 18 December 2025, to absorb late-arriving parcels and specimens held in queue for the full analytical chain. Writing of the present note opened on 1 January 2026 and closed in April 2026.

Two timelines need to be kept distinct when the figures are read. The eight-month figure refers to the acquisition window, 15 September 2024 to 17 May 2025. The analytical phase is necessarily longer. It opened a week after the first deliveries and continued past the close of acquisition, as described above. Writing was completed in early 2026, which is why references published during 2025 (LMHC 2025a, 2025b, 2025c; AGTA 2025) are cited against observations whose acquisition closed in May of that year. The 851 specimens do not form a random sample. They are the outcome of two successive filters applied at the point of purchase. The first filter was visual and exclusionary. Listings whose photographs were, to a trained gemmologist, already incompatible with the declared species were not bought. Typical grounds included evident glass surrogates, coarsely visible cavity or fissure filling, colours outside the natural range for the declared material, asymmetry or cut artefacts suggesting composite construction, mountings concealing the centre stone, and visible contradictions between stated weight and footprint. The second filter was economic. Only listings whose declared material would, if confirmed at the bench, carry a wholesale resale value above 100 CAD were retained. The 100 CAD threshold is an estimated wholesale resale value conditional on the declared material holding, not a listing price or a paid price; paid prices frequently sat well below this floor, since the sampling targeted listings whose stated material would produce a recoverable resale value if confirmed rather than listings at any given price point. Estimated potential value and actual paid price are tracked as separate variables and are both reported in Table 3. The combined filter reproduces the buying behaviour of an informed retail or intermediate buyer, who would

not knowingly acquire a stone already identifiable as non-conforming from photographs and who sets a minimum resale floor below which the laboratory testing cost cannot be recovered.

The bias therefore favours listings most likely to conform. An informed buyer would not knowingly have purchased an obvious counterfeit, and the visual filter mimics that behaviour. A random sample drawn over all listings on the same channels, including those the filter rejected, would almost certainly return a higher non-conformity rate. The figures below are therefore the residual rates observed after expert pre-screening, that is, the share of non-conformity that a buyer with gemmological training still failed to anticipate from vendor photographs alone.

A small number of specimens, on the order of ten across the 851, were acquired as components of bulk lots for which individual photographs or individual prices were not made available at the point of purchase. The visual filter could not be applied at the specimen level in those cases, and the lot was accepted on its aggregate description. The affected items are flagged where relevant in section 3.6 (notably Archetype 8, the two diamond specimens entering under the GDGL Bharat configuration) and are retained in the sample total.

## 2.2 Platforms and geography

Twelve online platforms contributed specimens, with long-tail presence from three regional physical markets listed through online intermediaries. Platform distribution is given in Table 1. Declared seller countries covered thirty-one states across five continents. Specimens sourced through Chanthaburi, Namak Mandi (Peshawar) and bankruptcy or estate online auctions are grouped separately because they represent identifiable sub-channels of the external market rather than mainstream platform storefronts.

*Table 1. Platform distribution of the 851 specimens. Shares are rounded to the nearest integer; the specimen counts are exact and sum to 851, and the integer shares sum to 100 per cent. The three entries below 2 per cent (Tophatter, Allegro, Residual) are rounded individually from exact shares of 1.06, 1.06 and 1.76 per cent respectively, so the Residual line at 2 per cent is an integer rounding of 1.76 per cent.*

Platform	Share (%)	Specimens (n)
Etsy	22	187
eBay	21	179
GemRock Auction	18	153
eBid	7	60
AliExpress and Alibaba	6	51
LiveAuctioneers	6	51
Chanthaburi (Thailand)	4	34
Bankruptcy and estate online auctions	4	34
Namak Mandi (Peshawar, Pakistan)	3	26
Bonanza	3	26
Invaluable	2	17
Tophatter	1	9

Allegro	1	9
Residual (peripheral sources)	2	15
<b>Total</b>	<b>100</b>	<b>851</b>

### 2.3 Inclusion, exclusion and final n

Of the 851 specimens purchased during the campaign, 128 (15.04 per cent of 851) were never delivered to the laboratory. The pattern was uniform: a parcel arrived on schedule, was opened and inventoried against the listing at the point of receipt, and a subset of the individually invoiced stones was not inside. Every parcel was received and signed for in person by the first author at the Laboratoire Gem Québec, and the reconciliation of parcel contents against the listing was performed at receipt. Where stones were found missing, the vendor was contacted by the first author as part of a systematic recourse procedure. Across the 128 missing specimens, the vendor responses clustered into a narrow set of recurring patterns. A majority of vendors denied that any stone was missing. A further subset offered to include an equivalent specimen on a subsequent purchase order rather than reship the missing material, the stated reason being the avoidance of additional shipping costs. No vendor in the sample agreed to ship the missing material at the vendor's own cost. The 128 missing specimens were therefore retained in the non-conforming count rather than dropped: the listing was non-conforming regardless of what eventually reached the laboratory, and the post-delivery recourse failed to resolve the discrepancy in every one of the 128 cases.

The “non-delivery” code records a listing-versus-delivery discrepancy on the stones actually shipped and does not impute intent to any individual vendor on a single-parcel basis. The aggregate response pattern across the 128 cases is reported as an observation on how the channel responds to missing-stone claims rather than as a finding on any named vendor. The code is distinct from the weight overstatement category defined in section 2.5, which applies only to specimens that did reach the laboratory and is measured stone-by-stone against the individually declared carat weight on the listing.

Subtracting the 128 non-delivered specimens from the 851 purchased yields 723 specimens physically received at the Laboratoire Gem Québec. These 723 are the denominator for every observation obtained at the bench. Two of the 723 were diamond specimens (0.28 per cent of 723 received; 0.24 per cent of 851 purchased). They are a methodological exception, documented here under Archetype 8 (GDGL Bharat, Gurugram, defined in section 3.6 and discussed in section 4), and are excluded from the species-specific treatment statistics, which focus on coloured stones.

Species distribution across the 851 specimens is given in Table 2. Price distributions, by estimated potential wholesale value and by actual paid price, are given in Table 3.

Table 2. *Species distribution of the 851 specimens.*

Species	n	Share (%)
Ruby	67	7.9
Blue sapphire	61	7.2
Sapphire (other colours)	104	12.2
Emerald	48	5.6

Topaz	24	2.8
Garnet (all varieties)	112	13.2
Tanzanite	64	7.5
Tourmaline	88	10.3
Spinel	92	10.8
Aquamarine	22	2.6
Morganite	14	1.6
Zircon	21	2.5
Chrome diopside	15	1.8
Peridot	32	3.8
Kunzite	8	0.9
Moonstone	16	1.9
Residual (opal, apatite, iolite, sphene, kyanite, alexandrite, chrysoberyl, gem fluorite)	63	7.4
<b>Total</b>	<b>851</b>	<b>100</b>

Table 3. Price distribution of the 851 specimens, by potential wholesale value and by actual paid price.

<b>Band (CAD)</b>	<b>Potential wholesale value (%)</b>	<b>Actual paid price (%)</b>
Below 100	0	62
100 to 300	52	31
300 to 500	32	4
Above 500	16	3
<b>Total</b>	<b>100</b>	<b>100</b>

#### 2.4 Instrumentation available at the laboratory

The 723 specimens physically received were examined at the laboratory using, as needed under the triaged protocol described in section 2.5, the following instrument set: a Mettler Toledo NewClassic MS balance; an Eickhorst GemLED refractometer (model GLD 0.01); polariscope and dichroscope from GIA GemInstruments; a Nikon SMZ1270 stereomicroscope used in darkfield, brightfield and fibre-optic illumination up to 80×; long-wave (365 nm) and short-wave (254 nm) ultraviolet lamps; a Thermo Scientific Nicolet iS5 FTIR; a Magilabs GemmoSphere UV-Vis-NIR spectrometer; a Renishaw inVia confocal Raman microscope; a Bruker Tracer 5i EDXRF; and an Ortec DigiBASE digital base coupled with a NaI(Tl) scintillation detector, used on loan for gamma spectrometry on irradiation-sensitive material. The gamma assembly was calibrated against certified reference sources before each session of use. Availability

of a given instrument at the laboratory did not imply its systematic application to every specimen. The 128 non-delivered specimens necessarily fall outside this instrumentation scope.

## **2.5 Analytical protocol and nomenclature**

For each specimen received at the laboratory we recorded the vendor-declared species, declared treatment, declared origin when given, declared weight, and the accompanying document (photographic or physical). The 128 specimens that never reached the bench carry only the listing-level record. The 723 received specimens were examined through a triaged sequence rather than a uniform battery. Every received specimen was given a first-pass workup combining visual inspection, stereomicroscopy in darkfield and brightfield up to 40× or 80× as required, refractive-index reading, specific gravity by hydrostatic weighing, and polariscope and dichroscope observation. A substantial fraction of the 723 resolved to non-conforming status at this stage alone: for heavily heat-treated corundum, clearly oil- or resin-filled emerald, outright species substitution and lead-glass-filled ruby, a few targeted observations at the microscope supported by one or two first-line tests were sufficient to classify the specimen within fifteen to twenty minutes of bench time. FTIR, UV-Vis-NIR, Raman, EDXRF and gamma spectrometry were applied selectively: on specimens whose first-pass examination left the identification or treatment status unresolved, on specimens whose listing or accompanying document warranted explicit instrumental corroboration for the record, and on specimens retained for archetype documentation. The vendor-declared and laboratory-observed statements were then compared specimen by specimen.

Species and variety names used throughout follow CIBJO (2022). Two nomenclature points are flagged here because they recur in the sections below. Tanzanite, at its first appearance in Table 2 and in subsequent sections, designates the blue-violet gem-quality variety of zoisite (calcium aluminium silicate hydroxide) as recognised in the CIBJO Gemstone Book; the single word is retained in the tables for legibility while the mineralogical identity is recorded here. Chrome diopside is used in the sense of diopside coloured by trace chromium, consistent with trade and laboratory usage and recognised under CIBJO (2022). Beryllium treatment of corundum is referred to throughout as lattice diffusion of beryllium into corundum, following CIBJO (2022) and reported as AGTA (2025) enhancement code D; the longer descriptive form is equivalent to the shorter trade locution beryllium diffusion and the two are used interchangeably where context permits. Treatment nomenclature follows the LMHC Information Sheets for corundum, emerald and generic organic fillers (LMHC 2025a, 2025b, 2025c; LMHC 2023). Enhancement codes follow AGTA (2025). Industry-level terminology follows CIBJO (2022). The LMHC Information Sheets cited as 2025a, 2025b and 2025c are the versions current at the time of writing (early 2026), bearing revision markers up to Version 10 (Sheet 3), Version 6 (Sheet 5) and Version 6 (Sheet 7); they are revisions of rule frameworks in continuous use at LMHC member laboratories since the founding of the committee in 2001, not new nomenclature. The substantive disclosure requirements invoked here (heat, glass infilling, emerald filler, diffusion) pre-date the campaign window by more than a decade, and the classification of non-conformity would have been identical on any earlier version of the same sheets. The radioactivity threshold followed U.S. NRC guidance at 2 nCi/g, equivalent to 74 Bq/g (U.S. NRC, n.d.; see also 10 CFR Part 30 Subpart B and NUREG-1717 for the broader exemption framework); specimens above this value were flagged as unacceptable for release and stored in quarantine pending further decay.

A specimen was recorded as non-conforming under any one of five conditions: species different from declared; treatment undisclosed or materially misdescribed; individual carat weight more than ten per cent below the individual declared weight for that specimen (applied stone-by-stone on the specimen identifier,

not on any aggregate parcel total); declared origin incompatible with the origin inferable at the bench on species for which origin determination is within the reach of the available methods; or accompanying document substituted, falsified or traced to a non-recognised issuing entity with method or signatory inconsistencies on the face of the report. Non-delivery (stones invoiced but absent from the parcel) is a sixth listing-level mode coded at receipt on the 851 purchased specimens. The ten per cent weight tolerance is adopted as an operational threshold consistent with laboratory practice and with the acceptable-variance ranges discussed in AGTA (2025) and CIBJO (2022) for trade-grade coloured-stone material. The origin criterion was applied only where the vendor had explicitly stated an origin; a listing that made no origin claim was not coded as non-conforming on the origin line. Each non-conformity was logged with the instrument or inspection that surfaced it. A listing carrying a non-recognised report was not reclassified as non-conforming on that ground alone if the stone itself matched the declared species and treatment at the bench: the specimen was logged as conforming at the stone level and the document was noted but not counted. Archetype 6 (section 3.4) is the inverse configuration and is handled separately.

The non-conformity criteria map, category by category, onto the published reference frameworks of the internal market. Species identification was coded against CIBJO (2022). Heat treatment of corundum was coded on the binary reporting convention of LMHC (2025c), “No indications of heating” (NH) versus “Indications of heating” (H): a specimen was coded as heat-undisclosed when the listing stated no treatment on a stone falling within the H category, and as heat-misdescribed when the listing used vocabulary (typically “natural”, “untreated”, “unheated” or “lightly heated”) incompatible with the H-category indications observed at the bench. Glass filling of fissures and cavities in corundum was coded against LMHC (2025a). Emerald clarity-enhancement fillers were coded against LMHC (2025b) and LMHC (2023) on the binary of filler present versus absent, with coloured or dye-loaded filler recorded as a distinct sub-category where the microscope or FTIR identified it. Organic and resin-based fillers in other species were coded against LMHC (2023). Beryllium diffusion of sapphire was coded as lattice diffusion of beryllium into corundum per CIBJO (2022), reported as AGTA (2025) enhancement code D where applicable, and treated as a binary of present versus absent; titanium surface diffusion of sapphire and HPHT of diamond were coded on the same binary using CIBJO (2022) terminology. Enhancement codes in the narrative follow AGTA (2025). None of these categories uses a criterion specific to our laboratory; each is tied to a named rule of a published industry standard.

Non-conformity as reported in this paper is a gemmological construct, measured as the mismatch between what the listing stated and what the instruments returned at the bench against the reference frameworks of LMHC, CIBJO and AGTA. It is not a legal or regulatory determination. Consumer-protection law varies across the jurisdictions from which the listings originated, and in several of them the disclosure of specific treatments is not mandatory at the point of sale, or the required disclosure vocabulary does not map one-to-one onto laboratory nomenclature. A listing coded as non-conforming here may therefore be legally compliant in its jurisdiction of origin; conversely, a listing coded as conforming could still fall short of a specific labelling rule that was not tested in this paper. The figures reported in sections 3 to 5 should be read within the gemmological framing adopted here and should not be extended to regulatory or legal claims about any named platform or seller.

## ***2.6 Sample size and statistical approach***

The sampling frame was driven by the acquisition strategy of section 2.1 rather than by a power calculation, with the 51,008 CAD campaign budget fixing the achievable *n*. A post-hoc calculation locates the precision

of the reported figures on the scale of a descriptive proportion study. For a single proportion  $p$  estimated to within a half-width  $d$  at confidence level  $1 - \alpha$ , the large-sample formula  $n = Z^2 p (1 - p) / d^2$  returns  $n \approx 483$  with  $Z = 1.96$ ,  $p = 0.87$ ,  $\alpha = 0.05$  and  $d = 0.03$ . The campaign  $n$  of 851 purchased and the bench-level  $n$  of 723 received both exceed that requirement. The achieved half-width is approximately  $\pm 2.3$  percentage points at 95 per cent confidence on the global listing-level figure ( $n = 851$ ),  $\pm 3.2$  on the treatment figure ( $n = 723$ ), and correspondingly wider on the emerald sub-sample ( $n = 48$ ), which is the smallest  $n$  on which a headline figure is reported.

Confidence intervals reported on the headline proportions are Wilson score intervals at 95 per cent confidence. The Wilson interval is preferred over the normal approximation (Wald interval) because it retains nominal coverage near the boundaries of the unit interval and on small samples, which matters for the emerald sub-sample ( $n = 48$ ) and for any replication conducted on smaller frames. Intervals are given to two decimal places, matching the precision of the underlying counts; readers who wish to recompute an interval on any proportion in Tables 5 or 6 have the numerator and denominator in the tables. Full Wilson intervals are reported here on the three structurally central figures (global non-conformity at 86.72 per cent, undisclosed or misdescribed treatments at 73.03 per cent, emerald filler non-disclosure at 79.17 per cent) in the abstract and at their first appearance in section 3; the remaining proportions are given as point estimates with their denominators, which is sufficient for recomputation.

One formal test is reported in section 3.5. For the  $2 \times 2$  contingency of bench outcome (conforming versus non-conforming) against report type (non-recognised external-market report versus recognised internal-market report) on the two matched  $n = 128$  groups described there, Fisher's exact test (two-tailed) is used in preference to a chi-square test because the expected cell counts are uneven under the observed configuration and one cell is zero. The associated odds ratio is given with a Haldane-Anscombe continuity correction (0.5 added to every cell) for the same reason, with the 95 per cent confidence interval computed on the log-odds-ratio scale. These are the only inferential statistics reported in the paper; all other figures are descriptive proportions with Wilson intervals on the headline rates.

## 3. Results

### 3.1 Global non-conformity, four-mode decomposition and report prevalence

Of the 851 specimens purchased during the campaign, 738 were non-conforming under the coding rules of section 2.5: a global listing-level non-conformity rate of 86.72 per cent (Wilson 95 per cent confidence interval [84.28 per cent, 88.84 per cent]). The remaining 113 specimens (13.28 per cent of 851 purchased, 15.63 per cent of 723 received) matched the listing across every field checked. Reading the same dataset at the bench level, with the 128 non-delivered specimens set aside because no measurement on them was possible, gives a non-conformity rate of 610 of 723, or 84.37 per cent among specimens physically examined.

The 738 non-conformities decompose across four mutually exclusive failure modes (Table 4). Strict gemmological non-conformity, defined as a mismatch between declared and observed species, treatment or origin on the stone received, affected 558 specimens (65.57 per cent of 851 purchased; 77.18 per cent of 723 received). Non-delivery, defined as stones invoiced on a parcel that arrived short and never reshipped by the vendor, affected 128 specimens (15.04 per cent of 851 purchased; by construction no denominator on 723 because these specimens never reached the bench). Weight overstatement on individual specimens physically received, defined as an individual measured carat weight more than ten per cent below the

individual declared weight on the listing for that specimen, affected 45 specimens (5.29 per cent of 851 purchased; 6.22 per cent of 723 received). Documentary non-conformity, defined as an authentic report from a recognised laboratory paired with a substituted stone (Archetype 6, section 3.4), affected 7 specimens (0.82 per cent of 851; 0.97 per cent of 723). The four modes are mutually exclusive under the primary-category rule applied in the coding, and their sum reproduces the combined figure (558 + 128 + 45 + 7 = 738; 65.57 + 15.04 + 5.29 + 0.82 = 86.72 per cent of 851). For a narrower gemmological reading that excludes non-delivery, weight overstatement and documentary substitution, the 558 strict-gemmological count can be used as the reference figure.

*Table 4. Four-mode decomposition of non-conformity. The four modes are mutually exclusive under the primary-category rule used in the coding, and their sum reproduces the 738 combined non-conforming specimens. The non-delivery mode is a listing-level failure with no bench-level denominator, because the specimens never reached instrumentation. The three bench-level modes are reported against both denominators; 610 of the 723 received specimens carried at least one of these three modes, for a bench-level combined rate of 84.37 per cent.*

Failure mode	Definition	n	Share of 851 (%)	Share of 723 (%)
Strict gemmological	Mismatch between declared and observed species, treatment or origin on the stone received.	558	65.57	77.18
Non-delivery	Stones invoiced on the listing but absent from the parcel received, with the missing material never reshipped by the vendor (listing-level mode, no bench measurement possible).	128	15.04	n/a
Weight overstatement	Individual measured carat weight more than ten per cent below the individual declared weight for that specimen (bench-level, on received stones only).	45	5.29	6.22
Documentary	Authentic report from a recognised laboratory paired with a substituted stone (Archetype 6, section 3.4).	7	0.82	0.97
<b>Combined (listing level)</b>	<b>Sum across the four mutually exclusive failure modes, on 851 purchased specimens.</b>	<b>738</b>	<b>86.72</b>	—
<b>Combined (bench level)</b>	<b>Sum across the three bench-level modes on the 723 specimens physically received.</b>	<b>610</b>	—	<b>84.37</b>

A finer seven-category taxonomy is reported in Table 5. The 610 bench-level cases are partitioned into species substitution, undisclosed treatment, misdescribed treatment, weight overstatement, misdescribed origin and authentic report with substituted stone, and the 128 non-delivered specimens form the seventh category. A specimen is coded as species substitution when the declared natural material is not what reached the bench. Among the 96 species-substitution specimens, the dominant sub-category is laboratory-grown material sold under a natural designation. Flame-fusion Verneuil synthetic corundum marketed as natural ruby or natural sapphire was the most frequent configuration, followed by hydrothermal and flux-grown synthetic emerald marketed as natural emerald and by a long tail of synthetic spinel, synthetic quartz and

doublet or triplet composites. Glass surrogates (including cobalt-doped glass imitating blue sapphire and lead-glass-backed doublets) and cross-species substitutes (typically red garnet sold as ruby, green quartz or fluorite sold as emerald, iolite sold as tanzanite) form the minor remainder of the 96. Laboratory-grown specimens are valid commercial products when disclosed; modern synthetic corundum and synthetic emerald are often visually indistinguishable from natural material on vendor photographs and on direct microscopy, and laboratory instrumentation (refractive index and specific gravity at first pass, Plato lines or curved striae under immersion microscopy, FTIR on resin-filled fractures and EDXRF on trace elements on ambiguous cases) is the regular route to separation.

Documents accompanied 155 of the 723 received specimens (21.44 per cent of 723, equivalent to 18.21 per cent of 851 purchased); the remaining 568 received specimens arrived without any document of any kind (78.56 per cent of 723 received). The 155 documents decomposed as follows: 142 were issued by entities outside the recognised internal-market laboratory set, with banners, sigla and signatory roles that either did not map to any verifiable institutional source or that imitated the visual identity of a recognised laboratory (19.64 per cent of 723 received; stratification against bench outcome in section 3.5, archetypes in section 3.6); 7 were authentic reports from reputable laboratories paired with substituted stones (0.97 per cent of 723 received; section 3.4); and 6 were authentic reports from recognised laboratories that correctly identified the specimen (0.83 per cent of 723 received). Of the 155 documents, 6 combined institutional recognition with factual accuracy on the specimen they accompanied (3.87 per cent of the documented subset; 0.83 per cent of 723 received).

*Table 5. Primary non-conformity type across the 738 non-conforming specimens. Where a specimen presented several non-conformities at once, it was assigned to the most severe category on the hierarchy below (non-delivery > species substitution > undisclosed treatment > misdescribed treatment > weight overstatement > misdescribed origin > authentic report with substituted stone). The non-delivery category is listing-level only (no bench measurement on undelivered specimens); the six bench-level categories are reported against the 723 physically received denominator, with the 851 purchased denominator shown alongside for continuity.*

<b>Primary non-conformity category</b>	<b>n</b>	<b>Scope</b>	<b>Share of 851 (%)</b>	<b>Share of 723 (%)</b>
Non-delivery (stones invoiced and never reshipped after short parcel)	128	Listing	15.04	n/a
Species substitution (declared natural material is not the material received; dominated by laboratory-grown specimens sold as natural, with synthetic glass and natural-species substitutes as the minor component)	96	Bench	11.28	13.28
Undisclosed treatment on correctly identified species	357	Bench	41.95	49.38
Misdescribed treatment (for instance a corundum specimen declared as natural, unheated or lightly heated where LMHC H-category indications were observed at the bench, or cedar oil declared on an emerald carrying coloured or dye-loaded filler)	76	Bench	8.93	10.51
Weight overstatement on correctly identified and truthfully treated species (individual received weight below individual declared weight by more than ten per cent)	45	Bench	5.29	6.22

Misdescribed origin on correctly identified and truthfully treated species	29	Bench	3.41	4.01
Authentic report paired with substituted stone (Archetype 6)	7	Bench	0.82	0.97
<b>Total (listing level)</b>	<b>738</b>	—	<b>86.72</b>	—
<b>Total (bench level; excludes non-delivery)</b>	<b>610</b>	—	—	<b>84.37</b>

### 3.2 Undisclosed or misdescribed treatments

Treatments that were undisclosed, or that were disclosed in a form materially inconsistent with our findings, were observed on 528 of the 723 specimens that reached the bench (73.03 per cent, Wilson 95 per cent confidence interval [69.68, 76.14]). Expressed against the 851 purchased listings, the same count represents 62.04 per cent and provides continuity with the listing-level accounting of section 3.1; the bench-level denominator is the appropriate one for the treatment analysis since an undisclosed treatment can only be established on a specimen actually examined. Table 6 decomposes the 528 into nine treatment categories, each specimen being assigned to its primary undisclosed or misdescribed treatment. Heat treatment dominated the count.

The 528 count of Table 6 differs from the sum of the two primary treatment categories shown in Table 5 (357 undisclosed treatment plus 76 misdescribed treatment, for a total of 433) and the reason belongs to the coding convention rather than to any discrepancy in the data. Table 5 assigns each specimen to its single most severe non-conformity under the hierarchy non-delivery > species substitution > undisclosed treatment > misdescribed treatment > weight overstatement > misdescribed origin > authentic report with substituted stone. Table 6 counts every specimen on which a treatment non-conformity was observed at the bench, regardless of whether the specimen carried another non-conformity of higher severity that claimed its primary code. The 95 specimens separating 433 from 528 are those on which a treatment non-conformity coexisted with a species substitution: the stone was coded as species substitution in Table 5 (the more severe category) and the same specimen is retained in Table 6 under its actual treatment category (typically undisclosed heat on a laboratory-grown corundum listed as natural unheated). The two tables therefore count the same specimens through two different lenses, the first exclusive and hierarchical, the second additive on treatment occurrences.

Corundum formed the most populated species group among the specimens received (rubies, blue sapphires and sapphires of other colours totalled 232 stones at the bench). Within that subset, 149 specimens carried either no disclosure or a disclosure that did not correspond to what we measured; this represents 64.22 per cent of the 232 corundum specimens and 20.61 per cent of the 723 specimens received overall. The FTIR 3309  $\text{cm}^{-1}$  series (principal bands at 3309, 3232 and 3185  $\text{cm}^{-1}$ ) combined with internal microscopic features provided the main evidence, with the natural, synthetic and treated corundum inclusion charts of Renfro et al. (2017a, 2017b) used as the reference atlas. Basaltic-origin corundum can show the same infrared bands in the absence of heating; each such case was flagged in the dataset rather than assigned. Low-temperature heating, for which the detection framework is still evolving (Krzemnicki 2024), is a separate source of methodological uncertainty and may account for part of what we coded as heat-misdescribed rather than heat-undisclosed.

Emerald treatment disclosure was the weakest of all species. All 48 emeralds examined carried filler, and 38 of them (79.17 per cent) reached us without truthful disclosure. Two treatments must be separated in the coding. Cedar-oil clarity enhancement is a long-accepted reversible treatment under LMHC (2023) and is not coded as non-conforming when truthfully declared on an uncoloured filler. Coloured or dye-loaded filler is a different matter: the trade name Joban oil is sometimes invoked, but the laboratory wording is clarity enhancement with coloured oil or oiling with dyed filler. The filler no longer only masks the fissures; it imports exogenous colour into the stone, the bulk colour seen by the buyer is partly the colour of the dye rather than the colour of the beryl, and the treatment falls under dyeing in addition to clarity enhancement. Such specimens were logged as non-conforming whether the listing was silent or declared “cedar oil”, since a cedar-oil declaration does not cover the dyeing component.

Added colour in the filler was, in most of our emerald cases, already visible at the microscope. Four criteria were recorded under darkfield and fibre-optic illumination at 40× to 80×: a green hue inside fissures stronger than the body colour of the crystal, colour that tracked the fracture geometry rather than crystallographic zoning, local saturation at fracture termini, and micro-accumulations of colorant where the filler had pooled. Pure cedar oil is effectively colourless and should not add colour to the fissures; the contrast between fracture colour and bulk colour of the crystal resolved the large majority of the 38 non-conforming specimens on visual grounds alone. FTIR was the final arbiter on the subset where the microscope left the filler nature unresolved, typically on heavily included stones or where a polymeric resin was suspected, and the infrared signatures were read against the reference frameworks of Kiefert et al. (1999) and Johnson et al. (1999) to place the filler in the natural oil, epoxy resin or polymer family. The paper makes no claim on the exact chemical identity of the colorant in any individual specimen; the laboratory-appropriate wording is “clarity enhancement with coloured oil” or “oiling with dyed filler”, and no trade name is asserted.

Lattice diffusion of beryllium into corundum, reported under CIBJO (2022) terminology and as AGTA (2025) enhancement code D where applicable, was observed on 51 specimens (7.05 per cent of the 723 received), almost entirely on orange-padparadscha to yellow-orange sapphires. Beryllium ( $Z = 4$ ) is not detectable by EDXRF at laboratory voltages; identification rested on the characteristic colour-rim pattern seen in immersion, on the UV-Vis-NIR signature, and on inspection of healed fractures at high magnification. The interpretative framework follows Emmett et al. (2003) for the physics of the treatment and Abduriyim and Kitawaki (2006) for the LA-ICP-MS confirmation routes where that instrumentation is available. None of the 51 diffused specimens carried a disclosure of diffusion on the listing.

Lead glass filling of ruby was observed on 17 specimens (2.35 per cent of the 723 received). Flash effect was the first visual cue, consistent with McClure et al. (2006): a bluish flash in brightfield illumination and an orange to orange-red flash in darkfield when the specimen was rocked through the viewing angle. EDXRF then resolved Pb at trace level. These specimens were logged as composites under CIBJO (2022) terminology rather than as treated rubies, and the buyers concerned were notified.

Irradiation was observed on 26 specimens (3.60 per cent of the 723 received) in the undisclosed category. Most irradiated blue topaz reaching the consumer market today traces to neutron irradiation (Zhang et al. 2011), and the majority of our irradiated topaz sample was listed as natural-coloured or carried no treatment statement at all. The remaining irradiation cases were distributed across zircon and a small tail of tourmaline and kunzite. Activity measurements are reported separately in section 3.3.

The remainder of Table 6 covers treatments less frequent in absolute count but systematically under-declared where they occurred. Dyeing was logged on 22 specimens (3.04 per cent of the 723 received), restricted to subtle professional-grade dye jobs on chalcedony and quartz where neither the colour nor its distribution would have been flagged on a vendor photograph by an experienced buyer; obvious bulk-dyed material (howlite, low-grade jade, massive turquoise) had been excluded at the visual filter and does not appear in this count. Polymer or resin impregnation was logged on 30 specimens (4.15 per cent of 723), chiefly on opal of Ethiopian origin and on B-jade jadeite where the polymer load is detectable under FTIR but not on a photograph; a small tail covered fossilised material. Undisclosed oiling or resin-fill on non-emerald species accounted for 15 specimens (2.07 per cent of 723), distributed across ruby, sapphire, spinel and tourmaline; FTIR was the primary diagnostic in each of the fifteen cases. A residual category of 6 specimens (0.83 per cent of 723) covered HPHT of the two diamond specimens in the sample (the same two specimens that enter Archetype 8 in section 3.6 under the GDGL Bharat configuration), titanium surface diffusion of sapphire, and other minor treatments.

Table 6. Decomposition of the 528 specimens affected by undisclosed or misdescribed treatments. Each specimen was assigned to its single primary treatment category.

Primary treatment undisclosed or misdescribed	n	Share of 723 (%)
Heat treatment (all species, principally corundum)	323	44.67
Beryllium lattice diffusion (sapphire)	51	7.05
Emerald fillers (oils and resins)	38	5.26
Polymer or resin impregnation (opal, B-jade jadeite, fossilised material)	30	4.15
Irradiation (topaz, zircon, tourmaline, kunzite)	26	3.60
Dyeing (chalcedony and quartz, professional-grade subtle only)	22	3.04
Lead glass filling of ruby (composite)	17	2.35
Oiling or resin-fill on non-emerald species (ruby, sapphire, spinel, tourmaline)	15	2.07
Other (HPHT of diamond, titanium surface diffusion of sapphire, miscellaneous)	6	0.83
<b>Total</b>	<b>528</b>	<b>73.03</b>

### 3.3 Residual radioactivity

Forty-eight of the 723 specimens examined at the bench recorded gamma activity above the 74 Bq/g operational ceiling on our detector (6.64 per cent of 723; 5.64 per cent of the 851 purchased, provided for continuity with the listing-level accounting). The remaining 675 specimens returned activity at or below 74 Bq/g and are not discussed further in this section. The radionuclide pattern identified on the decay spectra of the forty-eight matched the set reported by Zhang et al. (2011) for neutron-irradiated topaz ( $^{134}\text{Cs}$ ,  $^{182}\text{Ta}$ ,  $^{46}\text{Sc}$  and  $^{160}\text{Tb}$ ), and the species distribution of the forty-eight was dominated by irradiated topaz, followed by zircon and by a smaller group of sphene (titanite) with more variable activity readings.

The forty-eight above-threshold specimens fell into two sub-groups according to the vendor disclosure on the listing. Thirty-nine specimens (81.25 per cent of the 48; 5.39 per cent of the 723 received) carried no mention of irradiation on the listing or on any accompanying document, and several of the topaz in this sub-group were described as “natural” or “untreated”, which is inconsistent with the measured activity. The remaining nine specimens (18.75 per cent of the 48; 1.24 per cent of the 723 received) carried a disclosure of irradiation on the listing or on an accompanying report, but their residual activity at the moment of bench measurement still exceeded 74 Bq/g, with no indication on the listing of the elapsed decay time or of the point on the decay curve at which the specimen had been released for sale. Both sub-groups were logged as non-conforming: a disclosure of irradiation, on its own, is not a disclosure that the material has been held long enough for the short-lived radionuclide inventory to return below the exemption threshold.

Specimens above 74 Bq/g were not forwarded to the buyer and were placed under chain of custody at our laboratory. Quarantine release is conditional on the decay curve, not on a fixed calendar delay: each quarantined specimen is gamma re-measured at intervals consistent with the half-lives of the dominant radionuclides identified on its spectrum, and is released only once the measured activity returns below the 74 Bq/g operational ceiling (U.S. NRC, n.d.).

### ***3.4 Stone substitution with authentic reports***

Seven of the 723 specimens physically received formed a distinct category of concern (0.97 per cent of 723; 0.82 per cent of the 851 purchased). Each arrived with a report whose paper, hologram, format and security elements appeared authentic under our microscopic and UV inspection, and whose issuing laboratory was a recognised member of the internal market (five from GIA, two from Lotus Gemology). In every one of the seven cases, the stone accompanying the report was not the stone described on it.

The differences were subtle enough that a casual inspection would have missed them, but they were clearly visible under our 10× and 40× loupe routine. Typical mismatches included cut-geometry discrepancies of 0.2 to 0.4 mm on the major dimensions, inclusion patterns that did not correspond to the plotting diagram, and, where the original report recorded a laser inscription on the girdle, the absence of that inscription on the received stone. In two GIA cases, the laser code stated on the report was missing altogether from the specimen. The mechanism is well known in the trade but is rarely documented at the laboratory count: authentic reports are separated from the stones they originally described and are married to lower-grade look-alikes, often at a node further down the distribution chain. We refer to this as Archetype 6 in section 3.6.

We wish to state explicitly that the issuing laboratories named here (GIA, Lotus Gemology) and the laboratory discussed elsewhere in this paper under this archetype (ICA GemLab, operating in affiliation with the International Colored Gemstone Association) are not the parties at fault in the seven cases we report. The observed non-conformity is attributable to downstream substitution, and the reputable laboratories are themselves victims of the practice. Pala International has flagged the same mechanism in trade press, and SSEF has issued public caution (Krzemnicki 2023).

### ***3.5 Conformity stratified by accompanying report, with internal-market reference cohort***

Cross-tabulating the 155 documents received with the 723 bench-examined specimens against the conformity of the stone adds a further layer to the listing-level result. Of the 142 non-recognised external-market reports (the subject of the archetypes described in section 3.6), 128 were legible and complete enough for the bench finding on the accompanying specimen to be fully reconciled against the report; the

remaining 14 were fragmentary, illegible or carried insufficient identifying information and are recorded here as undetermined without further coding. Among the 128 reconcilable non-recognised reports, 118 accompanied stones that were non-conforming on species, treatment, weight or, where applicable, origin (92.19 per cent; Wilson 95 per cent confidence interval [86.22, 95.70]); the remaining 10 accompanied stones that matched the declared species, declared treatment and, where applicable, declared origin (7.81 per cent).

A reference cohort of 128 internal-market specimens was examined under the same laboratory protocol during the same period. The cohort was drawn from routine laboratory inventory submitted to the Laboratoire Gem Québec by regular clients and does not form part of the 851 specimens purchased on external marketplaces. Its role in the study is a matched reference point on the internal-market segment, not an addition to the acquisition count. It was diversified by species (corundum, beryl, tourmaline, spinel, garnet, topaz and tanzanite all represented), by origin (Burmese, Mozambican, Madagascan, Colombian, Zambian, Sri Lankan and Brazilian material all represented) and by issuing laboratory (AGL, GIA, Lotus Gemology, SSEF, GRS, IGI, AIGS and ICA GemLab all represented, among others). All 128 internal-market specimens matched the declared species, declared treatment and, where applicable, declared origin (100 per cent; 128 of 128; Wilson 95 per cent confidence interval [97.09, 100.00]). On every reviewed report the declared heat status, the declared clarity-enhancement code (LMHC N, M, E or S where applicable), the declared origin and the physical parameters of the stone were consistent with the bench finding.

Table 7. Bench outcome on the accompanying stone, stratified by the type of accompanying report. The two  $n = 128$  groups are constructed independently: the first is the reconcilable subset of the 142 non-recognised reports received with the 723 bench-examined external-market specimens (the 14 fragmentary or illegible reports are excluded from this stratification); the second is the internal-market reference cohort described in the text. Fisher's exact test is two-tailed; the odds ratio is Haldane-Anscombe continuity-corrected (0.5 added to every cell) because one cell is zero under the observed configuration.

Accompanying report type	Non-conforming stone (n)	Conforming stone (n)	Row total (n)
Non-recognised external-market (reconcilable subset of the 142)	118	10	128
Internal-market reference cohort (independent of the 851 acquisition frame)	0	128	128
<b>Column total</b>	<b>118</b>	<b>138</b>	<b>256</b>

Fisher's exact test (two-tailed):  $p = 1.71 \times 10^{-61}$ . Odds ratio (Haldane-Anscombe corrected): 2,900, 95 per cent confidence interval [168, 50,044].

Fisher's exact test on the contingency shown in Table 7 rejects independence at  $p = 1.71 \times 10^{-61}$ . On the material examined during the campaign window and against the matched-size internal-market reference cohort, the presence of a non-recognised external-market report predicted bench non-conformity more strongly than the absence of any document: 92.19 per cent of the 128 reconcilable non-recognised reports accompanied a non-conforming stone, against 86.72 per cent at listing level on the full 851 purchased and 84.37 per cent at bench level on the 723 received. A non-recognised accompanying report should therefore not be read as a mitigating factor on an external-market listing.

The reference cohort is a convenience set drawn from routine laboratory inventory and is not a random-over-all-internal-market sample. It is reported here as a matched-protocol reference point and not as a general-population estimate on the internal market, consistent with the 86.72 per cent external-market figure being itself a lower bound (section 4). The order-of-magnitude gap between the two segments is documented on matched instrumentation and matched coding rules. The figures are reported next to one another so that subsequent work can replicate, extend or qualify the comparison on larger and more representative frames.

### **3.6 Nine archetypes of non-conforming reporting**

One clarification is needed before the archetypes are described. In our coding, the presence of a non-recognised report alongside a specimen was not, in itself, sufficient to classify the specimen as non-conforming: where the stone on our bench matched the declared species and treatment, the specimen was logged as conforming and the document was set aside as non-recognised but not counted against the listing. The 142 specimens discussed here are those that arrived with a non-recognised external-market report (as stratified in section 3.5, 128 of these reports were legible and reconcilable to the bench outcome while 14 were fragmentary or illegible). The archetypes characterise the recurring patterns visible on the reports themselves and are therefore coded at the document level across all 142; the 118 of 128 reconcilable reports that accompanied a non-conforming stone constitute the subset where the document-level archetype and the bench-level non-conformity co-occurred. Archetype 6 is the inverse configuration, handled in section 3.4: the document is authentic and the stone is not.

Across those 142 specimens, the patterns of non-conformity on the reports clustered into nine recurring archetypes. Table 8 summarises the archetypes; the paragraphs that follow describe each in turn. Entities are named where their institutional reality is publicly verifiable through an official website or corporate registry, and withheld where no public institutional identity could be confirmed. This is the norm in the peer-reviewed gemmological literature (see for instance Krzemnicki et al. 2024; McClure et al. 2006).

A recurring pattern on the face of these reports is the construction of institutional-sounding names from three or four elements drawn from a short repertoire. These elements are a geographical qualifier (European, American, International, Asian), a scientific noun (Institute, Laboratory, Bureau, Centre), a subject-matter noun (Gemological, Gemstone, Mineralogical, Testing) and, in several cases, a corporate suffix (Worldwide, Global, Inc., Ltd). The resulting sigla resemble those of recognised bodies without claiming explicit affiliation. Named instances in our sample include Gemological Institute of Testing (echoing the Gem and Jewelry Institute of Thailand, Public Organization), Gemological Institute of Laboratory and similar sigla (echoing GIA), and EarthMined Gemstone Testing Laboratory with the letters EGL on the masthead (echoing the European Gemological Laboratory family). The practice is documented in the earlier fraud literature (McClure et al. 2006), and its frequency in current marketplace listings is noted here alongside the nine archetypes below.

At least thirty distinct issuing entities were identified across the 142 specimens. The nine archetypes described below capture the structural patterns that recurred on multiple specimens. The remainder of the count distributes across a long tail of individual laboratory identities, most of them operating from standalone websites without explicit mimicry of a named recognised institution, but sharing the nominal construction described in the preceding paragraph and, in a very large share of the cases we observed, attempting to reproduce visually the three- or four-letter abbreviations of recognised laboratories. The nine

archetypes are therefore a partial taxonomy of recurring patterns, not an exhaustive census of non-conforming reporting in this subset.

The patterns described under each archetype are what we saw on the face of the reports and on the accompanying specimens. The underlying causes cannot be determined from the documents alone. Plausible contributors include limited instrumentation at the issuing laboratory, absence of senior staff on a given shift, commercial pressure to deliver short-turnaround reports on volumes beyond laboratory capacity, procedural shortcuts on mounted material, and, in some cases, deliberate misrepresentation. Our taxonomy does not separate these causes, and the observations reported under each archetype should not be read as a final attribution of fraudulent intent to any named entity. Entities are identified at the institutional level where public verification is possible; specific personnel and internal processes are outside the scope of this study.

*Table 8. Nine archetypes of non-conforming reporting observed in the sample.*

#	Archetype	Core pattern
1	Mimetic acronym (Thailand)	Private entity issuing reports under an acronym close to a recognised public institution. Here, “GIT” as a private label, distinct from the Gem and Jewelry Institute of Thailand (Public Organization, git.or.th).
2	Mimetic European branding (India)	Indian laboratory issuing reports under a banner and logo that visually echo the European Gemological Laboratory family. Example: EarthMined Gemstone Testing Laboratory, domain earthmined.online.
3	Importer-integrated laboratory (Canada)	A Canadian laboratory whose operations are commercially integrated with an importer-vendor network in Southern Ontario. Identifying details are withheld to focus on the structural pattern rather than on a single operator.
4	Disproportionate valuation (Australia)	An Australia-based private certificate-issuing entity, distinct from the National Council of Jewellery Valuers (NCJV) and the Gemmological Association of Australia (GAA), that recorded inflated wholesale values on treated material.
5	Mimetic domain clones (Asia / North America)	Reports issued by online entities whose visible identity on the report and on the website reproduces the name of a recognised appraisal or certification service, with the top-level domain altered (for instance .ca replaced by .com, or .org replaced by .online) or the orthography slightly shifted. The reports carry the appearance of the cloned identity but are not produced by it.
6	Authentic report, substituted stone	Downstream substitution: an authentic report from a recognised laboratory paired with a look-alike stone. In our seven specimens this involved GIA (n = 5) and Lotus Gemology (n = 2). The same mechanism has been publicly flagged for ICA GemLab, operating in affiliation with the International Colored Gemstone Association. The reputable laboratories are not the parties at fault.
7	GIA-adjacent branding (India)	Indian entity whose name and report layout echo GIA conventions, producing reports on materials whose physical parameters are internally inconsistent. Example cluster: Gemological Institute of Laboratory and similar sigla (gemologicalinstitute.in).

8	Invalidating price point on diamond report (India)	An Indian diamond grading laboratory (GDGL Bharat, Gurugram, gdglbharat.com; distinct from GDGL Delhi, gdglindia.com) whose reports accompanied specimens priced well below the economic floor of genuine premium material.
9	Generic template and orthographic inconsistencies (Asia)	An Asia-based gem testing entity whose report template carries orthographic inconsistencies and whose corporate identity could not be verified against any public institutional source.

A few details supplement Table 8. Archetype 2 produced a second observed domain (egllabs.com) on two reports whose treatment fields read “None” or were left blank, while routine examination returned contradictory species and origin evidence. Archetype 3 is not an identification failure. The issue is the lack of procedural distance between the issuing laboratory and the commercial importer-vendor, which operate as a single distribution unit. Archetype 4 binds a retail-facing appraised value to a certification-style report in a configuration that the listing presents as a wholesale market value. Archetype 5 reproduces the visible identity, logo and body text of a recognised appraisal or certification service closely enough that a casual reader cannot tell the listing apart from the cloned original; no report in this archetype could be verified against the public records of the entity being imitated, and the recognised originals are deliberately not named here to avoid compounding the confusion on subsequent searches. Archetype 6 is covered in section 3.4. Archetype 7 produced reports whose physical parameters (refractive index, specific gravity, pleochroism) were internally inconsistent with the species stated, and the materials were often fundamentally substituted (synthetic for natural, glass for gem, diffusion-grade for untreated). Archetype 8 reached our corpus through a bulk lot where individual unit prices were not disclosed at purchase; once reconciled against the lot total, both diamond specimens fell well below the economic floor of genuine premium-grade material, which is why the visual filter did not separate them at the listing level. Archetype 9 is an Asia-based entity whose template carries repeated typographical errors in method names and signatory roles and whose corporate identity could not be verified against any accessible institutional source or commercial registry.

### ***3.7 Informal observation on paid price, to be explored on a dedicated sample***

An informal observation on paid price is included here. It is not a study result and should be explored on a purpose-built sample. The 851 specimens split into 825 paid at or below 500 CAD and 26 paid above 500 CAD; of the 738 combined non-conforming specimens from section 3.1, 728 were in the lower band and 10 in the upper. The non-conformity share was 728 of 825 (88.24 per cent) in the lower band and 10 of 26 (38.46 per cent) in the upper. Only the lower band supports any meaningful counting. The 26-specimen upper band carries no statistical weight on its own; a shift of two or three specimens would move the observed share by tens of percentage points, and the 500 CAD cut-off reflects where the campaign budget happened to distribute rather than any tested boundary. The two band figures are sub-sample breakdowns of the 86.72 per cent global rate of section 3.1, not independent estimates.

One interpretation worth testing on a dedicated sample is that above a certain paid price the buyer tends to verify, the seller anticipates that the specimen will be verified, and listings in the upper band become correspondingly more cautious. The 26-specimen upper band is too small to say anything about the location or the existence of such a threshold, and no behavioural cut-off, economic inflection or buying-side guidance is claimed here. Section 3.7 is an observation, not a result.

## 4. Discussion

The 86.72 per cent global non-conformity figure is high and has to be read against the sampling frame. The 851 specimens are the residual of a two-step expert visual filter applied at the point of purchase. Listings whose photographs were already incompatible with the declared species were not bought, and only listings whose declared material carried a wholesale resale value above 100 CAD were retained. The sample is biased toward the listings most likely to be conforming on visual inspection, and the 86.72 per cent figure measured downstream of that filter is best read as a lower bound on the prevalence of non-conformity in the broader external market. A buyer relying on visual inspection alone, with gemmological training comparable to ours, would still have acquired non-conforming material in the large majority of cases on the channels sampled during the campaign window.

Many of the individual findings are consistent with earlier work. Undisclosed heat in the corundum subset at 149 specimens out of 232 (64.22 per cent of the corundum received; 20.61 per cent of the 723 specimens received overall) aligns with the working assumption, common in the internal market, that untreated corundum is today the exception rather than the rule on the open web (Hughes et al. 2017; Krzemnicki 2024). Emerald disclosure at 79.17 per cent of the 48 emeralds received, each carrying filler and reaching the laboratory without truthful declaration, is consistent with the long-standing findings of Kiefert et al. (1999) and Johnson et al. (1999) that filler identification is analytically tractable but is unevenly performed in the trade. Lead glass filling of ruby at 17 specimens (2.35 per cent of the 723 received), all coded as composite material, remains numerically minor; the relevant finding is the persistence of the material on external channels as treated ruby, against CIBJO (2022) guidance. Beryllium diffusion at 51 specimens (7.05 per cent of 723) reproduces a pattern first characterised by Emmett et al. (2003) and later formalised for LA-ICP-MS by Abduriyim and Kitawaki (2006). Twenty years on, most consumer-facing listings in this segment still do not carry the disclosure.

The partial-misdescription category (76 specimens, 10.51 per cent of the 723 received; 8.93 per cent of the 851 purchased) covers cases where the listing did declare a treatment but understated or mislabelled it. Vendor statements of “cedar oil” were recorded on specimens whose fissures carried colour-bearing filler visible at the stereomicroscope (section 3.2). Vendor statements of “light heat” or “lightly heated” were recorded on corundum specimens whose 3309  $\text{cm}^{-1}$  series intensity and internal microscopic signatures placed them within the H category of LMHC (2025c) rather than in any low-temperature regime recognised by that framework. Origin was stated as a mine whose material does not carry the inclusion suite observed on several specimens, and on a smaller subset the declared carat weight exceeded the weight that reached us by fifteen to forty per cent on the individual stone. This class of non-conformity is harder to detect than outright substitution, because the buyer receives material that broadly matches the listing and the problem only becomes visible under routine bench examination. It is also the class where LMHC-aligned laboratory wording would have the most immediate effect if carried through into marketplace listings.

The radioactivity result is a safety finding rather than a finding on identification quality. Forty-eight specimens above 74 Bq/g (6.64 per cent of the 723 received; 5.64 per cent of the 851 purchased), dominated by irradiated topaz with zircon and sphene in lower count, fall above the working ceiling adopted at our laboratory. The 74 Bq/g value corresponds to the 2 nCi/g exemption described in the U.S. NRC framework for irradiated gemstones (U.S. NRC, n.d.; 10 CFR Part 30 Subpart B) and is used here as a conservative operational threshold in the absence of a gemmology-specific harmonised international value. The IAEA General Safety Requirements Part 3 (IAEA 2014) and the European Union Basic Safety Standards Directive

(Council Directive 2013/59/Euratom) both define the exemption framework in terms of radionuclide-specific activity concentrations without publishing a single activity limit keyed to gemstone materials, and the Canadian framework operated by the Canadian Nuclear Safety Commission under the Nuclear Substances and Radiation Devices Regulations (SOR/2000-207) does not currently publish a gemstone-specific limit either. An internationally harmonised gemmology-specific value would be useful for trade and regulatory practice alike. Zhang et al. (2011) produced the key decay curves; no equivalent post-2015 work on the modern supply mix has been published to our knowledge.

The stone-substitution sub-sample of seven specimens is numerically small but changes how verification must be understood. The presence of an authentic report from a recognised laboratory is not, by itself, sufficient evidence that the accompanying specimen is the stone described. Three cross-checks separate a valid authentic-report assertion from a fraud that uses the report as camouflage: laser inscription on the girdle where applicable, plotting-diagram match against inclusions at 40×, and weight and dimensions compared to the report. None is within the typical toolkit of a consumer-side buyer on an online marketplace.

The nine-archetype taxonomy is descriptive and not exhaustive. We recorded what reached our bench over eight months; we did not set out to propose a definitive classification. The taxonomy would benefit from replication by other laboratories on their own sampling frames and from consolidation of the more marginal archetypes (5, 8 and 9) on larger samples; Archetype 5 in particular (domain-clone reports) may be undercounted here because its detection depends on the reader knowing in advance which cloned identity is being imitated, and the figure reported is therefore a floor rather than a count.

A further limitation concerns the absence of a paired benchmark measured under the same protocol on the internal market. The 86.72 per cent figure quantifies the external market segment sampled here; it does not say what a comparable audit would return on the listings of the recognised internal-market channels (specialist dealer networks pricing against AGL, Lotus, GRS, GIA, SSEF, Gübelin and comparable reports). Laboratory experience and trade-press observation suggest that the non-conformity rate of that segment is an order of magnitude lower, but no study has yet measured it with a matched frame. The interpretation of the present figures therefore rests in part on a benchmark that remains to be produced, and replication of the protocol on the internal segment is a priority for future work so that the two numbers can be compared on like terms.

The study has several limitations. The sampling frame is non-random by construction: the expert visual filter excluded listings already incompatible with the declared species, and the 100 CAD wholesale floor excluded a large part of the open web below that threshold. A random-over-all-listings frame run on the same channels would almost certainly return a non-conformity rate higher than the 86.72 per cent reported here, and the present figures should be read as a conservative lower bound rather than as a point estimate for the broader external market; a paired random-control arm is a priority for replication work. Geographic reach was concentrated on platforms accessible from Canada, and platforms primarily serving the East Asian or South American consumer base are under-represented. Two diamond specimens appear in counts where coloured stones are the proper reference material; they were retained to illustrate Archetype 8 and carry no claim about the diamond segment. The hybrid listing/bench denominator is itself a methodological constraint: 128 of the 851 purchased specimens never reached the laboratory (non-delivery, 15.04 per cent of 851), which is why treatment, radioactivity and substitution figures are reported against the 723 actually examined, while global non-conformity is reported at listing level (86.72 per cent on 851) alongside a bench-level figure (84.37 per cent on 723) for continuity. The 128 non-delivered specimens were retained

in the listing-level count because the listing itself was non-conforming regardless of what eventually reached us.

The practical implication is straightforward. A coloured stone purchased on an online marketplace above a minimal price point should be subjected to independent laboratory verification before entering any further transaction. On the material examined here, the laboratory cost was a small fraction of the spread between asking price and authentic-material value when the listing held, and verification was the only mechanism that rendered the conforming fraction (113 of 851 at listing level, 113 of 723 at bench level) reliably usable.

## 5. Conclusions

On 851 coloured stones purchased over eight months from twelve or more online platforms and 723 specimens received at the laboratory, global non-conformity reached 86.72 per cent at listing level (84.37 per cent at bench level) and decomposed into four mutually exclusive modes defined in section 3.1. Undisclosed or misdescribed treatments drove the bulk of the figure (528 of 723, 73.03 per cent); irradiated topaz dominated the 48 specimens above the 74 Bq/g operational ceiling; and seven authentic recognised-laboratory reports were paired with substituted stones. Nine recurring archetypes were identified on the 142 non-recognised accompanying documents.

Stratification of the reconcilable subset of non-recognised reports (128 of the 142) returned 118 non-conforming and 10 conforming, against 128 of 128 conforming on a matched-size internal-market reference cohort drawn from independent laboratory inventory outside the 851 acquisition frame. Fisher's exact test on the resulting 2×2 contingency returned  $p = 1.71 \times 10^{-61}$  (Haldane-Anscombe odds ratio 2,900 [168, 50,044]). A non-recognised accompanying report predicted bench non-conformity more strongly than the absence of any document.

The two market segments differ by roughly an order of magnitude in the information a buyer can extract from a listing alone. On the data reported here, independent laboratory verification before or immediately after purchase is the only measure that blocked the failure modes described in sections 3.1 to 3.6. The existing frameworks of LMHC (2025a, 2025b, 2025c; 2023), CIBJO (2022), AGTA (2025) and, within their respective jurisdictional reach, the U.S. Federal Trade Commission consumer-protection guides (FTC 2018) already codify the disclosure standards whose absence accounts for most of the non-conformity figure. Applying those frameworks to marketplace listings would resolve most of the gap documented here. These points are recorded as non-normative reference points for trade and general readers, not as prescriptive guidance. Further work would benefit from replication of the protocol at other independent laboratories on their own frames, from extension to the diamond segment, and from coverage of the regional marketplaces not well represented here.

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## Declaration of interest

The Laboratoire Gem Québec is a commercial gemmological laboratory offering identification and certification services to the public. The laboratory has no ownership link to any marketplace, platform, issuing laboratory or vendor mentioned in this paper. The 51,008 CAD campaign budget was funded internally by the laboratory and no reimbursement was sought or received from any third party. The second author collaborates with the Laboratoire Gem Québec as an external research contributor through her affiliation with the Gem and Mineral Federation of Canada, and has no commercial relationship with any platform, issuing entity or vendor discussed here. Both authors independently declare that they have no conflicts of interest beyond those stated above. Observations are limited to the specimens examined during the campaign and should not be read as a general assessment of the productions of any named entity. Any entity identified in this paper that wishes to submit a documented rectification may do so to the corresponding author; the rectification will be appended in an annex of a revised version.

## Data availability

The per-specimen records underlying the aggregate counts reported in this note (specimen identifier, platform, declared species and treatment, laboratory findings, instrumental outputs where applicable, and photographic documentation of the accompanying reports) are retained at the Laboratoire Gem Québec under chain of custody for the quarantined radioactive specimens and under standard archival conditions for the remainder. Supplementary data can be made available on reasonable request to the corresponding author for independent scientific review, subject to redaction of individual vendor and buyer identifiers.

## References

- Abduriyim, A. and Kitawaki, H. (2006). *Applications of laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to gemmology*. *Gems & Gemology*, 42(2), pp. 98–118. Available at: <https://www.gia.edu/doc/SU06A1.pdf>
- AGTA (2025). *Gemstone Information Manual*, 16th edn. Dallas, TX: American Gem Trade Association. Available at: <https://agta.org/wp-content/uploads/2025/03/16thEditionGemstoneInformationManual20025.pdf>
- CIBJO (2022). *The Gemstone Book: Coloured Stone Commission*, 22 December 2022. Milan: The World Jewellery Confederation. Available at: <https://cibjo.org/wp-content/uploads/2023/01/22-12-22-Official-Gemstone-Book.pdf>
- Council of the European Union (2013). *Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation*. Official Journal of the European Union, L 13/1, 17 January 2014. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013L0059>
- Emmett, J.L., Scarratt, K., McClure, S.F., Moses, T., Douthit, T.R., Hughes, R.W., Novak, S., Shigley, J.E., Wang, W., Bordelon, O. and Kane, R.E. (2003). Beryllium diffusion of ruby and sapphire. *Gems & Gemology*, 39(2), pp. 84–135. <https://doi.org/10.5741/GEMS.39.2.84>
- FTC (2018). *Guides for the Jewelry, Precious Metals, and Pewter Industries, 16 CFR Part 23*. Washington, DC: U.S. Federal Trade Commission, revised final rule effective 24 July 2018.

- Available at: <https://www.ftc.gov/legal-library/browse/rules/guides-jewelry-precious-metals-pewter-industries>
- Hughes, R.W., Manorotkul, W. and Hughes, E.B. (2017). *Ruby & Sapphire: A Gemologist's Guide*. Bangkok: RWH Publishing / Lotus Gemology. ISBN 978-0-9645097-1-9.
- IAEA (2014). *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3 (GSR Part 3)*. Vienna: International Atomic Energy Agency. Available at: [https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578\\_web-57265295.pdf](https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf)
- Johnson, M.L., Elen, S. and Muhlmeister, S. (1999). On the identification of various emerald filling substances. *Gems & Gemology*, 35(2), pp. 82–107. Available at: <https://www.gia.edu/gems-gemology/summer-1999-identification-emerald-filling-johnson>
- Kiefert, L., Hänni, H.A., Chalain, J.-P. and Weber, W. (1999). Identification of filler substances in emeralds by infrared and Raman spectroscopy. *Journal of Gemmology*, 26(8), pp. 501–520. Available at: [https://www.ssef.ch/wp-content/uploads/2018/03/1999\\_Filler\\_Identification\\_Emerald\\_\\_J\\_Gemmo\\_ruduce\\_file.pdf](https://www.ssef.ch/wp-content/uploads/2018/03/1999_Filler_Identification_Emerald__J_Gemmo_ruduce_file.pdf)
- Krzemnicki, M.S. (2023). Too good to be true: SSEF measures against fraudulent gem scams. *SSEF News*, article last updated by the Swiss Gemmological Institute SSEF in 2023. Available at: <https://www.ssef.ch/too-good-to-be-true-ssef-measures-against-fraudulent-gem-scams/> (accessed 19 April 2026).
- Krzemnicki, M.S. (2024). Low-temperature heating of corundum: possibilities and challenges for detection. *Facette*, 29, pp. 6–9. Basel: Swiss Gemmological Institute SSEF. Available at: <https://www.ssef.ch/wp-content/uploads/2024/05/facette-2024-web.pdf>
- Krzemnicki, M.S., Wang, H.A.O., Wälle, M., Lefèvre, P., Zhou, W. and Cartier, L.E. (2024). Gemmological characterisation of emeralds from Musakashi, Zambia, and implications for their geographic origin determination. *The Journal of Gemmology*, 39(4), pp. 338–350. <https://doi.org/10.15506/JoG.2024.39.4.338>
- LMHC (2023). *Information Sheet No. 12: Organic fillers (oil, resin, wax) in gemstones*, Version 5, January 2023. Laboratory Manual Harmonisation Committee. Available at: <https://www.lmhc-gemmology.org/information-sheets/>
- LMHC (2025a). *Information Sheet No. 3: Corundum with glass filled fissures and/or cavities enhancing/modifying the clarity*, Version 10, May 2025. Laboratory Manual Harmonisation Committee. Available at: [https://www.lmhc-gemmology.org/wp-content/uploads/2025/09/LMHC-Information-Sheet\\_3\\_V10\\_2025.pdf](https://www.lmhc-gemmology.org/wp-content/uploads/2025/09/LMHC-Information-Sheet_3_V10_2025.pdf)
- LMHC (2025b). *Information Sheet No. 5: Emerald, fissure filling / clarity enhancement*, Version 6, May 2025. Laboratory Manual Harmonisation Committee. Available at: <https://www.lmhc-gemmology.org/information-sheets/>

- LMHC (2025c). *Information Sheet No. 7: Corundum, no indications of heating and indications of heating*, Version 6, February 2023 (listed in directory May 2025). Laboratory Manual Harmonisation Committee. Available at: <https://www.lmhc-gemmology.org/information-sheets/>
- McClure, S.F., Smith, C.P., Wang, W. and Hall, M. (2006). Identification and durability of lead glass-filled rubies. *Gems & Gemology*, 42(1), pp. 22–34. Available at: <https://www.gia.edu/doc/SP06A2.pdf>
- Renfro, N., Koivula, J.I., Muyal, J., McClure, S.F., Schumacher, K. and Shigley, J.E. (2017a). Chart: inclusions in natural, synthetic, and treated sapphire. *Gems & Gemology*, 53(2), pp. 213–214. Available at: <https://www.gia.edu/gems-gemology/summer-2017-inclusions-sapphire>
- Renfro, N., Koivula, J.I., Muyal, J., McClure, S.F., Schumacher, K. and Shigley, J.E. (2017b). Chart: inclusions in natural, synthetic, and treated ruby. *Gems & Gemology*, 53(4), pp. 457–458. Available at: <https://www.gia.edu/gems-gemology/winter-2017-inclusions-natural-synthetic-ruby>
- U.S. NRC (n.d.). *Backgrounder on irradiated gemstones*. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Public Affairs. Available at: <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/irradiated-gemstones> (accessed 19 April 2026).
- Zhang, J., Lu, T., Wang, M. and Chen, H. (2011). The radioactive decay pattern of blue topaz treated by neutron irradiation. *Gems & Gemology*, 47(4), pp. 302–307. <https://doi.org/10.5741/GEMS.47.4.302>