



IMA-CNMNC guidelines for assessing the natural geological origin of minerals

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Abstract. Establishing whether a newly discovered solid phase qualifies as a mineral of natural geological origin requires a thorough evaluation of its context of occurrence. This paper builds on the existing guidelines of the Commission on New Minerals, Nomenclature and Classification (CNMNC) and introduces updated recommendations, developed with input from the International Mineralogical Association (IMA) Mediation Committee (MC), aimed at strengthening the credibility of CNMNC mineral proposals, particularly for species with uncertain origins. Through a critical re-evaluation of three case studies (tewite, wumuite, and liguowuite), it is shown how textural and contextual evidence, or the lack thereof, impacts the assessment of natural authenticity. We propose an enhanced documentation checklist that incorporates geological, textural, and isotopic criteria to reduce ambiguity, avoid misinterpretation of anthropogenic phases, and safeguard against potential fraud.

1 Introduction

Minerals are the solid building blocks of the universe. According to the International Mineralogical Association's Commission on New Minerals, Nomenclature, and Classification (IMA-CNMNC), a mineral is defined as a homogeneous, naturally occurring solid substance formed through geological processes. This definition highlights that minerals originate from natural geological activity.

Biominerals are mineral substances for which organisms play a significant role in their formation but where geological processes are also involved. An example is the formation of the urea mineral in guano deposits, where a non-human organism, dead or alive, excretes a liquid that later crystallizes through evaporation, which is a geological process: evaporitic sedimentation. In contrast, solid chemical substances that entirely form within living organisms, such as kidney stones or pearls, are not classified as minerals according to the IMA-CNMNC definition, since their formation does not involve

any geological process. This distinction is important for accurately categorizing homogeneous natural solid substances within the field of geosciences.

As a result, the validation of a new mineral species relies on demonstrating its formation through natural geological processes. In recent years, however, CNMNC evaluators have increasingly encountered challenges with minerals proposed from contexts lacking clear *in situ* evidence, such as heavy mineral concentrates or isolated grains. Hazen et al. (2017) underscored the need for caution when dealing with minerals that blur the line between natural and anthropogenic origins. A further debated case concerns minerals formed on burning coal dumps, where distinguishing between natural self-ignition and human-induced fires is critical. To clarify this issue, the CNMNC issued specific guidelines stating that such phases may be approved as minerals only if their natural, non-anthropogenic origin is convincingly demonstrated (Parafiniuk and Hatert, 2020).

In response to these challenges, the IMA-CNMNC must consider evolving its criteria, particularly for cases where contamination, synthetic analogues, or unintentional laboratory synthesis could obscure the interpretation of natural origin. The geological setting and mode of occurrence are essential to define a mineral as natural. Since objections to new minerals of uncertain origin often arise from questions about their occurrence, the CNMNC should review and potentially revise its guidelines to clarify expectations for documenting the geological context in new mineral proposals. Such revisions would help to address concerns related to anthropogenic contamination and potential fraud more effectively. A more rigorous requirement for describing the mineral material would also ensure that applicants demonstrate a comprehensive understanding of the mineral's origin and have thoroughly evaluated the possibility of contamination.

In this context, the IMA Mediation Committee (MC) prepared a report in 2024, which was subsequently endorsed by the CNMNC. The aim was to contribute to a clearer redefinition of the natural status of new minerals of uncertain origin. This initiative calls for a more rigorous description of the geological context and the analytical techniques employed in the characterization of IMA-CNMNC proposals for minerals whose natural origin may be questionable. In essence, it formalizes good practices that careful authors already adopt on their own initiative. This update is not intended to introduce entirely new procedures but rather to formalize and reinforce existing good practices, in accordance with the 2024 recommendations of the IMA-MC. The goal is to minimize ambiguity and prevent misattribution due to anthropogenic influence or, in the worst cases, fraudulent claims.

2 Methodological framework for documentation

To ensure consistent and transparent evaluation of new mineral species, we recommend that submissions include the following components:

1. *Geographic locality.* Ideally, the locality should be specified to the nearest meter using latitude, longitude, and elevation. When such precision is not feasible – especially for historical specimens – the locality should be described as precisely as possible. For older material (e.g., from museum collections), efforts should be made to retroactively determine the collection site.
2. *Sample type.* Indicate the origin and the appearance of the sample, such as drill core, outcrop, hand specimen, dredge, or mineral separate, meteorite, or micrometeorite.
3. *Sample size.* Provide the dimensions and/or weight of the sample.
4. *Collector.* Identify who collected the sample. If it was not the applicant, describe how the sample was obtained.
5. *Collection date.* Specify when the sample was collected and when it was acquired by the researcher.
6. *Geological mode of occurrence.* Describe the geological setting (e.g., stratigraphic formation, intrusion, volcanic flow, hydrothermal vein, placer deposit, metamorphosed sedimentary or igneous rocks, hydrothermally altered rocks, meteoritic alteration). Particular attention will be paid to minerals harvested from old mines in which fire was used as a means of extracting ore: “fire-setting”. This ancient technique is responsible for the formation of numerous anthropogenic minerals collected in situ: metallic lead from the reduction of galena; zincite from the combustion of sphalerite; bunsenite, aerugite, johanngeorgenstadtite, xanthiosite, etc. from the combustion of Ni-Co arsenides (nickeline, safflorite, skutterudite, etc.).
7. *Age of material.* Indicate the best-known approximate age (e.g., Devonian or ~ 400 Ma). If available, include maximum and minimum age estimates and the method of age determination, with references. In some cases, isotopic dating may help in confirming the non-anthropogenic origin of the sample. Note that very often the host rock's age may differ from that of the new mineral.
8. *Associated minerals.* Provide a complete list of coexisting minerals directly associated with the new mineral at the micron, millimeter, and centimeter scale but also with the surrounding mineral paragenesis at the decimeter and meter scale
9. *Isotopic composition.* Report isotopic data for abundant elements such as oxygen (^{16}O , ^{18}O), carbon (^{12}C , ^{13}C), and nitrogen (^{14}N , ^{15}N) for possibly organogenic mineral and oxygen (^{16}O , ^{17}O , ^{18}O), magnesium (^{26}Mg , ^{24}Mg), and aluminum ^{26}Al for possible meteoritic mineral (e.g., Bindi et al., 2012). These values help to constrain potential origins and offer quantitative insights into source variation.
10. *Rare earth element spectra.* Performs and interprets comprehensive analyses in the case of minerals that contain rare earth elements (REEs). It is geochemically impossible, without human intervention, for them to contain only one of these elements (e.g., “texasite”, $\text{Pr}_2\text{SO}_4\text{O}_4$; Peacor et al. 1982). In nature, these elements are so chemically similar that they are always found together in minerals, in variable yet consistently close proportions. These relative proportions define characteristic distribution spectra. When describing an REE mineral, the most complete analysis possible must therefore be carried out. The spectrum can then be discussed to explain the dominant REE in the genetic context and geological occurrence (e.g., Brugger et al., 2025).

11. *Mineral origin.* Include any available evidence or interpretation regarding the mineral's formation process. For a magmatic mineral, in which conditions did it crystallize from the magma? For metamorphic species, which are the temperatures and pressure of formation? For alteration phases, in which Eh-pH conditions did they form and from which parent species? For species originating from space, in the case of meteorites, they must be validated by the Meteoritical Society before the new minerals they contain are submitted to the CNMNC. In the case of micrometeorites not submitted to the Meteoritical Society, they must undergo isotopic analysis (see point 9) and/or detailed chemical analysis in the case of metallic meteorites: Fe, Ni, Co, Ga, Ge, Ir, Pt.
12. *Synthetic equivalents.* Describe any known industrial or synthetic counterparts of the proposed mineral. For example, bahariyaite (IMA 2022-022) (Miyawaki et al., 2020), described in a water reservoir in an oasis in Egypt, is identical to potassium permanganate, KMnO_4 , a synthetic compound widely used to disinfect and sanitize water reservoirs and wells. Yttriaite-(Y), a native tungsten assemblage described at the Bolshaya Polya river in Russia (Mills et al., 2011), is like synthetic cermet used in space applications, particularly nozzles and warheads for missiles and hypersonic rockets (e.g., Fletcher and Phillips, 1978).
13. *Sample extraction.* Describe how the sample was extracted from the rock outcrop
 - a. by hand using a hammer and chisels;
 - b. mechanically using a jackhammer, a drill, or a boring machine with carbide-based cermets (see point 14);
 - c. with explosives, in which case it is important to mention the type of explosive (black powder, ammonium nitrate gel, ANFO, plastic bonded explosive, shaped charge, newly developed explosive Hypex Bio©, nuclear test, etc.) and the type of ignition (detonating cord, detonator with or without delay, etc.) (Ellern, 1968; Meyer et al., 2016). In fact, in the case of extraction using explosives, considerable temperatures and pressures are reached. Significant changes in the chemistry of minerals can occur (formation of nanodiamonds, quasicrystals, neoformed ammonium, peroxides, chlorine minerals, etc.) (e.g., Panich et al., 2020; Bindi et al., 2021; Ivanova et al., 2017). Pyrotechnic ignition elements such as detonators and delays are made up of numerous elements, metals, or compounds that contaminate rocks: Al, Cu, Pb, Hg, Ni, Fe, Ag, Au, Pd, Sb, Se, Te, Sr, Ba, Si, Ti, etc. For reasons of traceability of batches of explosives, pyrotechnic elements, and gunpowder, solid exotic elements or compounds such as Ho, Sm, Gd, and Ga are sometimes added as solid taggants (e.g., Seman et al., 2019; Galluser et al., 2022). Since the combustion of explosives is always incomplete, it is quite common to find microcrystals of explosive residues (PETN, picric acid, dinitronaphthalene, etc.) (Orlandi and Panunzi, 1998), some of which, particularly nitrates, can be confused with natural minerals (gwihabaite, niter, nitratine, nitrobarite, buttgenbachite, salmiac, etc.).
14. *Sample processing.* Outline how the sample was processed, including techniques such as mechanical crushing and milling, and specify the alloy used for grinding tools, e.g., steels with C, Mn, W, Mo, V, Cr, Co; sintered metal carbides, especially WC, TiC, TaC, or NbC in Co–Cr–W alloys (Stellite®); or SELFRAG process electric fragmentation (see Sperner et al., 2014). Clearly describe each step if multiple stages were involved.
15. *Grain separation methods.* Provide details on mineral separation procedures, including
 - a. panning, sluicing, or shaking table separation;
 - b. magnetic separation;
 - c. electrical separation, e.g., SELFRAG with the separation of conductive minerals in their insulating matrix;
 - d. liquid medium density separation, including
 - a. dense liquids, specify the medium (e.g., brine, bromoforme, diiodomethane, sodium, lithium or cadmium poly-tungstates, Clerici and Thoulet liquors, barium bromide, cesium tellurobromide);
 - b. sense aqueous thixotropic suspensions, specify the material (e.g., ferrosilicon, lead shot, magnetite, chromite, barite, glass beads).

The use of ferrosilicon aqueous suspensions is particularly concerning, as this material is produced in electric furnaces at very high temperatures (1500–2000 °C), forming numerous refractory by-products (silicides, carbides, nitrides, phosphides, sulfides, etc.) which can contaminate the separated minerals.
16. Provide details on the method and reagents used for mineral separation by flotation in the presence of water and air bubbles: the additives used pose a high risk of contamination or modification of the mineralogical composition (copper sulfate, sulfuric acid, sodium hydroxide, sodium cyanide, lime, potassium xanthate, dithiophosphates, thionocarbamates, etc.).
17. *Cleaning of mineral samples:* indicate whether physical or chemical cleaning of the samples studied has

been carried out. It is extremely common for mineral enthusiasts or dealers to use physical methods or aggressive substances to clean minerals, remove rust, dissolve calcite deposits, or improve the luster of crystals (Allington-Jones, 2017). Duthaler and Weiss (2023) describe a dozen physical cleaning methods and around 50 chemical substances used as cleaning agents. The most used acids are hydrochloric, oxalic, formic, acetic, phosphoric, and citric acids. Rust stains are removed with oxalic acid or buffered sodium hydrosulfite “dithionite”. Native metals such as copper or silver regain their metallic luster after treatment with hydrochloric acid, thiourea, cyanides, ammonium oxalate, etc. Often following chemical cleaning, when rinsing is insufficient, synthetic crystalline efflorescence can be observed (Kampf and Mills, 2010).

18. *Potential contamination.* Assess the likelihood of contamination and describe the measures taken to prevent or detect it.

3 Importance of geological context and contamination risk

The origin of a proposed new mineral is generally straightforward to evaluate when the specimen can be directly examined within its geological context, such as in a hand sample or thin section. However, the issue becomes significantly more complex when the material derives from mineral separates, especially from industrial concentrates subjected to extensive processing.

Such processing chains may involve drilling, blasting, extraction, transport, crushing, sorting, shaking, flotation, and other treatments. Each step introduces opportunities for contamination by anthropogenic materials or by unrelated minerals processed along the same chain. In these cases, single-crystal or monomineralic fragments often lack crucial contextual information, making it difficult to establish the identity of the source rock or the precise locality.

It is therefore essential that proposers clearly explain any potential sources of contamination and describe the precautions taken to rule out artificial origins. This includes addressing the possibility of fraudulent or unintentional synthesis, as documented in the literature (e.g., the cases of “texasite” and “albrittonite”; Peacor et al., 1982). Proactively addressing these concerns enhances the credibility of the proposal and helps ensure that the mineral’s natural origin is not in doubt.

4 Case studies

Tewite (IMA 2014-053) (Li et al., 2019), wumuite (IMA 2017-067a) (Xue et al., 2020), and ligowuute (IMA 2020-097) (Xue et al., 2022) are three W-bearing minerals de-

scribed from the same locality, from the same sample, which turns out to be a heavy mineral concentrate.

4.1 Tewite, ideally $(K_{1.5}\square_{0.5})(Te_{1.25}W_{0.25}\square_{0.5})W_5O_{19}$

Tewite, from the Pan–Xi region (China), was extracted from a heavy mineral concentrate. A key observation supporting its natural origin is the sharp intergrowth with tellurite (TeO_2), interpreted as a late-stage crystallization product. The source rock is a lightly weathered biotite adamellite near a gabbro contact, and associated minerals include scheelite, tellurite, and monazite-(Ce). These associations provide a plausible paragenesis and argue in favor of natural formation (Li et al., 2019). It is important to note that tewite, although it could initially be considered questionable due to the presence of tellurite in the synthesis products (or reactants), gained stronger support only after the publication of the wumuite description and the emergence of new textural evidence. In particular, Fig. 2 of that paper (Xue et al., 2020) shows intergrowths of wumuite, tewite, and scheelite, with features, such as larger crystal sizes and the presence of phases not listed among the starting materials, that strongly support the natural origin of both species.

4.2 Wumuite, ideally $KAl_{0.33}W_{2.67}O_9$

Also recovered from the same sample, wumuite shows compelling evidence of natural origin. Inclusions of scheelite within wumuite grains and intergrowths with tewite and other accessory phases (e.g., ilmenite, zircon) demonstrate a coherent mineral assemblage consistent with a single geological event (Xue et al., 2020). The presence of multiple textural relationships, supported by BSE imaging, strengthens its case.

4.3 Ligowuute, ideally WO_3

The case of ligowuute, a tungsten trioxide nanocrystalline phase, is borderline. Despite being found alongside tewite and wumuite, it lacks clear intergrowths or inclusions. The sample’s nanoporous texture and occurrence in concentrates raise concerns about contamination or artificial origin. Trace levels of K, Na, Ca, and Te are insufficiently distinctive to preclude synthetic origins, and no petrographic context is shown to support its natural formation (Xue et al., 2022). Although the authors cite analogies with the other two species, the absence of reproducibility and contextual anchors weakens the argument.

All three species were described from the same crushed sample of biotite adamellite, with no replication in subsequent sampling. This common provenance, along with the authors’ synthesis of the same compounds, raises further questions about potential contamination and the reliability of the sample. The comparative analysis of tewite, wumuite, and ligowuute highlights both the potential and the pitfalls of validating minerals from processed concentrates. While

tewite and wumuite exhibit textural evidence (e.g., inclusions, intergrowths) and mineral associations that support a natural origin, liguoowuite does not meet the same threshold. Its nanoparticle texture and lack of petrographic or paragenetic support – combined with the authors' own synthesis – make it difficult to exclude a synthetic or contamination origin. These cases underscore a broader issue for CNMNC: isolated monomineralic grains, particularly from heavily processed or possibly anthropogenically altered materials, require rigorous documentation to confirm their natural origin. Essential indicators include reproducibility, petrographic context, and unambiguous mineral associations. In their absence, the burden of proof must shift toward demonstrable geological plausibility rather than inferred analogies with co-occurring phases.

5 Recommendations and conclusions

Authors submitting proposals for new minerals recovered from concentrates must explicitly address the possibility of contamination or artificial origin. It is essential to document what measures were taken to prevent contamination and whether any steps were taken to avoid fraudulent claims. Complete disclosure of all sample processing stages is critical, as is a thorough evaluation of potential synthetic analogues or industrial by-products.

The examples discussed above show that the most definitive evidence of natural origin is textural: intergrowths with other minerals, solid or fluid inclusions, or associations in multigrain samples that enable the inference of a plausible source rock. In contrast, isolated monocrystalline grains, although visually appealing, are insufficient unless accompanied by contextual features. Textural images must be included to support claims, particularly those showing the mineral embedded in a broader assemblage or within the host rock (e.g., lava, xenoliths, or ejecta). Examining larger grain sizes within the concentrate may also help reveal such contextual associations.

To improve the reliability and transparency of CNMNC evaluations, the following requirements should be included in the guidelines for minerals of uncertain origin:

- inclusion of textural images showing mineral intergrowths or inclusions,
- complete disclosure of all sample processing stages,
- evaluation of synthetic analogues and possible industrial contamination,
- emphasis on contextual mineralogy and geological provenance,
- isotopic data where feasible to constrain formation pathways.

These standards will help establish a clearer threshold for acceptable evidence, reduce unnecessary debate, and reinforce the credibility of the mineralogical record. Encouraging authors to anticipate and address these requirements at the submission stage will streamline CNMNC review and decision-making.

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