Revisiting the felsőbányaite-basaluminite question : nomenclatural synonymy and unresolved structural issues

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Abstract

Felsőbányaite (1853) and basaluminite (1948) share the formula $Al_4(SO_4)(OH)_{10}·4H_2O$, and were shown to be crystallographically identical in 1997, leading the IMA to discredit basaluminite in 2006 in favor of the older name. This nomenclatural choice is not an issue. Instead, this opinion article explores a more focused contemporary question: is the poorly crystalline material that geochemists continue to refer to as basaluminite in acid mine drainage (AMD) and acid sulfate soil (ASS) the same as the well-ordered felsőbányaite of the type locality at all structural scales? In addition to nanoscale point flaws, XRD/PDF and EXAFS study has revealed a pattern in which the two materials do not co-occur as a single

species undergoing gradual ordering usually would. Rather than seeking to overturn the 2006 verdict, some researchers have acknowledged the similarity between the two materials as possibly “fortuitous”. The evidence basis is actual but limited, primarily based on work by a single research group. 97.6% of applied AMD/ASS articles employing either term as a working identification still use basaluminite, according to a full-text literature count (using Dimensions.ai, 2006–2025), which shows that the applied literature has, in practice, not adopted the ruling after articles using both names in passing are set aside. In order to resolve the issue, the present study compares the strength of the original crystallographic case with the structural evidence, outlines what kind of findings would and would not elevate the distinction to species status, and suggests a direct comparative study along with more explicit reporting practices in the applied literature.

Keywords: felsőbányaite; basaluminite; mineral nomenclature; acid mine drainage; nanomineralogy

Introduction

Mineral nomenclature periodically confronts a recurring problem: two minerals, described independently and often decades apart, are later shown to share a common structure, yet each has already taken root under its own name in a different corner of the literature. Resolving the resulting synonymy is, formally, the task of the IMA Commission on New Minerals, Nomenclature and Classification, which applies the principle of priority to decide which name a species should carry going forward (Nickel and Grice, 1998). The pair felsőbányaite and basaluminite is a case in point: two names, given nearly a century apart and in two different countries, to a mineral of the same reported formula, $Al_4(SO_4)(OH)_{10}\cdot 4H_2O$ (Kenngott, 1853; Haidinger, 1854; Bannister and Hollingworth, 1948).

This case raises two separate questions that are easy to run together. The first is nomenclatural: which name has priority under IMA rules? This question is not being revisited here because it was resolved in 2006 (Burke, 2006). The second is structural: are the natural, poorly crystalline materials that environmental geochemists still call “basaluminite” adequately represented by the well-ordered felsőbányaite whose structure was solved in 1997 (Farkas and Pertlik, 1997), or do they possess reproducible structural or chemical differences that matter for mineral identity? That second question is less settled than the nomenclature suggests, and it is the one this article is actually about.

The approach taken in this article is to weigh the evidence on each side as fairly as possible rather than to argue toward a predetermined conclusion. That means giving the original crystallographic case its due before turning to the newer nanoscale work; being explicit about how narrow the evidence base for reconsideration actually is; testing the impression that the applied literature has not followed the 2006 ruling against an actual literature count rather than leaving it as an assertion; and setting out, concretely, what further evidence would be needed to settle the question one way or the other.

A short history

Felsőbányaite was first described in 1853, from spherulitic crusts on baryte and antimonite at the Baia Sprie mine in what was then Felsőbánya, Hungary, and is now Baia Sprie, Romania (Kenngott, 1853; Haidinger, 1854). Almost a century later, Bannister and Hollingworth (1948) described a white, plastic, clay-like mineral from Old Lodge Pit, Northamptonshire, England, and named it basaluminite, a contraction of “basic aluminum sulfate”. Both minerals carry the same formula, $Al_4(SO_4)(OH)_{10}\cdot 4H_2O$.

The question of whether the two identified minerals belonged to the same species was not directly tested until 1997. After solving their crystal structures, Farkas and Pertlik (1997) discovered that they were the same. Because of this, basaluminite was discredited by the

IMA in 2006 as part of a larger mass discreditation effort (Burke, 2006), and the earlier term, felsőbányaite, was given priority. Under current nomenclature, this is settled: basaluminite is not a valid species.

According to Buzatu et al. (2016) and Papp (2004), Baia Sprie is not a small footnote in mineralogy, but rather one of the most abundant type sites in Europe, home to six species, including felsőbányaite. That matters for more than local color. Baia Sprie, which is still an AMD-affected site today (Buzatu et al., 2016), provides a useful natural check on the question this article is really about: does the well-ordered, type-locality phase ever form under the conditions that produce the poorly crystalline material AMD geochemists call basaluminite, or do the two occupy genuinely separate environmental niches? This is because felsőbányaite in the strict, type-locality sense has not been reported from an active acid mine drainage (AMD) setting (Lozano et al., 2018).

Two questions, not one

Since the arguments used for this article depends on maintaining them apart from the structural question, it is worthwhile to state clearly the few concepts that underpin mineral nomenclature. When two independently named minerals are shown to be structurally and compositionally identical, the earlier-published name takes precedence regardless of which is more well-known or commonly used; the later name is officially discredited. This is in accordance with the IMA-CNMNC procedure, which defines a valid species against a type specimen and a type locality (Nickel and Grice, 1998). An informal return to "basaluminite" outside of that process would be incompatible with the way the system is intended to function because the same Commission also manages the reference lists and authorized abbreviations by which species are tracked once identified (Warr, 2021). Burke (2006) documented the discrediting of basaluminite (1948) after Farkas and Pertlik (1997) proved structural identity, which is what happened in this case. Nothing that follows challenges the

fact that this process was carried out appropriately or that the 2006 decision was the best one given the information at the time.

A more specific question remains unanswered: is the material that is still referred to as basaluminite in studies of AMD and acid sulfate soils (ASS) (Adams and Rawajfih, 1977) and sufficiently represented by the felsőbányaite described by Farkas and Pertlik (1997), or does it have repeatable structural or chemical properties that call for different treatment? That is not a dispute about which name has nomenclatural primacy; rather, it is a question regarding material identity beyond the structural information determined in the 1997 study. The first question was addressed by the IMA verdict. Because the analytical methods that could address it, such as solid-state NMR, sulfur K-edge EXAFS, and XRD/PDF analysis, were not included in the case in 2006, it did not and could not anticipate the second.

Why has the 2006 decision held up well?

Since a case for reconsideration is only as strong as the case it is revisiting, it is important to treat the older material fairly before moving on to the more recent evidence. For more than a century, mineralogy has used the working definition that two materials are the same species if they produce the same space group, unit cell, and atomic coordinates within resolvable error. Bulk crystal-structure determination has long been the standard and reasonably decisive method for establishing mineral-species identity. Farkas and Pertlik (1997) found that basaluminite and felsőbányaite matched the requirement. Carrero et al. (2017) clearly confirmed the same Al-octahedral framework with outer-sphere sulfate coordination that Farkas and Pertlik had hypothesized; nothing in the nanoscale literature listed below contradicts their conclusion at the length scale they observed. The 2006 discreditation was not a hurried or weak decision; it used the field’s standard procedure and produced a clear result that was subsequently validated by nanoscale research. The only question this article addresses is whether the normal approach, which is enough for the majority of applications,

is adequate for a material whose environmentally significant behavior might be controlled by structure at scales the approach is unable to resolve.

What the nanoscale evidence actually shows, and how much of it there is?

Rather than allowing the citations to suggest more independent confirmation than actually exists, it is important to be clear that the justification for categorizing AMD basaluminite as potentially separate from felsőbányaite is based on a tiny, closely related body of evidence. The XRD/PDF and EXAFS results were presented by Carrero et al. (2017). In line with Farkas and Pertlik (1997), they found that both natural and synthetic basaluminite share short-range structural order with felsőbányaite; basaluminite also carries point defects and sulfur-coordination features that were not resolved in 1997; and, according to the authors, the similarity between the two "could be fortuitous." Neither they nor this article claimed to have reversed the 2006 discreditation. A second piece of information is added by a partially overlapping but methodologically distinct line of investigation. In their study of the local structure and aging behavior of basaluminite in a variety of pH and sulfate conditions, Lozano et al. (2018) point out two important points: first, basaluminite formed in AMD settings is consistently very disordered, with no single crystals reported; second, felsőbányaite in the strict sense is a rare mineral that has not, to our knowledge, been reported from an AMD environment. They refer to the fortuitous-resemblance theory of Carrero et al. (2017) as a possibility rather than a definitive conclusion. As things stand, the evidence base for treating the two as possibly different is real but still limited: basically, the synchrotron-based work of one active research group, published in two journals, has not yet been verified by a different laboratory using other samples (Carrero et al., 2017; Lozano et al., 2018.

Why point defects might matter, and might not?

It is now widely known that mineralogical characteristics can actually alter with nanoscale particle size in ways that go beyond measurement noise surrounding a particular bulk structure (Hochella et al., 2008). However, it is possible to argue that many valid mineral species also have defects, vacancies, stacking disorder, or nanocrystalline domains, which do not distinguish them from their more ordered counterparts. Within a species, disorder is prevalent and does not necessarily indicate a second phase. Point defects in AMD basaluminite are indicative of scale-dependent activity that can sometimes, but not always, differentiate a true nanomineral from its bulk counterpart rather than a distinct phase.

Since the current evidence does not clearly lead to one possibility, it is helpful to be clear about what kind of finding would alter that assessment: (i) The discreditation in 2006 may simply indicate that basaluminite has ordinary, non-systematic disorder; (ii) it may represent a distinct, reproducible crystallinity state of the same species, similar to how some minerals have well-recognized poorly-crystalline and well-crystallized varieties without being reclassified (e.g., 2-line and 6-line ferrihydrite); (iii) it may carry a distinct, formation-environment-specific defect population without yet warranting species status; (iv) it may represent a truly distinct formation pathway that just so happens to converge on a similar local structure; or (v) it might be an example of accidental structural similarity between two materials that shouldn't be regarded as identical at all, as suggested by Carrero et al. (2017). Based on the strength of the non-co-occurrence pattern that will be described later, the existing data may be more in line with (iii) or (iv) than (i), but they do not yet differentiate (iii), (iv), and (v) from one another and cannot rule out (ii).

A defect population that tracks systematically with the formation environment instead of acting as random noise around a particular structure, along with a failure to grade continuously between the disordered and ordered forms, would argue in the direction of (iii)-(v). This is essentially what the non-co-occurrence observation provides: if AMD basaluminite were merely poorly crystalline, nanoscale felsőbányaite that was precipitated

early in a single ordering pathway, then it would be reasonable to anticipate at least sporadic co-occurrence, or at least to demonstrate a gradational relationship, wherever that pathway operates. Rather, basaluminite in AMD settings is universally disordered with no single crystals observed, according to Lozano et al. (2018), whereas felsőbányaite is mainly limited to its uncommon, orderly occurrences and unreported from AMD. It is more difficult to reconcile a straightforward one-precursor, gradual-ordering concept with the failure to show a gradational link between the two materials across the settings examined thus far. Nevertheless, this absence cannot be interpreted as evidence against such a pathway due to the current sampling base's limitations.

Literature-search methodology

To evaluate the extent to which the applied literature has adopted the IMA-approved name, a full-text search was performed using the Dimensions.ai database. Searches were conducted in August 2026 and covered publications indexed between 2006, the year of the IMA discreditation of basaluminite (Burke, 2006), and 2025. Records containing the terms *"basaluminite"* and *"felsőbányaite"* were identified using full-text indexing. Because spelling variations occur in the literature, searches for felsőbányaite included both *"felsőbányaite"* and *"felsobanyaite"*.

To focus on environmental applications, results were further restricted to records containing at least one of the terms *"acid mine drainage"*, *"AMD"*, or *"acid sulfate soil"* in conjunction with the mineral name. Publication counts were extracted separately for each mineral name and subsequently cross-referenced to identify records containing both terms. This allowed the calculation of (i) studies mentioning only basaluminite, (ii) studies mentioning only felsőbányaite/felsobanyaite, and (iii) overlapping studies containing both terms.

Because full-text database searches may return false positives arising from acronym matches, bibliographic references, nomenclature lists, or incidental mentions, the results are interpreted as indicators of terminology usage rather than as exact counts of studies reporting mineral identification. Representative records from the "felsőbányaite only" category were manually inspected to assess the frequency of such effects.

Does it change how the environmental literature should be read?

Basaluminite is treated as a separate named phase in standard mineralogical references on acid sulfate waters (Bigham and Nordstrom, 2000; Jambor et al., 2000), and it is still mentioned in mine-drainage hydrogeochemistry reviews as a control on dissolved Al and trace-element mobility across the acidic-to-circumneutral transition (Nordstrom, 2011; Nordstrom et al., 2015). A reproducible full-text search of the Dimensions.ai database (2006-2025; see Methodology) identified 556 publications containing the term *basaluminite* and 71 containing *felsőbányaite* or *felsobanyaite*. Restricting the results to AMD/ASS-related contexts yielded 425 and 36 records, respectively (Table 1). By directly cross-referencing the two applied-context sets rather than just comparing their totals, this is further explained: just 10 of the 399 articles that use basaluminite only exhibit the reverse, a 97.6% share after articles mentioning both are set away. The basaluminite applied-context collection contains 26 of the 36 felsőbányaite applied-context pieces (Table 1).

Table 1. *Full-text mention counts, Dimensions.ai, 2006–2025.*

Term	All articles	AMD/ASS context only
“basaluminite”	556	425

“felsőbányaite” / “felsobanyaite”	71	36
Overlap (applied-context studies mentioning both)		26
“Basaluminite” only (applied-context, no felsőbányaite)		399
“Felsőbányaite” only (applied-context, no basaluminite)		10
Share of disjoint applied-context studies using “basaluminite”		**97.6%**

The two sets of 425 and 36 articles are not disjoint; a cross-referencing of the underlying publication records reveals that 26 of the 36 applied-context “felsőbányaite” articles (72%) also appear in the applied-context “basaluminite” set. This is consistent with an article that cites Carrero et al. (2017)'s synonymy statement once in passing while using “basaluminite” as its own working term throughout. After eliminating that overlap, there are 399 articles that use "basaluminite" without also matching "felsőbányaite" in this context, compared to 10 articles that exhibit the opposite trend. This is a 97.6% share, which is greater than the about 92% number calculated straight from the two totals. A closer examination of those ten further reduces the case for "felsőbányaite" as a truly independent working choice: some are keyword-collision false positives (an IMA-CNMNC mineral-symbol list matching on "AMD" as an unrelated abbreviation, Warr, 2021; a battery-recycling article on fluoride removal with no connection to either mineral, Aliyev et al., 2025) rather than articles that identify their own AMD samples as felsőbányaite. One of the ten is Buzatu et al. (2016), which was previously mentioned as the Baia Sprie type-locality research. This is a valid mineralogical usage of the name, but it focuses on the type locality rather than a competing applied identification.

Taken together, the number of applied AMD/ASS articles that treat felsőbányaite as their own working identification for environmental material, independent of basaluminite, is small enough to be examined individually and does not obviously exceed one or two. That said, a roughly eight-fold difference in raw mentions (556 vs. 71) and a disjoint-count share above 97% is a large enough gap that residual keyword noise is an unlikely full explanation, and it is consistent with the impression that originated this article: the applied literature has not widely adopted the IMA-approved terminology, at least as measured by full-text usage within the Dimensions.ai corpus.

The question a skeptical reader should ask is direct: does the felsőbányaite/basaluminite distinction actually change how this environmental-geochemistry work should be interpreted, its sorption behavior, its thermodynamic treatment, its stability field, its XRD fingerprint in field samples? As far as we are aware, this has not been directly tested, and we do not present our own recent articles on rare earth elements or U(VI) immobilization in AMD systems (Liu et al., 2022; Liu et al., 2026) as having tested it either; those studies use the material under the conventional name, as does the rest of the field. That gap is not a rhetorical dodge; it is the honest state of the evidence, and it is why the question matters rather than why it can be set aside. If AMD-precipitated basaluminite and type-locality felsőbányaite behave identically with respect to trace-element sorption and stability, the terminological question is mostly a matter of correct citation. If they do not, a substantial applied literature has been treating two materials as interchangeable on the strength of a 1997 bulk-structure result that later nanoscale work has since complicated. Which of these is true remains an open empirical question.

What would settle it?

A direct comparative study, using consistent methods on samples held side by side, would do more than further isolated characterizations of one material or the other, and would ideally come from more than one laboratory. At minimum this would mean examining:

- historical or topotype felsőbányaite from Baia Sprie;
- well-characterized natural AMD-precipitated “basaluminite” from multiple, independently sampled localities;
- synthetic basaluminite prepared under controlled conditions, ideally by a research group not involved in the original XRD/EXAFS work;
- their long-range structure (as in Farkas and Pertlik, 1997) alongside their short-range, defect-sensitive structure (as in Carrero et al., 2017);
- hydration and dehydration behavior under comparable conditions;
- chemical composition and defect chemistry; and
- where possible, direct evidence of formation and transformation pathways, rather than inference from non-co-occurrence alone.

In the meantime, authors working on AMD and ASS systems can improve the usefulness of the applied literature without waiting for that study by simply reporting what they actually measured instead of the name by convention: whether the identification is based on XRD, EXAFS, or another spectroscopic method; whether an indication of crystallinity or particle size is available; and whether "basaluminite" is being used as a working, historical label for a poorly crystalline AMD precipitate or as a claim about species identity with felsőbányaite. This would enable readers in the future and any potential comparative analysis to identify the precise content that each article is discussing.

Where does this leave things?

Nothing is disputed here either. The 1997 structural determination demonstrated equivalency at the length scale it assessed, and the 2006 discreditation appropriately followed from that outcome. That conclusion was not refuted by the nanoscale work conducted in 2017–2018. It added structural information at shorter length scales from a still-limited and partially overlapping body of evidence, which raises a valid but unanswered question about whether felsőbányaite adequately represents all material historically referred to as basaluminite or whether some AMD material has repeatable properties that call for distinct treatment. For reasons unrelated to the IMA-CNMNC process, we do not believe the field should go back to using "basaluminite" as a species name by informal consensus. However, unless a comparison analysis is conducted, which, as far as we can tell, hasn't been done yet, authors should reasonably be more precise and specific in their reporting about which material they mean.

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