

Point-wise response to the review_McGowan, Edward

General comments

I strongly believe this is a great manuscript that draws attention to popular types of media that non-geologists can easily encounter in the public domain. It is therefore important to understand how geology is represented in these media. Video games have been covered in several papers in the past few years, but this manuscript makes the reader consider other media forms, especially those other than film/TV.

The manuscript was well written, and the author, who is clearly a PTCG collector, considered many of the key aspects about the PTCG during their research, such as focusing only on English cards to avoid missing other language-exclusive artworks, and to make the dataset more manageable. They clearly put a lot of effort into analysing the data and presented it clearly.

I do, however, have some concerns about the content of the manuscript, such as whether it is plausible enough to consider that PTCG collectors would use AI to identify minerals in the artwork, especially when it is so rare for a card to include a mineral. Perhaps the AI aspect would be more appropriate as its own manuscript, investigating how accurately they perform against popular media forms (e.g. stills from movies, or in comic books as well). Furthermore, the final summary points and conclusion feel rushed and leave the reader lacking in their understanding of why this research is truly important.

Response

The author sincerely thanks the reviewer for the encouraging comments and thoughtful suggestions. The reviewer's familiarity with both geoscience and the PTCG has greatly improved the quality of this manuscript, particularly through comments regarding the practical use of the cards and their educational implications.

The author agrees that typical PTCG collectors are unlikely to use AI to identify minerals or to evaluate the geological accuracy of the illustrations. Accordingly, the manuscript has been revised to clarify that the AI analysis is not intended to represent collector behavior. Instead, it serves as a comparative analytical tool for evaluating how current AI systems interpret the same stylized images that may be used in future educational settings.

The AI component remains within this study because it directly supports the central conclusion that the simplified visual template of minerals affects both human and AI interpretation. Rather than serving as an independent evaluation of AI performance, it provides additional evidence for the visual standardization identified in the PTCG illustrations.

To address the reviewer's final concern, the Discussion and Conclusion have also been substantially expanded to better explain the broader significance of the study, including its implications for science communication and practical educational applications.

Specific comments

Does the author truly believe that there is a significant number of PTCG collectors who would use AI to identify minerals within the artwork? As a geologist and PTCG collector myself, I have never once considered the accuracy of the illustrations on the cards, nor thought to use AI to identify them. In my experience of over 20 years in the hobby, collectors are more likely to appreciate nice artwork and not question the realism of it. This can potentially even go as far as most collectors recognising it is depicting a fantasy world and therefore it is acceptable for the artwork to not be accurate.

Response

The author agrees with the reviewer's perspective and does not believe that typical PTCG collectors use AI to identify minerals or evaluate the geological accuracy of the illustrations. Before conducting this study, the author had never questioned the geological accuracy of these illustrations either. Like most collectors, the appeal of the artwork was far more important than whether the depicted minerals reflected natural geological systems.

The AI analysis was therefore not intended to represent collector behavior. Instead, it was introduced as a comparative analytical tool to examine how current AI systems interpret the same stylized illustrations that may be used in future educational activities. Because these illustrations are unconstrained by scientific conventions, they also provide an opportunity to investigate how popular media constructs a shared public image of minerals.

Accordingly, Section 4.4 has been substantially expanded to emphasize that these familiar illustrations can serve as effective entry points for discussing authentic

geological processes and encouraging critical thinking about geological representations in popular media.

If Pokémon cards that contain minerals only account for 1% of the entire English printed roster, how many ‘mineral cards’ would the average collector actually have/see? Taking a reasonable number of 2000 in a collection, that would equate to someone only having 20 ‘mineral cards’. This seems very low and might not have a significant impact on their understanding of true mineral structures. Furthermore, is it not possible collectors are able to understand that the artwork contains fantasy elements given they depict fantasy monsters.

Response

The author agrees that mineral-themed cards represent only a small fraction of the PTCG catalogue and are unlikely to substantially influence the average collector's understanding of mineralogy. Likewise, most collectors understandably recognize these illustrations as part of a fantasy world rather than realistic geological representations.

However, this study does not aim to evaluate their passive influence on collectors. Instead, it investigates the educational potential of this curated collection when intentionally used for science communication. Although mineral-themed cards account for only about one percent of all released cards, the dataset now contains 223 illustrations spanning nearly three decades, providing a diverse resource for classrooms, museums, and outreach activities.

Accordingly, Section 4.4 has been revised to clarify that the significance of this dataset lies in its educational application rather than its influence on the average collector.

Ice was identified by a human expert (the author) as the most common mineral (Figure 4). However, it is barely spoken about within the text. Instead, the text focuses mainly on the other five identifiable minerals (e.g. quartz, calcite, and zircon). What is ice's significance to the results in terms of accuracy of illustrations, reasonable environments etc? Either explain the results regarding ice or remove it from the criteria/data.

Response

The author agrees that the original manuscript did not adequately explain the significance of ice. Accordingly, Section 4.2 has been expanded to discuss this category in greater detail.

Ice represents the most confidently identified mineral because its interpretation is supported by both crystal morphology and contextual evidence. This makes it an ideal reference for evaluating whether the universal crystal template persists even when mineral identity is well constrained. Despite this high confidence, MCA shows that ice forms the most tightly clustered group, and more than half of the inferred ice crystals resemble tetragonal prisms, although terrestrial ice (ice Ih) crystallizes almost exclusively in the hexagonal system. These findings provide some of the strongest evidence for the proposed universal crystal template.

The implications of this research (Sections 4.3 and 5) feel very rushed. The results strongly support the author's conclusion that mineral depiction within PTCG is oversimplified. However, the reasoning provided for this is lacking, only stated as influenced by gemstone markets and museum displays. The author does not appear to consider the fact that many PTCG illustrators likely lack a geological background and that some art styles may purposely choose not to take inspiration from realism or detailed accuracy (e.g. Shinji Kanda or Hyogonosuke). The author does allude to the latter in Section 4.1 but not considered again. After 30 years of producing Pokémon cards, the hobby is arguably more popular than ever, and a lack of accurately illustrated minerals does not appear to dissuade collectors. Therefore, is the Pokémon Company not justified in its approach to continue to “reproduce this selective imagery”? It would be great to expand further on these considerations.

Response

Section 4.4 has been substantially expanded to address these points. The revised discussion now recognizes that most Pokémon illustrators are professional artists rather than geologists and that highly stylized crystal imagery is an understandable artistic convention. The manuscript also explicitly acknowledges that the Pokémon Company is fully justified in prioritizing artistic appeal over scientific realism. Rather than criticizing this approach, the study examines how these shared artistic conventions shape public perceptions of minerals and how they can be used for geoscience communication.

Continuing the last point, the author simply says “geoscience educators might consider addressing these media representations”, which I agree with. However, it would be great to also expand on this further and provide examples. This would improve the significance of the manuscript by providing educators with potential starting points that they could adapt into their lessons.

Response

Section 4.4 has also been expanded to provide practical examples for geoscience education. The revised discussion suggests using Pokémon cards as visual "hooks" in classrooms, museums, and outreach activities by comparing stylized illustrations with real mineral specimens to discuss mineral identification, geological environments, and artistic conventions. The manuscript also notes that these illustrations are freely available through public online card databases, making them readily accessible for educational use.

Technical comments

- Section 2.1, Line 39: How did you reach a total of 19,875 cards? I cannot find an online reference to this total anywhere, even on Pikawiz. Also, it is worth noting that some artworks are reprinted, not just for mini-sets but in full sets (e.g. “Professor Elm’s Training Method” has the same artwork used in E-series base, Unseen Forces, and Dragon Frontier). Therefore, this total would not represent unique artworks.

Response

The original number (19,875) referred to the total number of card entries listed in the *Pikawiz* database. Because many cards, particularly Promo and mini-set releases, reuse existing artwork, reporting an exact total is potentially misleading. Accordingly, the manuscript has been revised to state that approximately 20,000 card entries were manually screened.

- Section 2.1, Line 40: Did you include Promo cards or other mini-sets such as the McDonalds or Trick & Trade sets as well? Most of the latter reprint existing artwork and count it as a new card by including a new holo pattern or stamp.

Response

Yes, Promo cards and mini-sets, including the McDonald's and Trick & Trade series, were included in the initial screening. However, most are reprints of existing artwork with different holo patterns or stamps. Only cards containing new artwork were retained as unique entries. Section 2.1 has been revised to explicitly state this exclusion criterion.

- Section 2.1, Line 40: Was the Pikawiz database cross-referenced with any other database to confirm all cards were accounted for?

Response

The original submission relied solely on the *Pikawiz* database. To address this point, a second manual screening was conducted in July 2026 by cross-referencing *Pikawiz* with the *Pokellektor* database (<https://www.pokellektor.com/sets>), which also included the recent Chaos Rising set. The two databases showed a high degree of consistency, with only minor discrepancies among promotional cards. The methodology has been updated accordingly.

- Section 2.1, Line 43: How confident are you that the coverage and list you came up with was “exhaustive”? Did you manually screen the cards once or more times? A quick search on Google and Bulbapedia shows there are several cards from the HGSS series that include evolution stones (e.g. HGSS base Arcanine #1), and there are at least three different artworks for “Old Amber”. From my interpretation of your methodology, these cards agree with your criteria.

Response

The reviewer is correct that the original claim of an "exhaustive" dataset based on a single screening was overstated. A second manual screening using both databases identified 21 additional mineral-themed artworks, including four previously overlooked "Old Amber" illustrations.

Regarding the Evolution Stones (e.g., Arcanine HGSS), these objects were intentionally excluded because this study focuses on environmental geological backgrounds created by illustrators, rather than pre-defined, franchise-specific items or gameplay mechanics (e.g., Evolution Stones and Terastal phenomena). Section 2.1 has been revised to clarify these inclusion and exclusion criteria to ensure a strict focus on natural environmental depictions.

- Section 2.1, Line 45: “distinct geological formations” is a very broad term that could capture many different elements that do not appear to be included, such as volcanoes. Also, how can you accurately identify a “limestone cave”? You later state on Line 98 that it is not possible to identify the lithology of host rocks. The definitions you describe in the Appendix (Line 285: Major rock types) are much better. I would recommend using them in the main text body as well as the Appendix.

Response

The term "distinct geological formations" has been replaced with broader environmental categories, and the unsupported reference to a "limestone cave" has been removed from the main text. To improve readability, the detailed visual diagnostic criteria have been relocated to Appendix B, while Section 2.1 now contains only the essential methodological description.

- Section 2.1, Line 48: “202 cards”, again I believe there are more.

Response

Following a second manual screening using two independent databases, the final dataset has been expanded from 202 to 223 unique artworks.

- Section 2.1, Line 48: “84 different artists”. I would be interested to know later in the manuscript if there are particular artists who like to include minerals in their artwork, or if there is a general average of 2-3 cards per artist.

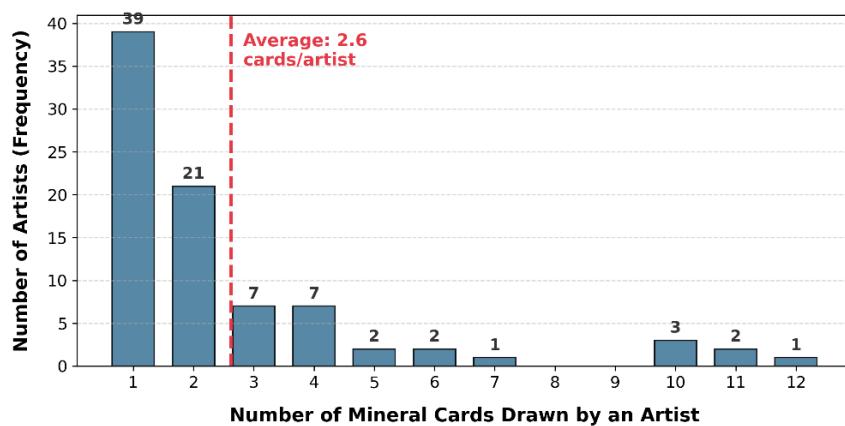
Response

Thank you for this valuable suggestion. Appendix A3 now includes a new analysis of illustrator distributions. The updated dataset contains 223 mineral-themed cards created by 85 illustrators, with an average of 2.6 cards per illustrator. However, approximately 70% of illustrators contributed only one or two cards, whereas six illustrators account for 29% of the dataset. Comparison with each illustrator's total published Pokémon cards further suggests that, with the exception of 5ban Graphics, several illustrators contributed mineral-themed artwork more frequently than expected. These results have been added to Appendix A3 and briefly summarized in Section 3.1.

Table. Top six illustrators contributing mineral-themed PTCG artwork.

Artist	Mineral-themed cards	Total Pokémon cards	Percentage (%)
5ban Graphics	12	1777	0.68
Kouki Saitou	11	669	1.64
Kagemaru Himeno	11	669	1.64
Midori Harada	10	360	2.78
Masakazu Fukuda	10	487	2.05
Ryo Ueda	10	472	2.12

(a) Distribution of Mineral Cards per Illustrator



**(b) Mineral Preferences among 11 Illustrators (≥ 5 cards)
(Out of 85 Total Unique Illustrators)**

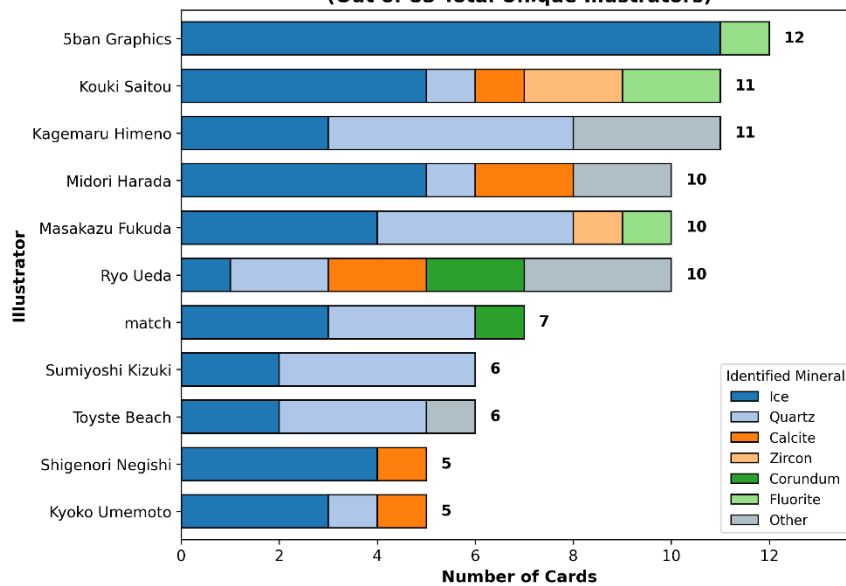


Figure. Illustrator distributions and mineral preferences. (a) Distribution of the number of mineral-themed cards designed per artist across all 85 identified illustrators. (b) Mineral type preferences among the top 11 illustrators who have each designed five or more mineral-themed cards.

- Section 2.3, Line 85: How does ChatGPT and Gemini fair against identifying real minerals?

Response

The author thanks the reviewer for this important suggestion. To determine whether AI misidentifications resulted from artistic stylization rather than limited mineral recognition, a new baseline experiment using 43 photographs of real mineral specimens was conducted.

The results showed high identification accuracy, with Gemini achieving 95%, ChatGPT 86%, and the specialized application 74%. A summary has been added to Section 2.3, and the full methodology and results are provided in the new Appendix C and Supplementary Excel dataset.

- Section 2.3, Line 86: Why was Rock Identifier used as the specialised app? Did it have the most positive reviews?

Response

Rock Identifier was selected because of its wide public accessibility and market dominance. At the time of this study, it was the highest-ranked geoscience application on both the Google Play Store and Apple App Store, with more than 10 million downloads and average ratings above 4.6 stars. As this study evaluates AI tools likely to be used by the general public, Section 2.3 now explicitly explains this selection rationale.

- Section 3.1, Line 96: Provide an exact number/ percentage of how many minerals occurred in caves and that were fully exposed.

Response

The requested values have been added to Section 3.1.

- Section 3.1, Line 101: It is not explained or alluded to until the Appendix how the length of minerals are calculated. I would recommend including a short explanation earlier in the text, such as in Section 2.1, so that readers are aware.

Response

A brief explanation has therefore been added to Section 3.1, stating that the official Pokémon heights were used as standard scale bars.

- Section 3.2, Line 135: Provide an exact percentage for the rock-scanning app to highlight how much less this agreed compared to the other AI apps.

Response

Section 3.2 has been revised to include the exact agreement rate (12%) for the specialized rock-scanning application.

- Section 3.2, Line 139: Provide one or two examples of “fantasy elements” identified in the cards.

Response

Section 3.2 now includes representative examples of fantasy elements to clarify this description.

- Figure 3 caption: Reference back to Section or Appendix as to what the “13 categorical features” are so that readers can quickly look at the figures and know where to go to in the text.

Response

The Figure 3 caption has been revised to direct readers to Appendix B, where the 13 categorical features are described in detail

- Figure 3 caption: Include a mention about the Benzécri correction in the main body of the text.

Response

A brief explanation of the Benzécri correction and its purpose has been added to Section 3.2 before referring readers to the Appendix.

- Section 4.1, Line 167: Has the lack of paragenesis and focus on rare crystals been reported in other forms of media? If so, it would be good to cite that here.

Response

The author searched the available literature but found no previous quantitative study specifically examining the scarcity of paragenetic mineral assemblages or the dominance of rare crystal morphologies in popular media.

- Section 4.1, Line 179: Artists may also be more familiar with particular mineral types or lack true awareness of other forms. I highly suspect many illustrators only have a limited background in geology, if any background at all.
- Section 4.1, Line 182: Again, it may not be an “artistic shortcut” if the illustrators are not fully aware of other crystal types. If their knowledge of minerals comes from limited geological media such as museums (as mentioned in the text), then they are only replicating what they have seen themselves.
- Section 4.1, Line 192: Again, perhaps the illustrators are unaware of other minerals such as amphibole or mica.

Response

The author agrees with the reviewer's interpretation. Section 4.1 has been revised to avoid implying that illustrators intentionally simplified mineral forms. Instead, the discussion now emphasizes that most Pokémon illustrators likely have limited geological training and are reproducing mineral imagery commonly encountered through museums, commercial mineral markets, books, and other popular media. Accordingly, the scarcity of amphibole, mica, and other common rock-forming minerals is interpreted as reflecting limited public familiarity rather than deliberate artistic choice. The Discussion also acknowledges that scientific realism is not required for the success of the PTCG, while noting that greater mineralogical diversity could further enhance its value for science communication without compromising artistic creativity.

- Section 4.1, Line 190: What do the statistics show when considering ice only?

Response

Section 4.2 now includes a dedicated discussion of ice. Although terrestrial ice crystallizes in the hexagonal system, more than half of the inferred ice illustrations depict tetragonal prisms. This provides strong evidence that even the most confidently identified mineral conforms to the same generalized crystal template.

- Section 4.2, Line 213: “Failure” is a strong word for saying this manuscript is investigating the minerals of a ‘fantasy world’. Numerous aspects of the Pokémon world are impossible in the real world. Why can minerals not be included in this?

Response

The author agrees that "failure" was unnecessarily strong for a fantasy setting. The manuscript has been revised to replace this wording with the more neutral terms "analytical limitation" and "discrepancy," clarifying that the discussion concerns the limitations of current AI rather than the artwork itself.

- Section 4.2, Line 216: “A human *could* recognize”. A trained geologist such as the author is capable of easily doing this, but could a non-geologist?

Response

The author agrees that this interpretation requires geological training rather than representing the perspective of a typical player. The manuscript now specifies that this observation refers to a geologically trained observer. Section 4.4 further explains how such knowledge gaps create opportunities for science communication by encouraging comparisons between stylized illustrations and real geological environments.

- Section 4.3, Line 235: Hyper-realistic digital illustrators such as 5ban Graphics and REND are relatively new to illustrating cards. Although their work is hyper-realistic, they have yet to illustrate cards with minerals. Perhaps with time, new cards will appear.

Response

Section 4.4 has been revised to acknowledge that the visual template identified in this study reflects patterns observed over nearly three decades of PTCG illustrations. The discussion also recognizes that future artists and evolving illustration styles may naturally introduce greater mineralogical diversity.

- Section 4.3, Line 240: Explain further why this is beneficial and how educators could use the PTCG as effective communication tools.

Response

Section 4.4 has been expanded to provide practical examples for educators. The revised discussion suggests using Pokémon cards as visual "hooks" in classrooms, museums, and outreach activities, where comparisons with real mineral specimens can encourage observation, geological reasoning, and critical evaluation of media representations.

- Section 5, Line 245: What about ice? This was the most common mineral identified.

Response

The Conclusion now explicitly discusses ice as the most frequently identified material, emphasizing that even this well-constrained category conforms to the same generalized crystal template.

- Section 5, Line 247: It has been previously mentioned AI also fall short in their ability to correctly identify minerals correctly for several other reasons such as not being able to consider surrounding environmental aspects or struggling with 2D image identification.

Response

The concluding paragraph has been revised to summarize the multiple factors contributing to AI misclassification, including limited contextual reasoning, difficulty interpreting crystal symmetry, and reliance on simplified visual features.

- Figure A1, Graph: The Scarlet & Violet series ended in September 2025 and was succeeded by Mega Evolutions, which is likely to continue well into 2027.

Response

The figure has been updated accordingly.

- Appendix B1, Line 293: “Official *average* heights” were used. Individual Pokémon, even from the same species, can drastically range in size. Also, where were the measurements acquired? Were they written on the cards or from Bulbapedia, for example?

Response

The measurements were obtained from the Bulbapedia database (https://bulbapedia.bulbagarden.net/wiki/Main_Page), which compiles official Pokédex data. Although individual Pokémon may vary in size, the official species height provides the most objective and standardized reference available. Appendix B1 has been revised to clarify the data source and scaling protocol.