Integration of remote sensing, gravity and geochemical data for exploration of Cu-mineralization in Alwar basin, Rajasthan, India

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\textbf{ABSTRACT}

In spite of the dominance of traditional mineral exploration methods that demand physical characterization of rocks and intense field work, remote sensing technologies have also evolved in the recent past to facilitate mineral exploration. In the present study, we have processed visible near infrared (VNIR) and shortwave infrared (SWIR) bands of Advanced space-borne thermal emission and reflection radiometer (ASTER) data to detect surface mineralization signatures in Mundiyawas - Khera area in Alwar basin, north-eastern Rajasthan, India using spectral angle mapper (SAM). The potential of SAM method to detect target under variable illumination condition was used to delineate galena, chalcopyrite, malachite etc. as surface signatures of mineralization. It was ensured that the identified surface anomalies were spectrally pure using pixel purity index. Spectral anomaly maps thus derived were integrated using weight of evidence method with the lineament density, geochemical anomaly, bouger anomalies were validated in the field and also using X-Ray diffraction data. Spectral anomaly maps thus derived were integrated using weight of evidence method with the lineament density, geochemical anomaly, bouger anomaly maps to identify few additional potential areas of mineralization. This study thus establishes the importance of remote sensing in mineral exploration to zero in on potentially ore rich but unexplored zones.

1. Introduction

Copper is one of the most widely used metals in India and its usage is next only to iron and aluminium in terms of volume. The Copper mineralization in Alwar District, Rajasthan, India has been recorded within the Kushalgarh, Sariska and the Thanaghazi Formations of the Ajabgarh Group (Mukhopadhyay, 2009). Presence of numerous old workings, huge mine dumps, slag heaps in the Jodhawas and Shyampura area in the Kushalgarh Formation within the biotite- marble and quartz- marble rocks and fine dissemination, stringers and small veins of mostly malachite are indications of Cu mineralization in the area (Heron, 1953; GSI, 2011, 2016). Surface indicators include malachite stain and specks of chalcopyrite within the brecciated quartzite. The Geological Survey of India (GSI) (2016) reported Cu mineralization within the Thanaghazi Formation is evidenced by the presence of malachite, chalcopyrite and bornite. Cu minerals occur as dissemination and stringers within the tremolitic marble, carbon phyllite host rocks. According to Dr S K Wadhawan, deputy director general, GSI, “A 108.10-metre-thick copper mineralization from the Alwar basin of the north Delhi fold belt found. The tentative resource of copper is about 11 million tonnes with sporadic presence of gold and silver that are 5–15 parts per million” (Times of India, 2012). GSI further reported that this is the first report of such large deposit from Alwar Basin and might turn out to be the largest occurrence in Western India.

Conventional mapping and exploration techniques may not be adequate in difficult and inaccessible terrains. Hence, there is a need to use modern techniques such as remote sensing to overcome this limitation and identify potential deposits of copper (Yang et al., 2005). Intensive field exploration activities are required in mineral exploration for understanding the geology of the area through lithological and mineral mapping, so that it leads to potential exploration targets (Sabins, 1999a; Sun et al., 2001; Thompson et al., 1999). For this purpose, remote sensing is already a validated tool for mapping indicator minerals of alteration and mineralization zones (Asadzadeh and de Souza, 2016; Kruse, 1996, 2012, Kruse et al., 2003; Ramakrishnan et al., 2013; Ramadan and Kontry, 2004). Traditionally, geological mapping and mineral exploration methods utilize physical characteristics of rocks and soils such as mineralogy, weathering characteristics,
geochemical signatures, and landforms to determine the nature and distribution of geologic units and to determine exploration targets for economic minerals (Bishop et al., 2011; Goetz et al., 1985, 2001, 2009). But remote sensing can detect subtle mineralogical differences, often important for distinguishing background rock formations and potential mineralization zones, which are often difficult to map during field survey (Boardman and Kruse, 1994; van der Meer et al., 2001; van der Meer et al., 2012; van der Meer, 1999, 2012, Madani et al., 2003). However, demarcating the mineral prospects zones using space-borne data is still in developing stage in India. Rajasthan state is rich in economical mineral deposits which need to be further explored and extended. Demonstration of remote sensing technology with reference to the quantitative information of the mineral constituents can further fill the gap between remote sensing and geochemistry (Borengasser et al., 2007; Cloutis, 1996; Chattoraj et al., 2018; Jain and Sharma, 2019; Kumar et al., 2020; Sengar et al., 2020). The aim of the study is to demonstrate the applicability of image processing techniques and spectral analysis of multispectral imagery in locating and characterizing potential copper rich zones in parts of Alwar District, Rajasthan, India.

2. Study area and geological setting

The area of Investigation, Mundiyawas-Khera is located 5 km south-west of Thanagazi Tehsil Head Quarter, Alwar District, Rajasthan. Geographically Mundiyawas-Khera area covers the longitudes 76° 12′00″E to 76° 23′00″E and latitudes 27° 26′45″ N to 27° 26′00″N. The study area covers parts of Alwar district of which the research focusses more on Khera block. It forms a part of the Alwar basin of North Delhi Fold Belt comprising rocks belonging to the Thanagazi Formation of the Ajabgarh Group of the Delhi Supergroup (Sinha-Roy et al., 1998; Gupta et al., 1981). Ridges of rocky and precipitous hills are observable features in the region. Geologically the area consists of Pre-Cambrian rock units belonging to Aravalli and Delhi Super Group (Fig. 1).

A thick pile of Proterozoic metasedimentary and metavolcanic sequences belonging to the Delhi Supergroup are exposed in the area (Chowdhury et al., 1984). These metasediments overlie basement gneisses with an unconformity (Naha and Mohanty, 1988). The study area exposes rocks of the Delhi Supergroup (DSG), which are classified into the Raialo Group, the Alwar Group and the Ajabgarh Group. The Raialo Group unconformably overlies gneisses of the basement, which contains rafts of quartzite and enclaves of amphibolite. The Raialo Group includes a thick lower sequence of vitreous white quartzite of Serrate Formation, which is overlain by a thick volcano-sedimentary sequence (Tehla Formation) constituting the upper part of Raialo Group. A well-developed unconformity represented by polymictic conglomerate and a structural break constrains the interface of Raialo and Alwar Group of rocks. The rocks of the Alwar Group have been classified into the Raigarh, Kankwarhi and Pratapgarh Formation. The generalized sequence of the Alwar Group is a basal conglomerate, arkose and quartzite followed by a sequence of argillaceous and impure calcareous rocks represented by pelitic schist containing different mineral assemblages, impure marble and para-amphibolite, which in turn is followed by a sequence of mainly arenaceous rocks with some amount of pelitic sediments. The Ajabgarh Group of rocks conformably overlies the predominantly quartzitic Alwar Group of rocks. It comprises metamorphosed argillites with intercalated arenites and subordinate carbonates. The Ajabgarh Group is subdivided into three Formations. The lower unit is mainly a carbonate facies (Kushalgarh Formation) and is succeeded by ferruginous quartzite-phylite-phyllite quartzite sequence (Sariska Formation). The upper Thanagazi formation is composed of carbon phyllites (often tuffaceous), andalusite-biotite-sericite-garnet-chlorite schist and some doubtful felsic volcanic rocks. Later intrusives mainly include metafelsic rocks and granites.

Western Region, GSI upon subsurface drilling operation in the area

![Fig. 1. Lithological Map of the study area with generalized stratigraphy (after Roy and Purohit, 2015; GSI, 2016).](image-url)
has reported more than 100 m thick sulphide mineralization associated with the meta volcano-sedimentary sequence (Khan et al., 2013). The ore mineralization mainly consist of chalcopyrite, arsenopyrite and pyrrhotite. The mode of occurrence is mostly in the form of disseminations, veins, stringers and foliation parallel layers which at times show discordant relationship (Khan et al., 2014). As far as the felsic volcanic host is concerned, ore mineralization occurs in dissemination form, at places as segregate in association with biotite which mostly occurs as rhombic, rectangular in stretched shape (Khan et al., 2013, 2014). This is indicative of syngenetic-type copper mineralization within the felsic volcanics as happened in case of Khetri copper deposit also (Golani et al., 1992, Banerjee, 1980; Pant et al., 2015; Khan and Sahoo, 2012). Hence, it is widely felt that the felsic volcanism is one of major force behind emanation of the mineralization, which got concentrated along the foliation planes, axial planar cleavages and other weak planes developed during late phase deformation. However, hydrothermal activity in the area must be prevalent phenomenon as evidenced by presence of quartz-carbonate veins within the felsic and dolomitic marble host rocks. Late phase silica metasomatism is quite prominent as manifested by development of tremolite within the dolomitic marble at metasomatic contact zones. A reducing depositional condition for sulphide mineralization is favoured by the occurrences of carbon phylite layers and carbonate veins (Boopathi, 2010). Khan et al., 2012 and 2013 reported that widespread distribution and association of sulphide minerals (dominated by chalcopyrite, pyrrhotite and arsenopyrite) within the meta-greywacke, quartzite, felsic volcanics and their altered varieties in different modes suggest a volcanic origin for copper mineralization. It has been recommended that adjoining areas can be further explored using the mineralization controls.

3. Materials and methods

3.1. Pre-processing

ASTER L1B data is used for mineral mapping and spectroscopic analyses in this study. Pre-processing is carried out prior to mineral mapping. A specific radiometric artefact associated with ASTER data is ‘crosstalk’ effect, caused by signal leakage from band 4 into adjacent bands 5 and 9 (Kalinowski and Oliver, 2004). Although the impact of crosstalk is negligible during image analysis, crosstalk correction has been applied prior to any further processing because the margin of error caused by crosstalk may have more considerable effect on the assumed data analysis than the degradation of image quality. Following crosstalk correction, radiometric and atmospheric corrections have been done. Atmospheric correction done using IARR (Internal Average Relative Reflectance) method gave out satisfactory reflectance images. As this
work takes substantial cues from data integration from multiple sources, as satellite data i.e. ASTER L1B, Resourcesat-1 LISS IV and Landsat 8 OLI data, the Bouguer gravity anomaly map of the World Gravity Map (WGM2012), georeferenced geochemical data points from GSI, 2016 report was projected onto WGS 84 datum and UTM Zone 43 Co-ordinate system during the pre-processing stage for the mentioned study area. Integration of all thematic layers including the interpolation was carried out at the same scale with same confirmed ground-based geo-locations for compliance of all layers to maintain synergy.

3.2. False colour composite (FCC) and band ratios

Just like vegetation is enhanced in a standard FCC due to high reflectance in the NIR region, Altered zones can also be visually enhanced by applying suitable band combinations. The SWIR false colour image created by applying bands 4, 6, and 8 to the channels, Red, Green and Blue respectively is useful for identification of alteration (Fig. 2) (Yajima et al., 2007). This is due to the fact that major altered minerals have characteristic spectral features in the SWIR region.

Intending to derive more information from the imagery, band ratios that highlight specific altered minerals have been generated. The characteristic absorption dips of altered minerals help to generate mineral specific band ratios. The ratios 4/6, 5/6 and 5/8 indicate the minerals Alunite/Kaolinite (Argillic), Sericite (Phyllic) and Epidote (Propylitic) respectively because of absorption dips at bands 6 and 8 (Fig. 3) (Yajima et al., 2007).

Moreover, Argillic alteration, phyllic alteration, propylitic alteration including calcite can be identified by the color composite image of band ratios by applying argillic alteration to red, phyllic alteration to green and propylitic alteration to blue channels. By doing so, the alteration assemblage can be visualized from the resultant color composite (Fig. 4) (Table 1).

3.3. Mineral mapping

MNF (Minimum Noise Fraction) is applied on the pre-processed image to reduce the dimensionality followed by PPI (Pixel Purity Index) to find the spectrally pure pixels. The reflectance spectra of the most spectrally pure pixels are matched with a reference spectral library to identify the mineral. Higher scores on a scale of 0–1 mean best matches. Considering this criterion and also the user’s knowledge about the area and pattern of mineral occurrences, the spectra with best match is chosen as a mineral endmember. The endmembers are then used to perform classification ideally on the inverse MNF image. In this study, Mineral mapping has been done using SAM (Spectral Angle Mapping) classification technique (Fig. 5, Table 2).

In SAM classification, the spectral similarity between the image spectra and the reference spectra is calculated. The spectral similarity is measured by calculating the angle between the two spectra, treating them as vectors in n-dimensional space (Rowan and Mars, 2003). The reference spectra in this case was extracted from the image after matching it with both library as well as laboratory generated spectra. Smaller angles between the two spectra indicate high similarity and high angles indicate low similarity. The spectral threshold value by default is 0.1. This threshold value for each endmember was reduced gradually until the classified pixels coincided with the lithology of the area.

3.4. Lineaments and lineament density

Lineaments extracted from ResourceSat-1 high resolution linear imaging self-scanner (LISS-IV) and Landsat-8 Operational Land Imager (OLI) satellite imagery (Roy et al., 2014; Ganduri et al., 2018; http://www.eotec.com/images/IRS_-_Current_and_Future). Major structural features in the study area were extracted using directional filtering technique (Chavez and Bauer, 1982; Pour and Hashim, 2015) (Fig. 6(a)). The lineaments mapped are of structural and geomorphological origin. The lineament density map which shows the length of lineaments per unit area is also generated (Fig. 6(b)). The corresponding rose diagram indicates that the overall strike direction of the lineaments falls in between NNW and NNE directions.

3.5. Gravity data

Bouger gravity data used in this study are point data extracted from WGM2012 Earth gravity model (2° x 2° resolution) provided by International Gravimetric Bureau (BGI). WGM2012 gravity anomalies are derived from the available Earth global gravity models EGM2008 and DTU10 and include 1°x1° resolution terrain corrections derived from ETOPO1 model that consider the contribution of most surface
masses such as atmosphere, land, oceans, inland seas, lakes, ice caps and ice shelves. These products have been computed by means of a spherical harmonic approach using theoretical developments carried out to achieve accurate computations at global scale. The point data containing bouger gravity values are then interpolated using spline technique to generate an interpolated raster layer (Fig. 7).

The interpolated bouger gravity map shows gravity values ranging from 57.11–97.30 mgals. Rock types within an area often contrast enough in density to cause gravity anomalies. For example, sedimentary rocks and their weathered derivatives that fill basins almost always have low densities due to dominance of Quartzo-feldspathic minerals and are characterized by gravity lows on anomaly maps. Mafic / basic rocks, which contain high density Fe-Mg minerals are often associated with gravity highs. These differences can be used to map large regions where rocks are inaccessible or concealed, to look for faults responsible for juxtaposing rocks of different densities or to infer structures such as basins, arches and buried intrusions.
Geochemical data for the study area was collected from GSI report (2016). As per the report, the sampling was done from lower order streams. The samples were analyzed by XRF (X-ray fluorescence) and ICPMS (Inductively Coupled Plasma Mass Spectrometry) methods. The elements of interest from this geochemical analysis are Mn, Ti and Cu. However, Mn and Ti are available as MnO and TiO₂ respectively from which proportions of Mn and Ti are extracted by oxide to element conversion. The extracted weight percentages are interpolated using spline method to generate individual concentration maps for Mn, Ti and Cu (Fig. 8). Spatial distribution of other important elements was also plotted using IDW interpolation method (Fig. 9). Lack of Mn and Ti can be seen near Khera area (Fig. 8). Likewise, an anomalous presence of copper can be observed near Khera where Mn and Ti concentrations are also less or absent (Fig. 8).

3.7. Weighted sum overlay

The Weighted Sum function overlays several rasters, multiplying each by their given weight and summing them together. In this study, the layers used for overlay are Lineament Density, Gravity, Geochemical maps (only Mn, Ti and Cu) and mineral map produced using SAM method. Prior to overlay, all the layers are standardized to a common range (1–10) so as to avoid any discrimination in assigning weightages. Out of these layers, maximum weightage is given to mineral map followed by geochemical maps, lineament density and gravity. The output of the weighted sum overlay will be a favourability map for potential copper deposits in the study area (Fig. 10).

The weights assigned for the corresponding evidence layers for use in the Weighted Sum Overlay technique is shown in the table below. Based on the weights assigned to each layer, their importance will be reflected in the Overlay analysis. The weights are assigned to the layers on the basis of their relevance and reliability to the present study. For instance, the gravity layer used is of a coarser resolution (2′ x 2′) and is more apt for small scale studies. Hence, the least weightage is assigned for this layer. The interpolated geochemical concentration maps (Cu, Mn, Ti) are also assigned lesser weightages as the sampling was done at 2 km interval. The mineral maps are given higher weightages because in these layers, each pixel (15 m) is classified based on their spectral properties, which makes it more reliable than the others.

### Table 1
The evidence layers used for weighted sum overlay.

| Evidence Layers                  | Weights Assigned (On a scale of 1–5) |
|----------------------------------|--------------------------------------|
| Cu concentration map             | 2                                    |
| Mn concentration map             | 1                                    |
| Ti concentration map             | 1                                    |
| Bouger Gravity Map               | 1                                    |
| Lineament Density Map            | 3                                    |
| Pyrite mineral map               | 4                                    |
| Malachite mineral map            | 4                                    |
| Chalcopyrite mineral map         | 5                                    |
| Galena mineral map               | 4                                    |

### Table 2
Number pixels and area covered (m²) by of the each end member class.

| Sl. No | End Member Mineral | Pixel count | Area (m²) |
|--------|--------------------|-------------|-----------|
| 1      | Galena             | 19          | 4275      |
| 2      | Chalcopyrite       | 1094        | 246,150   |
| 3      | Malachite          | 346         | 77,850    |
| 4      | Andalusite         | 3934        | 885,150   |
| 5      | Pyrite             | 204         | 45,900    |

ASTER has prodigally been used for mapping and detection of Cu-
mineralization (Alimohammadi et al., 2015; Amer et al., 2010; Chen et al., 2010; Gad and Kusky, 2007; Gomez et al., 2005; Guha et al., 2019; Pour and Hashim, 2011, 2012a, 2012b; Rowan et al., 2003; Rowan and Mars, 2003). SAM has widely been used in spectral remote sensing to map the surface expressions in all application fields (Van der Meer and Jong, 2003; Kodikara et al., 2015). SAM does not address the problem of spectral mixing (Pour and Hashim, 2014; Sanjeevi and Abhishekh, 2006; Sanjeevi, 2008). The most erroneous assumption made with SAM is that the endmembers chosen to classify the image represent the pure spectra of the reference material (Girouard et al., 2004; Kalinowski and Oliver, 2004; Kodikara et al., 2015; Pour et al., 2017; Rao and Guha, 2018; Zhang and Li, 2014). The reference spectrum in this case belongs to a pixel that comprises spectra of several other materials including the mineral of interest. So, the pixels classified on the basis of this reference spectra may not entirely consist of a particular mineral but it will also contain the mineral that is being looked for, because the minerals present within that pixel have similar chemical composition and belong to the same parent mineral group. Hence, the mineral map seems to be unaffected by this problem. The accuracy of a mineral map can be determined by the degree of coincidence it has with the corresponding lithology, and also with band ratios and FCC (Hewson et al., 2005; Ninomiya, 2004). Point to point ground validation of the classified mineral map revealed a substantial match at the scale under consideration. To further strengthen this, XRD (X-ray diffraction) analysis of representative samples validates the purity of the image spectra of mineral end-members. For example, the presence of malachite was verified in the field (Fig. 11(a)). The lab generated spectra of the sample collected from the field shows three prominent absorption dips at 1.4, 1.9 and 2.2 μm (Fig. 11(b)). The laboratory spectrum of malachite was compared with the ASTER reflectance spectrum from the same location from where the sample was collected. Both the spectra almost match with each other and a prominent absorption dip around 2.2 μm was observed in common between the two spectra (Fig. 11(c)). Infrared spectra of malachite up to 14 μm also help characterization of malachite Fig. 11(d). The XRD results of the sample collected from the field also helps to further validate the presence of malachite, based on the characteristic peaks of the XRD plot (Fig. 11(e)). It is observed from the lineament map that comparatively more number of linear structural features are present towards south-east of Khera area which may indicate possible zone of structural weakness. From the lineament density map it is also observed that the density is more towards the south-east direction of Khera. High lineament density values can be correlated with alteration zones to a certain extent coupled with possible structural weakness due to the presence of fractures / faults etc. which may have acted as conduits for emanation of hydrothermal fluids. However, the actual relevance of lineament density to copper deposits can be known only after the overlay process i.e., integration with other geophysical parameters.

The area of interest i.e., Khera and surroundings is mostly associated with almost high gravity values. One more noteworthy observation is that, of all gravity values (57.11–97.30 mgals) of the study area, the known locations of copper and gossan occurrences fall within a range of 74.88–80.20 mgals. The exact reason for this cannot be accurately inferred since the gravity data available is only for a regional level. However, it is inferred from the study that gravity range in indicative about high density structure in depth and hence, was taken as a thematic layer.

The distribution of elements in the surface is largely governed by the background elemental constitution, ore systems developed and secondary weathering processes. The mobile elements are mainly controlled by the process of weathering, whereas surrounding/underlying lithology is the key factor controlling immobile to slightly mobile elements (Mason and Moore, 1985). Taking these facts into consideration, a general interpretation, has been arrived at, to target potential copper occurrences / deposits. ÖZGÜR, 1993 reported selective absence of Mn and Ti among common minor and trace elements indicating blind copper deposits. Therefore, absence of Mn-Ti minerals should be considered as a favourable criteria for copper occurrence. The geochemical concentration maps for the elements Mn, Ti and Cu prepared on this
basis give satisfactory results. As expected, absence of both Mn & Ti can be seen near Khera area (Fig. 8(a),(b)). Also, an anomalous presence of copper can be observed in this area where Mn & Ti concentrations are also less or absent (Fig. 8(c)). This finding correlates with the surface indications in the form of malachite staining observed during field work. Notably, malachite is a prominent pathfinder for copper. The area is dominated by base metal mineralization and hence, altered minerals and pathfinder elements/ minerals (e.g. Cu-indicators like chalcopyrite, malachite and sulphide rich phases like pyrite and galena) play an important role, if the ore mineralization is to be addressed based on surface indicators (Banerjee, 1980; Boopathi, 2010; Golani and Narayan, 1992; Khan and Sahoo, 2012, Khan et al., 2013, 2014, Mendas and Delali, 2012; Mukhopadhyay, 2009; Nigam and Geological Survey of India, 2016; Pant et al., 2015; Sengar et al., 2020). This is why the SAM classified outputs has been given maximum weights, immediately followed by prevalent surface geochemical signatures, lineament density and gravity. It is also noted that lineament map and gravity maps are swapped there happens no significant to final weighted overlay.

The resultant of the weighted sum overlay visually infers that favourable areas for copper occurrences / deposits predominantly lie between east and south of Khera. The result concurs with all the evidence thematic layers. Apart from the favourable areas in the central region of the study area, some potential areas can be seen towards the south of Khera. Pixels classified as chalcopyrite in the mineral map as well as FCC highlighting alteration almost coincide with the same area which gives a strong clue of copper occurrence / deposit in the area (Figs. 4 and 5).

5. Conclusions

Chalcopyrite is the primary ore mineral of copper in the study area. SAM output shows the presence of chalcopyrite towards the south-east of khera. In the copper concentration map derived from stream sediment geochemical analysis, it can additionally be seen that there is an anomalous presence of copper in the central region of the study area. The approach used in this study helps to localise the area for further exploration with the help of Earth Observation & Ancillary data. In this
case, even though there are surface indications of copper like malachite near Khera area, relatively unexplored areas towards the south of Khera should also be explored intensively as they seem to be promising for potential copper deposits.

This study also gives an insight into the exploration strategy. Prior to mineral mapping or any spectroscopic studies, a suitability study for areas suitable for mineral mapping can be adopted. The mineral mapping of such in turn gives a final output at pixel level in terms of mineral classification.
Author statement

We, the authors while submitting our revised manuscript (R1) of article entitled “Integration of remote sensing, gravity and geochemical data for exploration of Cu-mineralization in Alwar basin, Rajasthan, India” for possible publication in International Journal of Applied Earth Observation and Geoinformation journal authored by Shovan Lal Chattoraj, Gokul Prasad, Richa U. Sharma, P.K. Champati ray, Freek van der Meer, Arindam Guha and Amin Beiranvand Pour outline their individual contributions to the paper using the relevant CRedit roles, as follows:

**CRediT authorship contribution statement**

Shovan Lal Chattoraj: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. Gokul Prasad: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing - review & editing. Richa U. Sharma: Investigation, Methodology. P.K. Champati ray: Investigation, Methodology. Freek van der Meer: Resources, Software. Arindam Guha: Visualization. Amin Beiranvand Pour: Writing - review & editing.
Declaration of Competing Interest

The authors whose names are listed immediately below certify that there have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), nor financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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