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# Mapping Color in History

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Project Summary

*Mapping Color in History* (MCH) is a Digital Humanities project that collects and contextualizes scientific data drawn from existing and on-going material analyses of pigments in Asian painting.¹ MCH aims to help chart how, when, and why specific colors were used in artistic practices in specific regions, particularly in South Asia and the Himalayas. The MCH website hosts a searchable database that organizes pigment data from works of art. By adopting an object-based data model, MCH seeks to make pigment information more readily available and applicable for art-historical research. At the same time, the project serves conservation scientists as a platform to view their data in comparative terms and locate their objects of analysis in their historical and geographic contexts.

*Mapping Color in History* is a multi-disciplinary project with three main components: 1) digital asset development (database), 2) conservation science research (core data), and 3) art historical research (core data). Directed by Dr. Jinah Kim, George P. Bickford Professor of Indian and South Asian Art and Professor of South Asian Studies at Harvard University, the project involves collaboration among conservators, conservation scientists, data specialists, computing specialists, curators, and art historians across many institutions. The NEH Digital Humanities Advancement grant supported the development of a pilot database and visualization tools that allow users to search a large collection of paintings by pigment, date, and location. Combining this metadata, users can determine what pigments were available and used in certain periods and locations based on particular works of art. This white paper describes the project’s origins and goals, and it provides technical details about the development of the database, data model, and public-facing website. It also discusses the challenges posed by the project’s primary vectors of analysis—mapping, color, and history—and how the three components of the project worked together to face them.

Project Origin

*Mapping Color in History* originated in Dr. Kim’s research for her second monograph, *Garland of Visions: Color, Tantra and a Material History of Indian Painting*, (UC Press, 2021).² Focused on Indic manuscript painting of the period between 1000–1500, this book examines the role of color in the spread of visual knowledge of Indic Buddhism from medieval South Asia to distant locations. In the course of her research, which received initial funding from a Getty-NEH post-doctoral fellowship in 2012-2013, Dr. Kim worked closely with conservation scientists and conservators to gather and generate pigment analyses. Joan Wright (Bettina Burr Conservator) and Michele Derrick (Schorr Family Associate Research Scientist) of the Museum of Fine Arts

(MFA), Boston) completed a fresh analysis of fifteen folios of South Asian manuscript painting in the MFA collection. Katherine Eremin (Patricia Cornwell Senior Conservation Scientist) and Penley Knipe (Philip and Lynn Straus Senior Conservator of Works of Art on Paper and Head of Paper Lab) at the Straus Center for Conservation and Technical Studies at Harvard Art Museums also contributed a set of pigment analyses.

Based on this initial core data set, Dr. Kim hypothesized that some pigments believed to have been developed in Europe and imported to South Asia after 1700 CE may in fact have been in use in South Asia before their invention and commercialization in Europe. However, she did not yet have enough data points to explore this hypothesis. The idea behind *Mapping Color in History* was to pursue this exploration by systematically compiling and organizing pigment analysis data. Collected into a searchable database, individual pigment analyses could be connected and made more historically meaningful.

The functionality of MCH expands upon existing databases for technical art historical investigation. For example, The Forbes Pigment Database housed under Conservation and Art Materials Encyclopedia Online (CAMEO) captures important material data that serves as a valuable reference for the field. However, the “wiki” model of the site does not capture the relational information between objects, pigments, and scientific analyses, and it does not allow for the historical and geographical contextualization of pigments. Colourlex, a science and art initiative supported by the Cogito foundation based in Switzerland, provides accessible information on elemental composition of pigments and analytical methods used for their identification, including a section that lists “first date of use” and “history of use” for each pigment. However, the database is limited by its focus on Western art (particularly post-Renaissance European painting) and its reliance on published data.

**Project Goals**

By commissioning and compiling further analytical study of pigments used in the rich history of painting in South Asia and the Himalayas, *Mapping Color in History* seeks to rewrite the history of pigments by highlighting the scientific and artistic interventions of the Indian subcontinent. The project aims to put Indian artisans and premodern chemists on the world map and foster deeper understanding of their contributions to the world of color. By making the artistic and scientific achievements of India’s past more accessible, the platform aspires to educate future generations about the importance of preserving this past.

Additionally, MCH endeavors to bridge a gap between scientific and art-historical research. When U.S. museums either conduct pigment analyses in their conservation labs or commission such analyses for treatment purposes, the results typically remain in the specific lab and/or institution. Published journal articles, conservation reports, and museum publications are often aimed at conservation audiences, and their language and data is not necessarily aimed at

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3 CAMEO, http://cameo.mfa.org/wiki
historical researchers, who have to navigate an uneven terrain of modes of data presentation and compilation. To better facilitate historical and art-historical research, MCH seeks to model and implement standards for compiling and comparing data generated at various institutions.

Grounded in a material approach to color, MCH investigates the dynamic between color’s tactical and physical properties and its experience in the digital age. Dr. Kim’s research into the relationship between pigment availability and preference in different periods inspired the project’s formation and growth. For example, contemporary popular understanding identifies the the Sanskrit term “kṛṣṇa” with “blue” based on the color of the Hindu god of the same name,. However, this term did not always mean “blue,” and the lord Krishna (Krṣṇa) was not always imagined as “blue.” In her work, Dr. Kim observed how artistic, painterly interventions appeared to precipitate the codification of Krishna as “blue.” But even then, the particular blue used to imagine and depict Krishna changed depending on where and when a work was made. MCH opens up this and similar questions about symbolically and historically significant colors to analysis: how did the rarity of naturally occurring blue pigments, such as ultramarine, shape the culturally specific meaning of “blue”? How did certain pigments affect the perception of dark skin tones and people of color in pictorial representations? By placing pigment analysis data in geographical and temporal context, MCH facilitates art-historical examinations of how the availability of pigments has informed the changes in the perception and symbolic meaning of colors over space and time.

Project Team

This project is led by Dr. Kim (PI), and the project’s technology co-directors are Rashmi Singhal (Director of Arts & Humanities Research Computing, Harvard University) and Jeff Steward (Director of Digital Infrastructure and Emerging Technology, Harvard Art Museums). Singhal oversees the digital aspects of the project and manages all interactions and reporting with outside vendors. Steward provides advice on the soundness of the database model and its interoperability with the Harvard Art Museums’ existing database. Project research assistants Francesca Penty, Evan Long, and Kristen Pearson enter and manage the data. Cole Crawford (Arts & Humanities Research Computing, Harvard) serves as a digital development coordinator. The project also has an advisory board composed of conservation scientists, conservators, and curators. Conservation specialists have been providing the necessary data for the project, and they are one of the primary intended user groups of the database. The advisory board serves in a consulting role and helps test the database as it develops, develops solutions to identified challenges, and shapes future areas of development. A full list of project team members is in the Appendix.

The initial database model and the basic admin interface were built by Digirati, a UK-based digital asset development company, with an internal grant from Harvard. For the NEH

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grant, Eldarion, a US-based software development company, built upon this baseline work to create a full-fledged relational database.

Project History

*Mapping Color in History* began as a pilot database idea in spring 2018 with the support of a Barajas Dean’s Innovation Fund for Digital Arts and Humanities from the Arts and Humanities Division of Harvard University. This funding turned out to be inadequate to support the development of a prototype database, in particular because of the challenges in the complexity and uneven nature of the historical information attached to each object. A manuscript may be dated to a specific time of a specific year, like circa 1497 CE, or it may be dated to a date range of a few decades, c. 1430-1450 CE, to a century, c. 15th century. The location of an object can also be very specific, from a neighborhood in Ahmedabad, Gujarat, India, to a very broad category, “Western India.” A manuscript may have been dispersed and collected in different collections, and the database needs to be able to accommodate identification of each folio under a “parent” object that may or may not be in the same repository.

Through consultations with conservation specialists at Harvard and MFA, as well as with Harvard University colleagues Rashmi Singhal (Director of Arts & Humanities Research Computing) and Jeff Steward (Director of Digital Infrastructure and Emerging Technology) during summer and fall 2018, it was determined that the project needed a custom database model. No existing database model can be plugged to capture the complexity of the historical data that the MCH project proposed to capture. In collaboration with Digirati, the project team spent 2019 creating a basic database and web application for data entry and testing the adequacy and efficiency of the baseline model.

Project Activities

Summary

The NEH grant funded the development of a digital infrastructure for the database and a public-facing website, the technical details of which are explained fully in the “Project Activities In Depth” section below. On the side of digital asset infrastructure development, we worked with Eldarion to transfer the pilot database model implemented by Digirati in 2019 to a Harvard-based hosting site. After Dr. Kim and research assistants compiled and cleaned existing and newly generated analytical data, we used it to test the pilot database. These tests allowed us to identify and implement necessary improvements to the database model and the administrative interface.

On the front end, we designed, mocked up, and developed a public-facing website. The website includes a search function, a timeline filter, and an IIIF-enabled image viewer. Users can browse objects in the database by color, pigment, and element. An interactive mapping tool
enables users to locate objects geographically and zoom in and out wherever data is located. Further improvements to the front end display of the data incorporated collection accession data and related work information. The website also includes a reference section that draws on the work of research assistants.

The grant also supported improvements to the project’s data collection and management workflows. We created a centralized, controlled spreadsheet for data management and established a web-based project management tool to facilitate collaboration. We also continued our efforts to ensure consistency across disparate data sets, for example by refining our controlled vocabulary for pigments and art-historical terms for style. Grant support for research assistants enabled us to run virtual workshops with specialists.

Database Model

*Mapping Color in History* is distinct from existing pigment databases in that its data model records information about art objects as well as pigments. Digirati designed and built a relational PostgreSQL database using the Python web framework Django, as well as an admin portal using Django Templates. Working with Eldarion, we incrementally refined the database and admin portal through ongoing conversations across the MCH team. In its current form, the database is split into two main sections: “Folio,” which deals with art objects, and “Inkwell,” which deals with colors and pigments (Figure 1). The interaction between these two sections is managed through an admin portal built using Django templates, which is where research assistants enter art objects and pigment analyses into the database.
“Folio” is centered on the “Works” table. This table records each artwork’s basic descriptive information through a combination of controlled fields and free-entry fields. Free-entry fields include the work’s title, accession number, dimensions, the URL of the object’s listing on its home repository website, its IIIF manifest (see below), and a notes field. The controlled fields—date, artist, repository, location, medium, style, and associated publications—are all linked to other tables in the database to keep entries consistent.

The “Inkwell” section of the database stores pigment analyses and data about colors, elements, and pigments. Each object can have one or more analyses associated with it. A single “Analysis” entry is an event associated with a single object and has a start date, end date, and analyst (such as an art conservator or consulting scientist). Analysts whose work is captured in the database are stored in a separate table that records their job title and institution. Analyses can also be linked to the publications from which they were sourced. Once a researcher adds an analysis to a table, they can add color-based pigment analysis entries to the overall analysis event. Each piece of pigment analysis data is classified according to a single term from the project’s controlled vocabulary for visible color. Within a Pigment Analysis, additive fields register identified Pigments, Elements, and Methodologies. This data structure accommodates multiple analysis methods used on different parts of the same object. Each identified pigment within an analysis is recorded along with a level of certainty (Certain >75%, Possible >30%, Unknown/Uncertain). In the case of mineral pigments, each identified element in an analysis is recorded with an amount (Major, Minor, Trace, Unknown). Employed analysis methods are linked to analysis points identified by textual descriptions and numerical references to the analysis point maps provided by analysts.

The MCH database depends on a number of controlled vocabularies. Because style terms for South Asian and Himalayan painting are not well defined, the project team developed a custom controlled vocabulary list with the aid of the Getty Art and Architecture Thesaurus Online (ATT, and we are continuing to refine it with the input of art historians and curators. The project team also designed a custom controlled vocabulary for color (see “Project Challenges: Color” below). The controlled vocabularies for pigment names and scientific information were developed in consultation with conservation scientists at the Harvard Art Museums and the Museum of Fine Arts, Boston (all of whom are on the MCH advisory board) and they reference the Museum of Fine Arts Boston’s Conservation and Art Materials Encyclopedia Online (CAMEO), and Getty Art and Architecture Thesaurus Online (ATT). The controlled vocabulary for analysis methodologies references CAMEO, the American Institute for Conservation (AIC) Wiki, and ATT.

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Data Collection and Management

Prior to the NEH grant, we developed templates for data collection that would allow us to align the pigment data we receive from conservation scientists more easily with the data model (Appendices C and D). For example, these templates explicitly ask contributors to choose from the controlled vocabulary for colors (see “Project Challenges: Color” below) and to identify whether pigments are “certain,” “possible,” or “uncertain/unlikely.” Implementing, evaluating, and refining these templates during the NEH grant enabled us to greatly improve the accuracy of our data.

In addition, project research assistants Evan Long and Kristen Pearson, whose work was funded by the NEH grant, helped improve our data entry workflow by creating a centralized spreadsheet for recording data. This spreadsheet, which the team works on collaboratively using Google Suite, keeps track of artwork and analysis data as it makes its way from the submitted templates to the database. This spreadsheet makes use of Google’s data validation features to incorporate the project’s controlled vocabularies. Long and Pearson also created a Kanban board using Trello, a web-based project management tool. This board keeps track of research tasks and serves as a centralized location for data entry resources that is especially useful for new research assistants joining the project. To improve workflows, we also developed a tagging system for related works and an approval tool with which scientists or Dr. Kim could review and approve data for publication.

In support of our data collection efforts, we continued our work with the MFA and the Harvard Art Museums and began new collaborations with additional institutions in the US (Virginia Museum of Fine Arts, Detroit Institute of Art, Cincinnati Museum of Art). We also continued to collaborate with institutions in India, in particular the Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS) Art Conservation Centre in Mumbai. In August 2022, we started a historic collaboration with the Asiatic Society Mumbai deploying the MCH mobile heritage lab to the institution and conducting on-site analytical research on art historical important manuscripts in the AS Mumbai collection.

Public-Facing Website

The public-facing website is built using the Javascript framework Vue and pulls from the Django database through a GraphQL API layer. The website was designed by Cara Buzell, also funded by the NEH grant.

As a result of the database model, the user experience of the MCH website is also centered on objects. This is true when searching works or browsing by pigment, color, or geographic location. For example, when browsing by the color green, the website will return objects with analyses that contain entries assigned to the visible color green. Users can filter their search by aspects of artwork data (object type, institutional collection, artist, medium, location, date) and analysis data (methodology, pigments, colors, elements). In addition, the

main search page includes a timeline that can be bracketed on either side independently of the descriptive date metadata (Figure 2). The default view for the search page contains image thumbnails, and users can switch to a map view, built with the open-source Javascript library Leaflet, that also reflects their search query and selected filters. Markers on the map feature pop-ups that contain a thumbnail image along with the object’s title, type, and date. Search results without geodata are reported above the map (Figure 3). Using the map and the timeline in conjunction, users can interactively examine the geographical distribution of pigments over time.

Figure 2. The Thumbnail view of the website’s main search page, showing search bar, filters, and timeline.

Clicking on an object’s image and metadata (Thumbnail view) or the “View Detail” link in the pop-up (Map view) takes the user to an object page. Below an object’s title, an “Artwork Info” section displays object metadata from the “Work” table. A IIIF viewer presents high-resolution, zoomable images (see “IIIF” below). Clicking an “Analysis” button opens a table displaying what colors and pigments were found in a given analysis (Figure 4). Under “Color,” each identified color is represented by a colored square. Identified pigments are listed under “Pigments,” each with a signal strength icon indicating the certainty of its identification. Elements listed by symbol under “Elements” are paired with black, gray, and white stars to indicate whether they are Major, Minor, or Trace, respectively. “Analysis Point” contains the textual descriptions and numerical references for analyzed points. Finally, “Location/Method” lists the analysis methods used to identify each color. In cases where different methods were used on different points of the same color, the methods have location descriptors.
**Figure 4.** Example Analysis view with identified colors, pigments, elements, and contextual metadata.

### IIIF

The website’s image display functionality utilizes the International Image Interoperability Framework (IIIF), known colloquially as “Triple-I F.” IIIF is a set of open standards for delivering high-quality, high-resolution digital objects and images. Singhal and Crawford built the project into a IIIF infrastructure built and maintained by Harvard’s Library Technology Services (LTS) to ensure long-term sustainability.

MCH draws on the data of multiple institutions, and the project’s IIIF workflow accounts for source institutions that already use IIIF as well as those that do not. On the backend, Crawford wrote a python library ([lts-iiif-ingest-service](https://lts-iiif-ingest-service)) to accommodate images from...
institutions that do not already use IIIF. This library handles the upload of new objects to the project’s digital asset management system, a process known as ingest. Specifically, the library helps other applications manage ingest credentials, upload images to S3 for ingest, create IIIF manifests, create asset ingest requests, and track the status of ingest jobs. In addition to serving the needs of MCH, this open-source library can now be used by future projects at Harvard to streamline the ingest process.

The data entry workflow also manages existing and new IIIF manifests. A IIIF manifest is a JSON document containing the image and metadata for a particular digital object. If the object already has a IIIF manifest from its home institution (for example the Harvard Art Museums), the researcher can include the URI for this manifest when creating the work in the database admin platform. If not, the researcher can create a manifest within the portal. The manifest creator can handle multiple images and provides options for their display. This feature is especially important for MCH, since the database contains multi-paged manuscripts.

The image annotation feature, while still in progress, allows researchers to indicate the location of pigment analyses on a high-resolution image of a given artwork. This feature relies on catchpy, an annotation server developed at Harvard as part of AnnotationX, an educational tool for annotating images, video, and text in Learning Management Systems like edX and Canvas. Crawford extended this tool to create point annotations and connect them to pigment metadata in the database.

Project Challenges

Each element of MCH’s main premise—mapping, color, and history—requires interpretive decisions. Our work describing subjective colors, pinpointing where objects were made, and refining object dates involves balancing the technical needs of the data model and website with the rigors of art-historical research. On the website, a page called “Our Process” also captures some of these decisions to communicate them to users.

Color

Color perception is shaped by psychological and social factors, and as a result, it is subjective and difficult to capture. In the face of this recognition, MCH takes a color realist position, focusing on the material substances employed in art to generate experiences of color. Mapping color in history, then, entails mapping the appearance and the use of specific colorants, including pigments and organic dyestuffs, that shaped people’s experiences of color. Ultimately, we hope that pairing visual and material definitions of color via analytical data will contribute to a more concrete, more materially-oriented understanding of the basis of subjective color judgments. To facilitate this goal, we have made some choices about vocabulary. Although what

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we call “color” in the project may be more accurately defined as “hue,” we use “color” to refer to what appears on the surface of an artwork. We use the term "pigments" to refer to the material basis of color in painting, but these materials also include other colorants like organic dyestuffs.

The subjective nature of color perception made devising a controlled vocabulary for color a necessary challenge for the project. Our vocabulary includes the major hues—red, yellow, blue, orange, green, and purple—and black and white, which control the shade and the intensity of a color value in painting. Three additional hues of pink, grey, and brown help document certain artistic interventions in modulating the intensity of hues and shades. Our material-oriented approach also includes “metallic” in our color vocabulary, grouping together gold, silver, and tin, among other apparent colors and effects. These decisions reflect our desire to make sure the database is useful for different user types. For example, an art historian can find objects using gold by browsing metallic colors, while a conservation scientist may choose to filter on gold as a mineral element.

Locations

For MCH’s purposes, “Location” refers to an artwork’s production site. This information, when available, allows for insights into where pigments were used. However, not all objects in the database come with location data from their home repositories, and the location data we do have is not all at the same level of granularity. This can be in part a result of different institutional metadata practices, but more often it is due simply to uneven knowledge about artworks. Dr. Kim and the project’s research assistants are instrumental to the gathering and refinement of location data. While this data is initially based on information provided by an object’s collecting institution, the team will modify and revise information in accordance with research findings. Geographic locations are maintained in the database’s “Locations” table. When adding a location, research assistants look up its URIs on both Geonames and the Getty Thesaurus of Geographic Names (TGN). They also include latitude and longitude coordinates. When an object is associated with a location, these coordinates power the object’s appearance on the public website’s interactive map. Since identifying locations, even broad ones like regions or states, is highly interpretive and can be controversial, contradicting arguments are recorded in a “Notes” field of the Location table.

It is not only art-historical curiosity that drives the goal of identifying the narrowest geographic terms possible for each object; this task is also necessary for the “mapping” element of the project. Locations need to achieve a certain level of specificity to be mapped, and the more specific a location is, the more accurately it can be mapped. Because of the uneven granularity of the MCH data, the map contains points with different representational relationships to the objects they indicate. If an object’s location can only be narrowed down to a

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large geographical area, such as the modern state of Gujarat, it is mapped to a centralized point in that area sourced from Geonames. We recognize that such a point represents a different type of information than the nearby point marking an object made in Khambhāt, a city in Gujarat. While we do not think this difference impedes a user’s ability to research the spread of pigments, we are interested in exploring ways to visually indicate this difference in future work on the project.

Dates

As with locations, we adopt the narrowest historical dates possible for each example. However, narrowing down a date—for example, from half a century to two decades—is at times a challenge and can be controversial. Dating objects is also complicated by modifications that happen after an object’s original creation. When an object has been altered at a later date and the pigment data reveals this modification, we record the date of the object's modification with a note indicating its original production date. When an object has been modified per modern preservation efforts, we record the date of the object's production with a note indicating the possibility of later retouching in certain analyzed areas.

Collecting institutions employ a variety of descriptive terms and strategies to indicate levels of certainty about object dates. The timeline function of the MCH website, however, requires numerical dates to function. The project team created a style guide to consistently handle the translation between these two types of data (Appendix B).

Project Timeline

The timeline for our activities was impacted by the COVID-19 pandemic. Work originally slated to start in March 2020 was delayed until mid-May. We were also unexpectedly unable to work with Digirati, the UK-based company that developed the pilot project. As a result, digital asset and interface development originally planned for Spring 2020 was largely delayed until Fall 2020, when we entered a contract with the US-based software firm Eldarion. We worked with Eldarion for two sprints from November 2020 to November 2021.

As a result of these delays, we were unable to implement the annotation capabilities we originally planned using IIIF. This feature, which we plan to add at a later point in the project, will make it possible to locate the data collection coordinates for each pigment on a high-resolution image of a given object. These data points can then be tied to specific analytical methods. The other challenge we faced was cleaning the project’s inconsistent data. In addition to the variation within date and location described above in “Project Challenges,” the pigment analysis data also introduced issues of interpretation, as different analysts may interpret the same raw analysis data into different pigment identifications. The cleaning process ended up taking much longer than initially anticipated, and new collaborations enabled by other internal and external grants added to our backlog. As a result, less than half of the data we have collected
is available on the end-user site for research. The remaining objects require further art historical research on each object and consistency review of the analytical data.

Project Outcomes

The project website (https://mappingcolor.fas.harvard.edu) went live in May 2022 and was followed quickly by a webinar show-and-tell session with conservators, curators, and digital humanities specialists to seek feedback on the site's usability and functions. Dr. Kim also shared the website through in-person and virtual presentations that reached anticipated audiences, including the local university community, conservation specialists and museum professionals in India, and librarians and scholars of South Asian art. Demonstrated enthusiasm for and interest in the project has already spurred new collaborations, such as with the Asiatic Society in Mumbai, that will add further analyses and objects to the MCH database. Conservators were especially excited by the ability to filter search results not just by pigment, but also by element.

This project has created an opportunity for participating graduate students research assistants to gain practical experience with digital humanities. In weekly meetings, Dr. Kim introduced these students to digital humanities methodologies and tools and encouraged them to research how other existing digital humanities projects are structured and developed. Through these meetings, the students and project assistants learned about basic principles of digital humanities along with best practices in digital humanities. This experience has improved their familiarity with digital humanities, and one PhD student, Vaishnavi Patil, proposed a digital humanities project of her own, which was funded by an internal grant from the Lakshmi Mittal and Family South Asia Institute, and others are also taking the digital humanities tools seriously in organizing and presenting their own research data.

The project has also reached audiences beyond the academy and GLAM sector, for example a high school student studying chemistry, who learned of the project from a family friend. After connecting with Dr. Kim and learning about the database, this student pursued independent research on color red on our database and used that information in her research paper on a modern Indian woman artist Amrita Sher-Gil and her use of color red. We are interested in further pursuing the pedagogical potential for MCH in high school settings as a way to connect STEM subjects and humanities material.

Project Evaluation and Impact

We have hosted multiple virtual workshop sessions to introduce the database and the project site to the interested groups. We held our first virtual session with conservation specialists and curators during which participants were asked to use the site and undertake certain tasks and respond to our queries. After each virtual workshop we sought feedback on the

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site’s functionality and features with a follow-up survey using Google Forms. The general response from the audience and the users was that they understood the site’s goals clearly and found it helpful. Respondents indicated that they could envision themselves using the site for teaching as well as research. These surveys also helped us identify future improvements for the interface, for example making the timeline feature easier to use.

One of the real-world applications of the database was seen in the Forbes symposium in conservation science held at the Smithsonian institute, Washington DC in June 2023. The MCH conservation scientist, Dr. Erin Mysak (now at the Museum of Fine Arts, Boston) presented a paper co-authored with multiple collaborators in the MCH project, “Mapping Color in History: A case study of pigments on painted palm-leaf manuscripts from South Asia.” The MCH database was referenced in another research paper presented at the symposium as providing important and helpful information. PI has been sharing the project at various conferences, including the Digital Humanities Conference held in Graz, Austria, in July 2023. The annual theme for DH 2023 was Collaboration as Opportunity, and our long-paper proposal “Translating science for humanities research: Mapping Color in History” was selected for the session on Humanities and Sciences and the paper demonstrated how the MCH brings together art historical and scientific research by harnessing the power of digital tools.

Another real world application of the project is our success in pursuing collaboration with collections in South Asia. Thanks to the visibility and the usability of the database, we are able to pursue collaborative research projects with institutions in South Asia, leveraging the MCH mobile heritage lab established in 2021. We have been on-site at the Asiatic Society, Mumbai documenting and pursuing non-invasive analytical research on a few art historically important manuscripts, including one of the earliest surviving dated painted manuscripts of the Aranyaka Parvan (a section of the famous Hindu epic, Mahabharata). We have collected controlled analytical data and conducted art historical research that would enrich our understanding of the early history of manuscript painting in South Asia while providing the Asiatic Society, Mumbai with robust research results and conservation recommendations. The data from this research will be made available on the MCH database further enhancing the project’s value as a historical data set.

Project Continuation and Long-Term Impact

We plan to continue developing MCH by applying for further funding. Our future priorities include implementing the IIIF annotation feature and continuing to clean and normalize the data, so that a larger proportion of the database’s content will be accessible to users. As more data is added to the database, we would like to implement deeper search capabilities that will aid users in navigating its objects.


Through conversations with users and the advisory board, we have also identified important refinements for the data model and the interface. To reckon with the difficulties posed by date and location data (See “Project Challenges” above), we will do further research into how the different numerical properties and levels of certainty associated with these data points can work better together. We would also like to explore whether the database model can incorporate more complex data from the pigment analysis reports, specifically the scientific visualizations and raw data they contain.

Another future goal is to highlight the art-historical research that has both enabled the database and is enabled by the database. We plan to develop new ways to visualize and present art historical data and bibliographic data on the database. By implementing the search engine library Elasticsearch, we hope to achieve major improvements on the search function that will accommodate cognate terms, local (foreign language) terms, and misspellings.\(^\text{16}\) We also hope to develop a system to indicate the rigor and accuracy of data. One of the visualization tools may be a time-lapsed map of distribution of certain pigments in use over time. We have already garnered the Phase III NEH grant to start transforming this database into a multidisciplinary research platform that accommodates across various fields in art and science. The future work plan also includes continuing our collaborative efforts in conservation science, finding funding and resources to support further controlled analytical research in pigments in different collections both in the US and in South Asia and elsewhere. We currently have analytical data for nearly 300 objects (291 to be exact) that we have collected so far, around one third of which come from concerted, controlled analysis campaigns that the MCH project has conducted in collaboration with our partner institutions and scientists. As we strive to build a critical mass for all periods in South Asia and the Himalayan region, we are also taking analytical data from objects from other parts of Asia. The PI’s vision is to make the MCH a research platform and reference data set that anyone interested in color, colorants, material history of painting and even conservation science can use for their own research and exploration for years to come.

\(^{16}\) Elasticsearch, https://www.elastic.co.
Appendices

Appendix A: Project Team and Participating Institutions (as of June 2023)

Principal Investigator/Project Director
Jinah Kim, George P. Bickford Professor of Indian and South Asian Art, Harvard University

Project Technology Co-Directors
Rashmi Singhal, Director of Arts & Humanities Research Computing, Harvard University
Jeff Steward, Director of Digital Infrastructure and Emerging Technology, Harvard Art Museums

Digital Technology Coordinator
Cole Crawford, Software Engineer/Humanities Research Computing Specialist, Arts & Humanities Research Computing, Harvard University

Consulting Scientists
Michele Derrick, Formerly Schorr Family Associate Research Scientist, Museum of Fine Arts, Boston
Erin Mysak, Schorr Family Associate Research Scientist, Museum of Fine Arts, Boston
Anjali Jain, MCH India coordinator and independent conservator

Project Assistants (Database management research, data entry, research on conservation techniques)
Francesca Penty, Mapping Color in History Project research assistant (2018-2022)
Evan Long, Mapping Color in History Project research assistant
Kristin Pearson, PhD Candidate in Anthropology, Harvard University
Athalia Meron, Harvard College '25, Physics and Chemistry
Jane Josefowicz, Harvard College '25, HAA and Classics

Art History Research Assistants
Raghunath Akarsh, PhD candidate in History of Art & Architecture, Harvard University (2022-2023)
Louis Copplestone, PhD candidate in History of Art & Architecture, Harvard University (2022-2023)
Sonali Dhingra, recent PhD (2021) in History of Art & Architecture; Robert N Ho Postdoctoral Fellow in Buddhist Studies, University of California, Berkeley (2023-2025)
Vaishnavi Patil, PhD candidate in History of Art & Architecture, Harvard University
Nandita Punj, recent PhD (2021) in Art History, Rutgers, State University of New Jersey
Victoria Andrews, PhD candidate in History of Art & Architecture, Harvard University

Advisory Board (as of June 2023)

Francesca Bewer, Research Curator of the Conservation and Technical Study Programs and Director of Summer Programs and Director of Summer Institute for Technical Studies in Art, Harvard Art Museums

Michele Derrick, Schorr Family Associate Research Scientist (until 2020), Museum of Fine Arts, Boston

Katherine Eremin, Patricia Cornwell Senior Conservation Scientist, Harvard Art Museums

Meena Sonea, former Executive Director of Lakshmi Mittal and Family South Asia Institute (until 2021)

Narayan Khandekar, Director of the Straus Center for Conservation and Technical Studies and Senior Conservation Scientist, Harvard Art Museums

Richard Newman, Head of Scientific Research, Museum of Fine Arts, Boston

Penley Knipe, Philip and Lynn Straus Senior Conservator of Works of Art on Paper and Head of Paper Lab, Harvard Art Museums

Anupam Sah, Head of Art Conservation, Research, and Training, Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS), Mumbai

Laura Weinstein, Ananda Coomaraswamy Curator of South Asian and Islamic Art, Museum of Fine Arts, Boston

Joan Wright, Bettina Burr Conservator Emerita, Museum of Fine Arts, Boston

Collaborating Institutions (as of June 2023)

Harvard Art Museums
Museum of Fine Arts, Boston
Weissman Preservation Center, Harvard Library
Detroit Institute of Art
Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS), Mumbai, India
Asiatic Society, Mumbai
Appendix B: Style Guide for Dates

<table>
<thead>
<tr>
<th>Certain Dates</th>
<th>Date</th>
<th>Start date</th>
<th>End date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific date</td>
<td>February 8, 1672</td>
<td>1672-02-08</td>
<td>1672-02-08</td>
<td>Do not index like 2/8/2011 or 8 February 1672</td>
</tr>
<tr>
<td>Year</td>
<td>1147</td>
<td>1147-01-01</td>
<td>1147-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 CE</td>
<td>10-01-01</td>
<td>10-12-31</td>
<td>Do not use “AD”. “CE” follows the date”</td>
</tr>
<tr>
<td>Year range</td>
<td>1660-1680</td>
<td>1660-01-01</td>
<td>1680-12-31</td>
<td>Do not abbreviate years.</td>
</tr>
<tr>
<td></td>
<td>50-57 CE</td>
<td>50-01-01</td>
<td>57-12-31</td>
<td></td>
</tr>
<tr>
<td>“Before date”</td>
<td>before 1758</td>
<td>1753-01-01</td>
<td>1757-12-31</td>
<td>Subtract more than 5 years where necessary.</td>
</tr>
<tr>
<td>“After date”</td>
<td>after 1865</td>
<td>1865-01-01</td>
<td>1870-01-01</td>
<td>Add more than 5 years where necessary.</td>
</tr>
<tr>
<td>Decade date</td>
<td>1660s</td>
<td>1660-01-01</td>
<td>1669-12-31</td>
<td></td>
</tr>
<tr>
<td>Century date</td>
<td>16th century</td>
<td>1500-01-01</td>
<td>1599-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd century CE</td>
<td>100-01-01</td>
<td>199-12-31</td>
<td></td>
</tr>
<tr>
<td>Partial century</td>
<td>early 16th century</td>
<td>1500-01-01</td>
<td>1533-12-31</td>
<td>Begin or end dates can be adjusted based on additional information. Never pluralize century.</td>
</tr>
<tr>
<td></td>
<td>mid 16th century</td>
<td>1534-01-01</td>
<td>1566-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>late 16th century</td>
<td>1567-01-01</td>
<td>1599-12-31</td>
<td></td>
</tr>
<tr>
<td>Century range</td>
<td>16th-17th century</td>
<td>1500-01-01</td>
<td>1699-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>late 16th-early 17th century</td>
<td>1567-01-01</td>
<td>1633-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1st-3rd century CE</td>
<td>01-01-01</td>
<td>299-12-31</td>
<td>Do not use “AD”. For centuries, “CE” follows</td>
</tr>
<tr>
<td>Certain Dates</td>
<td>Date</td>
<td>Start date</td>
<td>End date</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td>------------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Approx dates</td>
<td>c. 1700</td>
<td>1695-01-01</td>
<td>1705-12-31</td>
<td>&quot;century&quot; Enter “CE” with dates up until, and incl. the 5th century Add and subtract 5 years.</td>
</tr>
<tr>
<td></td>
<td>c. 1660-1670</td>
<td>1660-01-01</td>
<td>1670-12-31</td>
<td></td>
</tr>
<tr>
<td>Uncertain dates</td>
<td>1660 or 1661</td>
<td>1660-01-01</td>
<td>1661-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1660s or 1670s</td>
<td>1660-01-01</td>
<td>1679-12-31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>probably 1631</td>
<td>1631-01-01</td>
<td>1631-12-31</td>
<td>5 years at either side.</td>
</tr>
<tr>
<td></td>
<td>possibly 1631</td>
<td>1626-01-01</td>
<td>1636-12-31</td>
<td></td>
</tr>
<tr>
<td>&quot;BCE&quot; year</td>
<td>250 BCE</td>
<td>-250-01-01</td>
<td>-250-12-31</td>
<td>Do not use “BC”.</td>
</tr>
<tr>
<td>&quot;BCE&quot; year range</td>
<td>255-265 BCE</td>
<td>-255-01-01</td>
<td>-265-12-31</td>
<td></td>
</tr>
<tr>
<td>&quot;BCE&quot; century</td>
<td>10th century BCE</td>
<td>-100-01-01</td>
<td>-901-12-31</td>
<td></td>
</tr>
<tr>
<td>&quot;BCE&quot; century year</td>
<td>10th-7th century BCE</td>
<td>-1000-01-01</td>
<td>-601-12-31</td>
<td></td>
</tr>
<tr>
<td>&quot;BCE/CE&quot; year range</td>
<td>115 BCE-5 CE</td>
<td>-115-01-01</td>
<td>4-12-31</td>
<td>&quot;BCE&quot; and “CE” come after the date. Enter “CE” with dates up until, and incl. the 5th century</td>
</tr>
<tr>
<td>Date with printed date</td>
<td>1882, printed later</td>
<td>1882-01-01</td>
<td>1882-12-31</td>
<td>Latest date can reflect either the negative or print date at the discretion of curator</td>
</tr>
</tbody>
</table>
Appendix C: Analysis Report Template

Artwork Pigment Analysis Report

Report Completion Date:

Title:

Accession Number:

Repository:

Summary:

The folio was examined by [enter analysis technique(s) here] in numerous colored regions.

The resultant elemental analysis showed that the following colorants are present (MCH certainty level 'certain'):

•

These additional colorants are possible, but need further analysis for confirmation (MCH certainty level 'possible'):

•

These additional colorants are uncertain and would require repeat analysis for confirmation (MCH certainty level 'uncertain/unlikely'):

•

Analyst and Artwork Information
Fields marked with an asterisk are optional.

**Analyst Information**

Name(s) of analyst(s):
Job title:
Institution:
Project number*:
Date(s) of analysis:
Methods of analysis:
Analysis method model*:
(e.g. Bruker Artax XRF)

**Artwork Information**

Title:
Artist*:
Repository:
Accession number:
Related artworks:
(by accession number)
Classification*:
(Select from: album page, manuscript folio, painting, mural, painted textile, book cover, other [please specify])
Folio number*:
Parent work*:
(e.g. ‘From a Bhagavata Purana series’)
Annotated Image: Analysis Points and Description

Pigment Analysis
<table>
<thead>
<tr>
<th>Visible color</th>
<th>Pigments</th>
<th>Certainty level</th>
<th>Elements</th>
<th>Analysis point and description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green (example)</td>
<td>Orpiment 1</td>
<td>Major: As, S</td>
<td>Minor: -</td>
<td>Trace: 1, tree</td>
<td>1, tree (raman)</td>
</tr>
<tr>
<td></td>
<td>Indigo 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.*
Please specify analysis methodology

Infrared or UV images
Appendix D: Sample Analysis Report

Artwork Pigment Analysis Report

Report Completion Date: December 7, 2022

Title: Gaura-Mallara Ragini (A Musical Mode)

Accession Number: 26.389.A

Repository: Detroit Institute of Arts

Summary:

The folio was examined by XRF, vis-NIR FORS and with UV in numerous colored regions.

The resultant analysis showed that the following colorants are present (MCH certainty level 'certain'):

- Insect dye
- Tin paint
- Gold paint
- Vermillion
- Smalt
- Lead white
- Indigo
- Organic yellow
- Atacamite (salt green? Other copper chlorides may be present)
These additional colorants are possible, but need further analysis for confirmation (MCH certainty level 'possible'):

- Zn white/Ba white or lithopone

These additional colorants are uncertain and would require repeat analysis for confirmation (MCH certainty level 'uncertain/unlikely'):

---

**Analyst and Artwork Information**

*Fields marked with an asterisk are optional.*

**Analyst Information**

Name(s) of analyst(s): Christina Bisulca

Job title: Andrew W. Mellon Conservation Scientist

Institution: Detroit Institute of Arts

Project number*: 26.389.A

Date(s) of analysis: September-October 2021

Methods of analysis: XRF, vis-NIR FORS, UV examination

Analysis method model*: Bruker Tracer 5g XRF, ASD FieldSpec 4 spectroradiometer (350-2500 nm), Keyence VHX-7000 digital microscope with NightSea UV light source
Artwork Information

Title: Gaura-Mallara Ragini (A Musical Mode)

Artist*: India

Repository: DIA

Accession number: 26.389.A

Related artworks: None listed
(by accession number)

Classification*: Painting
(Select from: album page, manuscript folio, painting, mural, painted textile, book cover, other [please specify])

Folio number*:

Parent work*:
(e.g. 'From a Bhagavata Purana series')

Date: ca. 17th Century

Location:

Style*:
(e.g. Rajput)

Size: Image: Sheet: 7 5/8 × 6 1/2 inches (19.4 × 16.5 cm)
(H x W cm)

Medium: Opaque watercolor and gold on paper
(e.g. 'Ink and opaque watercolor on palm leaf')

Paratext*:
(inscriptions, labels, signatures etc.)

Text*:
(on the verso, recto, or both, and the chapter or title of the artwork; distinguish this from 'Paratext')

Exhibition history*:
Miniatures and Small Sculptures from India, Organized by the University of Florida, Gainsville, Florida, April 10, 1966 - May 29, 1966

Court, Village, and Monastery: South Asian Paintings from the Permanent Collection
Organized by Detroit Institute of Arts, Detroit, Michigan, June 25, 1994 - September 25, 1994
(exhibition name, location and year)

Publication history*:


A.C. Eastman. "Six Indian Paintings." Bulletin of the DIA 8, no. 5 (February 1927).


Naval Krishna, Catalog of the Indian Painting in the DIA, Master Thesis, University of Michigan, 1979]
(Chicago style: Firstname Surname. Publication Title. (Place: publisher) Year: page number.)

Notes*: Handwritten note on back reads "Bought in Delhi, 1914 / ?Jaipur / sky like Jammu, Pahari / but cf. 2 rag pictures, Rajasthani / probably 16th century" --This information accords with discussion in A.K. Coomaraswamy's _Rajput Painting_ and was probably written by him.
Annotated Image: Analysis Points and Description
## Pigment Analysis

*Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

<table>
<thead>
<tr>
<th>Visible color</th>
<th>Pigments</th>
<th>Certainty level*</th>
<th>Elements</th>
<th>Analysis point and description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Major</td>
<td>Minor</td>
<td>Trace</td>
<td>XRF (Please edit if other analysis technique)</td>
</tr>
<tr>
<td>Green</td>
<td>Cu green</td>
<td>1</td>
<td>Cu, Pb</td>
<td>Zn, Fe, Ca</td>
<td>Mn, Ni, K</td>
</tr>
<tr>
<td>Blue</td>
<td>Smalt</td>
<td>1</td>
<td>Cu, Hg, Pb, Zn</td>
<td>Fe, Co, Ni, As</td>
<td>Bi</td>
</tr>
<tr>
<td>Blue</td>
<td>Smalt</td>
<td>1</td>
<td>Cu, Zn, Pb</td>
<td>Hg, Fe, Co, Ni, As, Bi</td>
<td>Ca, Ba</td>
</tr>
<tr>
<td>White and pink</td>
<td>Lead white, insect dye</td>
<td>1</td>
<td>Cu, Pb</td>
<td>Zn, Ca, Fe</td>
<td>K, Ba, Ni</td>
</tr>
<tr>
<td>Red</td>
<td>Red dress</td>
<td>1</td>
<td>Pb, Cu</td>
<td>Zn, Ca, Fe</td>
<td>K, Ba, Ni, Hg</td>
</tr>
<tr>
<td>Gold</td>
<td>Gold in dress</td>
<td>1</td>
<td>Au, Pb</td>
<td>Ag, Fe, Zn</td>
<td>Cu, Ca, Ba</td>
</tr>
<tr>
<td>Blue</td>
<td>Smalt, lead white, tin paint</td>
<td>1</td>
<td>Pb, Sn</td>
<td>Sn, Fe, Co, Ni, As</td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>Indigo, lead white</td>
<td>1</td>
<td>Pb</td>
<td>Zn</td>
<td>Fe, Cu</td>
</tr>
</tbody>
</table>
Spectra Graphs

Green grass – Atacamite by FORS

Blue peacocks - smalt
Pink areas

Blue sky