MCH Tata White Paper, June 25, 2021

Building Capacity for research-based conservation in India: through the Mapping Color in History project

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MAPPING COLOR IN HISTORY

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I. Executive Summary

This white paper aims to share key findings of a collaborative research project sponsored by the Tata trust and the Lakshmi Mittal and Family South Asia Institute at Harvard [henceforth LMSAI]. This paper should be useful for specialists in conservation and heritage science fields as well as those in the museum sector, i.e. curators and museum administrators. The paper's target audience also includes policymakers and decision makers in government and private sectors working in the preservation of cultural heritage. In India, there is a lack of adequately trained conservators, conservation scientists, conservation facilities, equipment, labs, etc. to effectively conserve art. In particular, the necessary technical expertise and technological equipment for non-invasive analysis of pigments on centuries old manuscripts and paintings are lacking in India, as two recent workshops jointly run by LMSAI and the CSMVS museum in Mumbai revealed. We need a two-prong approach to improve the current situation: investing more resources on practical training and appropriate analytical equipment procurement while raising awareness for the importance of research-based conservation. In this light, the current project developed a model for internationally collaborative analytical research on historical pigments, addressing the need for research-based conservation and creating opportunities for practical training amongst local conservation specialists. We prepared and tested reporting templates that are specific to the region's infrastructure conditions. We established a basic mobile heritage lab unit that can be loaned to institutions that may otherwise have little access to such equipment. The project initially proposed to conduct workshops for practical training in pigment analysis and conduct analytical research on objects in four different museums in India to generate controlled analytical data for the Mapping Color in History project, a digital

humanities project under development as a searchable portal for compiling pigment analysis data for historical research. Due to the COVID 19 restrictions, workshops for practical training in pigment analysis and actual analytical research at different museums could not happen. We shifted our focus from conducting actual analytical research on objects in different museums to developing a model and protocols for collaborative analytical research in the future. We also designed a mobile heritage lab unit for pigment analysis with equipment needed for non-invasive analysis of objects and developed protocols for loaning and using the lab.

II. Background

Mapping Color in History [hence forth MCH, see http://mappingcolor.fas.harvard.edu] is a digital platform that PI (Prof. Jinah Kim) is currently developing at Harvard to compile and organize the newly generated information on pigments and make it more historically meaningful. MCH draws from existing and on-going research on scientific analysis of pigments with a capacity to add new data through collaboration with research centers that are engaged in pigments analysis in Asian painting and put them in a historical perspective.

Our general understanding of the history of pigments relies heavily on the data drawn from Western Art, and further analytical study of pigments used in the rich history of painting in India will help us understand the contribution of mostly unnamed Indian artisans and pre-modern chemists to the world of color. The project will place India's scientific and artistic interventions from the past on the world map while helping to rewrite the history of pigments. Providing an accessible digital platform (MCH) that can help better understand artistic and scientific achievements of India's past will help educate the future generation in the importance of preservation of the past. Over the twenty years of researching on painted manuscripts in India, PI has encountered numerous manuscripts and paintings in dire condition due to harsh environmental conditions and poor understanding, as well as lack of resources in conservation. The Tata grant proposal arose from PI's strong conviction that conservation of Indian manuscripts and painting needs a serious intervention to reform the apathetic attitude prevalent in archives and museums and to devise appropriate conservation treatment plans that will ensure the longevity of these irreplaceable historical treasures before they are damaged beyond repair. The Tata-LMSAI sponsored MCH project is the first step towards fulfilling this goal.

III. Methodology

The MCH project is a multi-disciplinary project. The three legs of the project are 1) digital asset development/digital humanities component (database), 2) conservation science research (core data), and 3) art historical research (core data). It brings together conservation scientists and conservators with curators and art historians through the tool of data science and web-based infrastructure specially designed and developed for the project. The Tata-LMSAI sponsored project addresses the need in conservation science research for the MCH project to acquire more controlled analytical data in pigment analysis on paintings in museums in India. As the

project had to change its scope and deliverables considerably due to the COVID19 pandemic, we focused our efforts to identifying the issues and shortcomings in the current conservation practices and devising protocols and a model for a mobile heritage lab that can be deployed for future research projects. We created a survey questionnaire for the current practitioners in the field of conservation and conducted in-depth interviews with individual specialists of different backgrounds and experience levels (See Appendix A).[1] The conservation landscape canvas also included a thorough historical literature review of the practice of conservation in India (prepared by Amalina Dave, project's in-country manager). We also consulted with conservation specialists at Harvard's Straus Center for Conservation and Technical Study regarding the requirements for establishing a mobile heritage lab and received guidance on scientific equipment required for base-line analytical research. We were able to work with one institution in India, CSMVS, to conduct material analysis research remotely with local specialists working in the CSMVS conservation lab. The CSMVS conservation lab's specialists collected analytical data following the guidelines from the MCH team at Harvard, and the MCH consulting scientist interpreted the data and gave feedback to the local team in Mumbai.

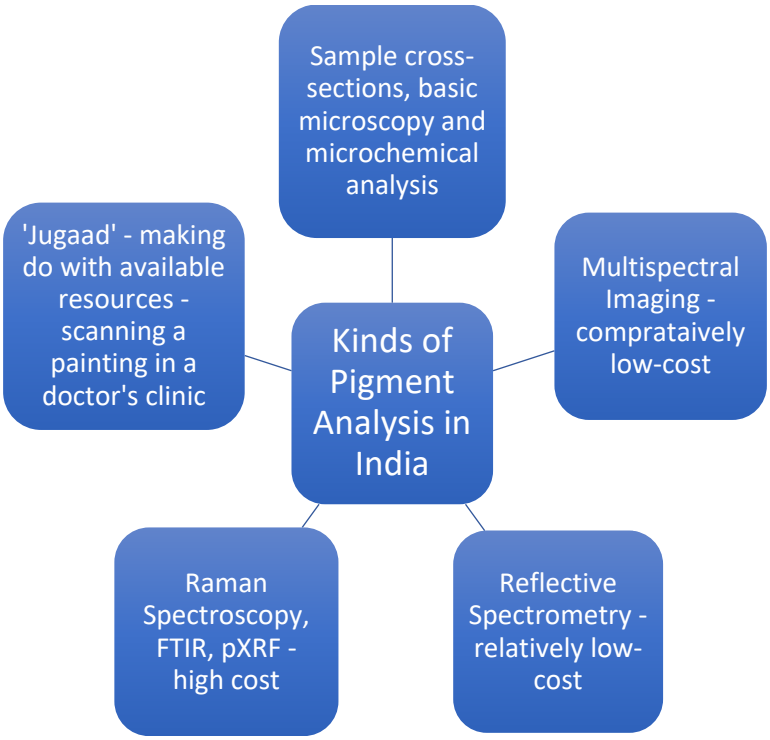
IV. Literature Review Outline

*Please see Appendix B for the full review.

Introduction

Pigments are central to South Asian artworks, but also one of the least-studied elements in conservation science in India. The lack of knowledge about the composition and techniques of pigments impacts our ability to make informed choices when undertaking the conservation of artwork and risks further degradation and irreparable damage to objects integral to our cultural heritage. Along with the tangible loss of objects, we also could lose intangible knowledge - histories of communities in which the art was created, pathways through which knowledge of pigments travelled, traditional skills used to create art, and the cultural dialogue surrounding artworks and manuscripts. Pigment Analysis uses scientific methodologies to non-invasively study the composition of pigments, through methods such as X-Ray Fluorescence (XRF), Raman Spectroscopy, Multispectral Imaging, and Fourier-Transform Infrared Spectroscopy (FTIR).

[1] We thank Mr. S. Girikumar, Mr. Sreekumar Menon, Ms. Amalina Dave, and Mr. Anupam Sah for participating in our survey and interviews.



Our current understanding of pigments relies largely on the study of Western art, and analysis done in the West. Pigment Analysis is in its nascent stages in India, and while there is an increasing awareness of the importance of Conservation Science in the preservation of cultural heritage and antiquities, resources are limited, knowledge exists in silos, and is not shared between institutions. Identifying the gaps in the study of pigments in South Asia through a multidisciplinary approach will lead us to a conservation science praxis that is collaborative, and involves different stakeholders, from state-led initiatives, to private collections, art historians, conservators, scientists, and educators. This literature review seeks to identify the pre-existing studies on pigment analysis in South Asian art, to identify the gaps in knowledge, and the unique challenge and potential for conservation science in India. Broadly, the literature will be assessed with the following intentions:

- To summarize the literature on pigment analysis in Indian/South Asian art till date
- To record the development of pigment studies in India/South Asia

Methodology

- Academic database searches, including JSTOR, Researchgate, etc
- Online searches of pigment databases
- Journals and other publications on pigment studies/conservation science

Chronology - a historical overview of the development of pigment studies within conservation science

Pre-1940s: The origins of the scientific analysis of pigments can be traced to the 1930s with Dr. S.Paramasivan's publications in scholarly journals, such as 'Technical Studies in the Field of the Fine Arts', and 'Proceedings of the Indian Academy of Sciences'.

1940s - 1960s: Literature from these decades increasingly deals with the study of techniques used in mural wall paintings and other artworks, microchemical analysis, as well as different methods of preservation. There is a focus on cave paintings and miniatures, as well as some sources in the scientific study of polychrome objects. A number of publications are on technical and chemical analysis, along with the structural study of objects.

1970s - 1990s: Due to scientific advancement, for example improvements in the methods of Raman Spectroscopy and X-Ray Fluorescence Spectrometry, there is an increase in literature on microchemical analysis of pigments. International scientists are increasingly analysing and publishing on South Asian artworks, and South Asian scientists and art historians are gaining visibility internationally. However, the focus of pigment analysis continues to be wall-paintings and murals, with comparatively fewer sources on paper and textile paintings and manuscripts.

2000s: The increased separation of government and private cultural heritage institutions contributed to scientific analysis and knowledge-generation being undertaken in silos. However, there is increased international collaboration in the preservation of cultural heritage, with global entities like UNESCO, ICOM, ICCROM, etc. investing extensively in heritage conservation. There is significant advancement in the methods being used, including gas-chromatography - mass spectrometry, multispectral imaging, etc. The portability of equipment for non-invasive analysis has broadened the scope for pigment analysis in remote regions, leading to the possibility of conservation science praxis in non-centralized institutions, smaller towns and cities, and contextually within the communities whose traditional techniques produce(d) art objects. A proliferation of online databases, digital access to historical and scientific studies, and increased access to resources, has made the sharing of knowledge possible across the world, including education in the field of conservation science.

V. Findings

Our survey and in-depth interviews with current practitioners illuminated a few important aspects of the current state of the field in conservation in India. Despite our initial hypothesis about the resource-poor nature of conservation environment in India, a number of institutions have access to funding for high-level conservation work, either through grants like Tata trust grant or through government and private initiatives. One interviewee described the glaring issue as that of human resources – "unemployability" of the workforce in conservation. The quality of training in conservation is uneven and haphazard even with, and partly because of, many certificate-granting workshops that are temporary in nature and not vetted through a curricular review. Conservation practice in India is more triage- and object-based rather than research-driven. There is hunger for more research-based conservation. Given uneven distribution of available analytical research tools, it is important to grow capacity and

awareness about the importance of analytical research in conservation. Another problem, especially in government-run institutions, is the lack of direction in management of resources and the absence of clear vision on the future of heritage conservation in India. (See Appendix C for the summary of canvas survey/interview results.)

No attempt has been made to compile analytical data on pigments across many institutions in different regions systematically. The findings from such a research project can help open people's mind about why it matters to do scientific analytical research for the conservation of historically meaningful objects. The MCH project with its mission to work with local institutions can have a positive impact on shift in attitudes toward analytical research-based conservation especially if the project can get buy-ins from large public museums.

One of the interviewees pointed out the importance of collaboration across institutions for resource sharing, especially the high-tech lab equipment for analytical research. Access to scientific analytical equipment is often arranged on ad-hoc basis based on an individual's affinity and personal connections. Having a more streamlined process and protocols for inter-institutional access to scientific equipment for research with the birds-eye view of which equipment across the country is available where and when can help mitigate the access issue.

Our team's effort to set up a mobile heritage lab for non-invasive analysis of pigments revealed further challenges in conducting collaborative research in heritage science in India. Identifying the types of equipment best suited for the Indian context which can be mobile was challenging, and so was the actual procurement process. We fortunately had support and guidance from Mr. Anupam Sah, the head of conservation at the CSMVS Mumbai, who as the country's top veteran expert in conservation was well connected and knew all the vendors and distributors that could help our team in India procure necessary equipment. Information about scientific lab equipment for conservation and where one could get them is limited. Knowing where to turn to with a question about analytical equipment can be helpful for conservators. Given the bureaucratic huddles of collaborating across different institutions, a template for inter-institutional collaboration in conservation will be helpful to mitigate bureaucratic difficulties in collaboration, and a guideline for best practice in research-based conservation can provide background information for those in the museum management to understand the need for collaboration and help reduce their hesitation and reluctance.

One of the key methodologies that are readily used for identifying inorganic pigments is the XRF (X-Ray Fluorescence) technique. The XRF technique helps identification of elements present in an analysis area, and the information gleaned from the XRF can provide substantial evidence for identification of inorganic pigments. Due to the prohibitive cost of acquiring a portable XRF unit like Bruker Trucker 5 for the MCH project in India, we had to modify our initial plan to procure an XRF unit for the project and find an alternative solution to conduct comprehensive pigment analysis. We modified our equipment procurement plan to focus more on assembling a mobile tool kit for multi-spectral imaging (MSI) technique, a non-destructive method that uses various filters in a specially modified camera to capture the image of an object under various light sources. Various pigments respond differently to various emitted lights, i.e.

Infrared, X-Ray, and U.V. thus the MSI generated images can aid the identification of some pigments present on the surface. Due to the restrictions of COVID 19, there was a significant delay in equipment procurement. We only succeeded in procuring all the necessary equipment in April 2021 as the grant period ended. We prepared a document outlining the protocols and procedures for loaning the mobile lab with the MSI kit to different institutions across India, which will be selected based on the strength of their commitment for conservation research and the fitness of the collection materials for the MCH project. The MCH mobile lab with the MSI kit will be instrumental in conducting pigment analysis at different institutions across India and will help systematically capture the findings of analytical research on historical pigments in India.

VI. Case Study in international collaboration in pigment analysis

- See Appendix F for sample analytical report from the case study

We initially proposed to work with four different institutions in India to conduct on-site pigment analysis research and training workshops, but the bureaucratic hurdles such as time-consuming nature of MOU agreement with different institutions when there is no existing template or model to follow, and more importantly, the COVID19 pandemic made it nearly impossible to pursue any on-site research during the grant period, which concluded in April 2021. Fortunately, thanks to the existing collaborative projects between CSMVS in Mumbai and LMSAI at Harvard, we were able to work with the CSMVS conservation lab led by MR. Anupam Sah to conduct some additional pigment analysis research in India. The following describes the process of conducting collaborative research between the MCH team and the CSMVS lab and its outcome.

After a few initial consultation meetings regarding the nature of the research required for the MCH project, during which Mr. Anupam Sah (Head of CSMVS conservation) expressed his firm support of the MCH project, PI curated a list of thirty art historically important objects in the CSMVS collection based on her own research and existing publications and shared it with the MCH team in India and the CSMVS conservation lab. In the meantime, LMSAI working with Harvard Global was able to arrange and pay for the time on CSMVS lab's pXRF machine as the MCH project could not afford to purchase a portable XRF machine dedicated to the project. PI prepared an annotated XRF map of each object/folio marking all the spots required for analysis for systematic analysis and documentation, using annotation feature of the image viewer program and assembling them using the Powerpoint program. This information was shared as pdf files via google drive and email. The MCH consulting scientist was available to answer any query regarding the equipment setting for analysis (like whether to screen the Rhodium peak or not, or whether Helium supplement is necessary for conducting analysis on Indian materials as Helium can help detect more lighter elements present in the painting.)

The conservation team at CSMVS first conducted a trial run on a set of folios on the first object in the list and shared the initial data with the MCH team to check the data accuracy and compatibility of presentation formats and to determine whether the machine generated data can be directly shared with the consulting scientist or not. The software that comes with pXRF

machine can generate files in certain formats, like csv, txt and pdz. The csv format turned out to be the most suitable to translate the data between different machines without the proprietary software attached to the machine. Our scientist then interpreted and plotted the data accordingly identifying elements and their strength present in the painting, and the India-based MCH conservation consultant (Ms. Anjali Jain) put this data into the MCH analytical data reporting template. The artwork information was provided by the CSMVS curatorial department according to the MCH reporting template (Please see Appendix F for the sample report from the study). This data is now being entered into the MCH database by the MCH team. Once the database goes live, the analytical data from this international collaboration with CSMVS will be available along with many other comparable examples elsewhere in the world.

This was a successful first attempt to collaborate internationally on a research project on historical pigments. Some areas of improvement include better communication between the teams in India and at Harvard and more proactive engagement and exchange after the initial data collection period. Most shortcomings were born out by the pandemic condition like lockdowns. Improving the level of engagement and exchange can be achieved by having a clearer set of expectations and goals of collaboration outlined at the outset, including establishing a reasonable response time between the parties and determining responsibilities for rechecking the data. As we interpreted the data provided by the CSMVS lab, more research questions arose to recheck and verify the data, like the clearer XRF data on substrate (most often paper) for baseline comparison. In some examples, it would have been useful to go back to check a specific color elsewhere in the same series of manuscript to get a clearer picture of presence of multiple pigments in one area.

VII. Suggestions for improvement of cultural heritage conservation environment

- We recommend thorough canvasing of the state of conservation in India's museums and cultural heritage institutions, both public and private, especially documenting availability of analytical equipment for research at each institution. See appendix A for sample questionnaire for this purpose. This task may be better carried out systematically under the government authority, like the newly proposed Indian Institute of Heritage (IIH).[2] If initiated by a private entity or a research institution, the task will require governmental support to be impactful.

- We recommend creating a digital infrastructure for cultural heritage institutions to connect across regional and sectional boundaries to collaborate and share on-going research and seek advice from those in the field. Once the digital asset for maintaining the database of conservation resources and specialists across the country are developed, this program for resource-sharing can be web-based and crowd-sourced with minimal overhead from the government or any institution that initiates it. Given the hazard of disinformation, it is important that such a web-based resource be

[2] See the study and proposal for the institute of cultural heritage, https://niti.gov.in/sites/default/files/2020-06/Improving-HeritageManagement-in-India.pdf

prepared by appropriate authority and vetted by respected veteran practitioners in the field with institutional (and desirably, governmental) support. It is also important that adequate resources are allocated to develop the necessary digital infrastructure as the software behind such infrastructure can be quickly outdated and dysfunctional if not designed carefully with longevity and ease of management in mind.

- We recommend that a committee of conservation specialists, including both domestic and international experts, be formed to study specific curricular needs for conservation training in India and to provide streamlined guidelines for conducting much needed practical workshops in conservation. In this regard, lessons from two prior workshops on the topic convened by CSMVS and LMSAI held in 2018 and 2019 (https://mittalsouthasiainstitute.harvard.edu/arts-program-art-and-architecture-conferences/) should prove useful, and the committee should consider the findings seriously.

- We recommend that cultural heritage institutions invest in scientific analytical research of cultural heritage for better informed preservation of cultural heritage. To this end, we recommend that there be a ten-year strategic planning to increase the research capacity at cultural heritage institutions across India. Some concrete steps for achieving this goal include 1) re-training existing workforce in research-based conservation methods, 2) encourage multi-disciplinary, inter-institutional collaboration, 3) investing in procuring analytical equipment, and 4) creating the position of conservation research scientist in cultural heritage institutions.

VIII. Next Steps: Vision for the MCH Mobile heritage lab for pigment analysis

The MCH project will continue to grow through collaboration with many institutions across the globe. One of the main goals of collaboration is to compile controlled pigment analysis data according to the MCH data collection guidelines for better historical and cultural understanding of pigment use and color perception over time.

The benefits of participating in the MCH project as an institutional research collaborator include 1) Access to scientific data compilation and management guidelines and support; 2) Collaborating institutions can increase the visibility of their collection in the digital realm and enhance understanding of objects in their collection; 3) Providing the data will help institutions/analysts to see their objects/ research results in comparative terms on the MCH database; 4) Participating institutions/analysts contribute to creating a digital knowledge common regarding the history of pigments (more broadly colorants) in the South Asian sub-continent and beyond. As we improve our digital platform and make the database more user-friendly, we hope to work with many institutions in India.

The most tangible and immediate outcome of the Tata-LMSAI sponsored project is the establishment of the MCH mobile heritage lab for pigment analysis. We will solicit proposals

from institutions with excellent painting collections to conduct a research project to investigate objects in their collection using the MCH mobile lab and participate in the MCH project. We will work with interested institutions to determine the utility of deploying the mobile heritage lab through the criteria of institutional research-readiness. If the collection materials are deemed art historically significant, such an institution will be given a priority. We anticipate each loan agreement to be for the period of 6-8 weeks with a goal of conducting analytical studies on 30 objects (mostly under 8”x10”). The MCH team will help design each institution’s research project and provide guiding protocols and templates. We have an India-based conservation specialist who will help coordinate and oversee the deployment of the mobile lab equipment and execution of actual analytical study. With a consulting scientist, a team of art historians and analytical data management specialists on the project, the participating institution will have access to the expertise and guidance for conducting analytical research on pigments for historical research. In the next three years, we hope to work with at least six institutions in tier two or smaller cities that have limited access to analytical equipment. The knowledge generated from the analytical research will enhance our knowledge of historical pigments in India and beyond. At the same time, we hope the access to the analytical equipment and expertise of the MCH team will help enhance the capacity for research-based conservation at local levels.

Appendices

A. Conservation Environmental Canvas Questionnaire
B. History and landscape of cultural heritage conservation in India: a literature review
C. Conservation Environmental Canvas Summary Infographics
D. Guidelines for conducting MCH pigment analysis research
E. MCH Pigment Analysis reporting template
F. Sample Pigment Analysis-analytical report
G. MCH Mobile Lab Equipment List

Appendix A.

MAPPING COLOR IN HISTORY

Conservation Environment Survey Questionnaire

Conservation department/capacity Y /N

Conservation specialist Y/N
If yes, how many?

- Understand the hierarchy/setup of conservation specialists
- How does the lab work?

Identify the name and the contact information of the conservation specialist(s) –

- Reach out to each individual and learn about their specialization and training;
    - ➢ initial institutional training
    - ➢ practicum- program(s) or institutions
    - ➢ years practiced

Do you have a conservation treatment lab? Y/N

- How big -
    - ➢ Space
    - ➢ How many projects can go on simultaneously?
- How many objects get treated per month?
    - ➢ What kind(s) of objects?
- Any equipment for scientific analysis?
    - ➢ XRF machine
    - ➢ Microscope
    - ➢ High-power magnifier
    - ➢ VSC or any special lighting equipment like Infrared, UV
    - ➢ Special camera with special filters for documentation

Plan/process for conservation treatment (line of command; management of conservation projects)

- Who determines which object to be treated?
- Who decides the treatment options?
- Do you have a separate operating budget for conservation of objects in your collection?
- How much/ What percentage of the operating budget?

The biggest challenge(s) the institution is facing when it comes to conservation:

Appendix B.

MAPPING COLOR IN HISTORY

History and landscape of Cultural Heritage Conservation in India: A Literature Review

Section I - 1930s – Independence 1947

Indian museums, in the way we visualize the modern museum, started being established in the early 19th century. The first one was under The Asiatic Society of Bengal in 1814, and it was not limited to archeological artifacts, but also natural history. The establishment of The Archaeological Survey of India in 1861 led to museums being centered more on archaeological material (Singh, K., 2015). Academic forays into research and surveying also occurred under institutions like The Asiatic Society of Bengal, and were largely limited to descriptive rather than analytical studies. "The earliest museums like that of Asiatic Society (1814), and The Madras Museum (1851) and the Indian Museum, Calcutta (1878) were not results of archaeological projects of the empire. Rather, other concerns like charting out a chronology of India's past and tapping manufactures were more prominent." (Singh, K., 2015)

An analytical approach to the study of historical artifacts and Conservation Science has over a century-long history in India, with the first articulations of intentional scientific analysis of antiquities leading back to the early 1930s. John Marshall, Director General of Archaeology in India (1910), and a professor of Classics from Cambridge University, wrote a text titled '*Conservation Manual: A Handbook for the use of Archaeological Officers and Others Entrusted with the Care of Ancient Monuments*' in 1923, published by the Government of India Press, Calcutta. The text was meant

primarily for Government Officials, with notes about the conservation of ancient monuments, and compiled information and reports of Archaeological Officers. In 1917 The Archeological Survey of India (ASI) established an archaeological laboratory in Dehradun, which would remain one of the main sites for conservation science in upcoming decades. However, these initial attempts into the study and preservation of Indian culture were limited – projects led by the British Raj, often with a lack of understanding of local and cultural contexts. Local attitudes towards the preservation of traditional and cultural artifacts, as well as preservation attempts carried out by the communities to whom the history belonged, are not recorded extensively until recent times. Though these intentions no doubt existed amongst South Asian scholars, artisans, and scientists - the systematic recording of conservation science began only in the 1930s in India.

Two institutions were critical in the formative years of conservation science development – the Madras Government Museum, now the Government Museum of Chennai, established 1851, and the Archaeological Survey of India (ASI). One of the primary sources for scientific analysis in conservation, S. Paramasivan, was an 'archaeological chemist' at the Madras Museum (Balachandran, 2019), and had a career spanning several decades, from the 1930s to the 1980s. Another such was Muhammed Sana Ullah working under ASI, first in Calcutta, and then in the ASI laboratory in Dehradun. It is important to situate the origins of 'archaeological chemistry' as occurring in institutions where the most decision-making bodies and head curators were British in origin. While by the early 20th century Europe and North America had already established the connection between scientific analysis and conservation, in India there was a parallel push to establish similar protocols and standardize conservation work, influenced to some extent due to colonization.

Recognizing the need for scientific analysis:

It is important to acknowledge that scientists like S. Paramasivan and Mohammed Sana Ullah of the Archaeological Survey of India were by the 1930s aware of the developments in several fields of science that informed conservation science research, for example the invention of Raman Spectroscopy and X-Ray analysis in 1928. By the 1940s Raman Spectroscopy was being applied to the study of pigments, binders, and other antiquities (*Current Science*, 1941). Paramasivan himself had been trained under C. V. Raman (Balachandran, 2019) as a chemist and physicist, and was subsequently hired at the Madras Museum with the intention of treating bronze sculptures that were at various stages of deterioration. Prior to him, other scientific and traditional methods for conservation had been attempted – in 1923 traditional artisans had been invited to restore the bronze sculptures with little luck, and methods for electrolysis had been attempted by Ram Singh Ahuja (Balachandran, 2019). However, no official laboratory space or standardized and tested methodology had yet been established. Paramasivan built upon Ahuja's work, and established first a temporary laboratory structure, and then a more permanent one on the premises of the museum. For Paramasivan, there was a direct link between the needs of museum collections and standardized, tested scientific methods. Though his initial work was related to restoration of bronze sculpture, he later went on to analyze metals in ancient coinage (Paramasivan, 1942), and the pigments, binders, and processes of ancient wall murals, for example the Brihadeswara Temple at Tanjore (*Current Science*, 1937). He also expanded his scope to woods, ceramics, while also advising the Botany and Zoology departments of the museum (Balachandran, 2019). Simultaneously, there were other scientists and archaeological chemists applying scientific principles at a few institutions in the country, including Mohammed Sana Ullah, and K. Govinda Menon. This move towards establishing science as central to object conservation led to Paramasivan being given the title 'Curator of Chemical Conservation' (Balachandran, 2019), indicating an active integration of analytical perspectives into what was traditionally considered the curatorial role of museums and institutions of cultural heritage.

Multidisciplinary Approaches:

From the initial years of conservation science in India, the approach was by necessity multidisciplinary – the intention to meld the sciences and the arts was central to the recognition of conservation science as a field. Shortly after initiating his work at the Madras Museum, Pramasivan writes, “In addition to training in archaeology and its methods, prehistory requires a basic knowledge of geology, ethnology, comparative anatomy, paleontology, zoology, botany, chemistry and the like” (Paramasivan, 1944). He also stresses on the need for surveying archaeological sites and collections, to create an interdisciplinary standardized approach to conservation challenges, “The primary goal is to plan out and conduct excavations scientifically”. In the same paper he indicates that Europe and the West have gained knowledge about archaeological objects and sites by studying pollen, phosphates, geochronology, and the like, and that “An understanding of the major problems from the point of view of geology, geography, climatology, palaeontology, biology, anthropology, archaeology enables one to develop a perspective of value in one’s efforts” (Paramasivan, 1944).

It is worth noting here that while Paramasivan definitely recognized the merits of a multidisciplinary approach, he often valued scientific analysis over textual and historical research. An interaction he had with the scientist Mohammed Sana Ullah from the ASI illustrates this. His reports of the Murals at the Brihadeswara Temple at Tanjore, and the additional samples he took of the murals themselves, had been widely reported in scientific literature. Some of the samples were sent to ASI for further analysis under Sana Ullah, who refuted some of Paramasivan’s earlier work, by conducting his own analysis of the samples. Sana Ullah had written extensively about the structure of Central Asian Murals, notably their pigments and binders, “The colours employed are gypsum, red and yellow ochres, lamp black, malachite, terre verte and lapis lazuli, which was evidently mixed with a suitable medium” (*Current Science*, 1940). He countered that Paramasivan was depending too much on the study of Italian Frescos to explain the

structure of the Tanjore murals, not considering the constraints of India's specific environment, or the textural evidence, both primary and secondary, about the paintings. Ullah's work in parallel to Paramasivan focused on the storage and museum safety of antiquities, based on their analysis, placing the application of scientific principles in a broader curatorial context. Paramasivan later refuted Sana Ullah's claims in *Current Science*. It is worth pointing out here that Parmasivan had direct access to a number of murals and artworks in Hindu shrines as a "high-caste Hindu", and Sana Ullah, a Muslim, was barred access from these spaces and so could not conduct on-site analysis (Balachandran, 2019). It is also important to locate scientific development and analysis within these cultural contexts as well – recognizing hierarchies in cultural institutions and museums in British India, as well as communal and caste dynamics.

International Collaboration and Knowledge-Sharing:

It is in part due to the integration of the British in positions of power in decision-making bodies that controlled the allotment of financial resources to museums that scientists like Paramasivan, Sana Ullah, Coomaraswamy, Menon, and others had access to Western models of scientific analysis of artworks. While this was often a hindrance in how resources were distributed, and projects prioritized, it still led to a cultural exchange of ideas. Paramasivan and his contemporaries relied on western publications to expand their knowledge base. This also meant that the dissemination of knowledge was limited to Indians privileged enough to speak English, and have access to elite networks. Paramasivan had extensive correspondence with Rutherford John Gettens at Harvard University's Fogg Museum in the early years of his career. They established a relationship based on knowledge-sharing and peer-review, with Gettens offering Paramasivan insight into the workings of international conservation laboratories, and eventually inviting Paramasivan to publish in the *Technical Studies in the Field of Fine Arts* journal in 1937 (Balachandran, 2019). At this juncture, there was already

agreement amongst conservation scientists that international collaboration and sharing of methods would foundational to the field, going so far as to articulate the need for a shared standardized vocabulary for analysis, and common goals in conservation science. The exchange between Sana Ullah and Paramasivan regarding the murals at Tanjore illustrated the need for this common ground, as one of the contentions of that debate had been using Italian terminology to describe Indian painting methods.

Recognizing Limitations of Laboratories/ Mobile Labs:

Though the initial years of conservation science in India highlighted several challenges, the foundations for more expansive research and practice were laid in the years pre-independence. These same institutions – Madras Museum, The Asiatic Society of Bengal, ASI - would build upon the analytical work done during the time British occupation. One such need that was identified in these years was the difficulty in replicating scientific models in remote areas, depending on the movement of objects and artworks from their original locations to urban centers. Paramasivan, in the latter years of his career, articulated the need for a mobile laboratory to treat bronze sculptures through electrolysis – a method that required large, often immovable equipment (Balachandran, 2019). Though this idea never reached fruition, it was borne of the early awareness of the need for sustainable, object-appropriate, scientific treatment of bronze sculptures. This is a need that exists even today, for a multitude of antiquities and artworks, be it ceramics, wooden and metal sculpture, manuscript, or monuments.

Section II - Indian Independence 1947 – 1990s

Indian Independence and the restructuring of the management levels of cultural heritage institutions, including museums and organizations like the Archaeological Survey of India and The Asiatic Society of Calcutta, coincided with the establishment of the International Council of Museums (ICOM) in 1946-1947, and an international awareness of the need to build scientific capacity in museums. Caladaro, in writing about the History of Conservation in Archeology and Anthropology (1987) highlights the global development of conservation science, indicating it was not just a western phenomenon, but also a process occurring in developing regions and the Commonwealth. Mortimer Wheeler, who was at the helm of the Archeological Survey of India from 1944-1948, had stressed the need for scientific analysis in archaeology, reinforcing the earlier efforts by conservation chemists like Paramasivan, Sana Ullah, and Coomaraswamy, and that legacy continued post-independence. There was an increasing push during this time to standardize infrastructure in museums in India, and introduce conservation as necessary to an institution's success. "It was Wheeler who first argued the basic necessity of scientific aids in archaeology in India" (Chakrabarti, 1982).

Recognizing the need for scientific analysis:

Conservation facilities were becoming more specialized during this time period, for example the Tamil Nadu Government Museum of Madras built upon the previous laboratory established by Paramasivan, expanding the laboratory space and extending the scope of objects that could be treated (Thangavelu, 1972). The conservation laboratory built capacity beyond the conservation of bronzes to include materials like ceramics, wood, and paintings. Scientific analyses, analyses-supported conservation

practices, and documentation of processes, also became central to the laboratory's functioning:

> "The laboratory has, besides analytical equipment, an electrolytic restoration plant, a Phillips portable X-ray unit, ultraviolet and infrared lamps, a vacuum impregnation tank, a fumigation chamber, a Carl Zeiss stereo microscope, a Carl Zeiss binocular research microscope, a thermohygrograph, a muffle furnace, a SICO metal hot-air oven with bimetallic thermo-regulator, a Sartorius original Selecta single pan-analytical balance, a special stand for the examination of paintings, a Kilburns Manesty electrically operated water still, a Philips conductivity measuring bridge, a Kilburns dual speed thermo-magnetic stirrer, a Zeal English-made wet and dry bulb hygrometer, a polarizing microscope, a student's microscope, a Feutron hygrometer and a Carl Zeiss spectrophotometer. Attached to the laboratory is a library where up-to-date technical books, magazines and periodicals are kept for reference…There is also a separate library, called the Connemera Public Library, which is located inside the Museum compound, where books covering the work of all branches are available." (Thangavelu, 1972)

Similar equipment and microscopes (Carl Ziess) are still being used currently at the Udaipur Palace Museum (Girikumar interview, 2021). In addition to identifying the need for scientific analysis, laboratories had also recognized the importance of documentation and gathering evidence-based academic resources.

Chakrabarti highlights the number of archaeological discoveries post-1947: "A significant step in this direction (natural scientific analyses in archaeology) was taken with the establishment of a radiocarbon laboratory in Bombay…which has branched out in recent years to include palaeo-environmental and metallurgical investigations. A second radiocarbon laboratory has started operating in Birbal Sahni Institute of Palaeobotany, Lucknow…Organized natural scientific groups are also active in archeology at the Deccan College Pune, and elsewhere." He goes on to say that "The

major tradition which has gathered momentum since Independence is the participation of the universities in archaeological field researches." (1987). Thangavelu similarly notes that "Besides research, technical examination and conservation, the laboratory is imparting training on conservation for those who join the museum technique course and for persons who are deputed from other institutions…Every year the curator is called upon to lecture to the students of archaeology of Madras University, leading to the M.A. degree. The curator has also been invited by other institutions to deliver lectures on conservation" (1972)

The National Museum, New Delhi, was established in 1949, containing a diverse collection dating from prehistoric times till 1857 (Agrawal, 1963). O.P Agrawal, a leading conservation scientist who went on to establish multiple laboratories across the country in subsequent decades, highlighted the structure of the laboratory and its staff, which continued in the vein of Balachandran's observations about Paramasivan's laboratory in the 1930s (2019). A chemist, and then Head of the Conservation Department, T.R. Gairola planned the laboratory in the National Museum in 1957. "The difficulty of setting up a working laboratory for immediate work in the initial stages was partly solved by the generous offer of the Director General of Archaeology in India, who transferred to the National Museum part of the equipment and staff from the conservation laboratory attached to the Museums Branch of his department. Since then the National Museum Laboratory has grown in equipment and staff, and now its activities include many different aspects of the scientific investigation and conservation of art-objects." (Agrawal, 1963). A description of the laboratory in 1963 narrates:

> "In one corner a well-equipped dark room has been set up where examination under the microscope and photo-micrographic work can be done. A separate room adjacent to the laboratory houses the gas plant, which supplies gas to all laboratory benches. Another well-lit room, adjacent to the main laboratory, is devoted to repair work."

A list of scientific equipment provided by O.P. Agrawal demonstrates the diversity of analysis taking place at the National Museum, "For chemical examination and analysis both micro- and macro-methods are used, and the laboratory is fully equipped for this work":

"SCIENTIFIC EXAMINATION-SPECIAL EQUIPMENT

I. Metallurgical microscope-Bausch and Lomb DM.

2. Chemical microscope-Zeiss-ikon.

3. Photomicrographic Equipment Model L -Bausch and Lomb.

4. Stereo-microscope-Bausch and Lomb.

5. Spectronic 20 colorimeter with reflectance attachment-Bausch and Lomb.

6. Hanovia Ultraviolet lamps.

7. Hot stage microscope-Reichert-room temperature to 22o00C.

8. K.B.L (India) 6 X 6 cm enlarger.

9. Polishing and grinding horizontal wheel for processing specimens for metallurgical examination.

10. Electric ovens.

11. pH meter." (Agrawal, 1963)

Multidisciplinary Approaches:

Similar to the Madras Museum and other scientific laboratories at the time, there was a diverse array of materials being analyzed and treated, including manuscripts and paintings on paper, oil paintings, textiles, and metallic objects. There was also an attached library of resources, illustrating the awareness for knowledge-sharing and up-to-date literature on scientific analysis in archaeology and conservation. While the staff of the laboratory was made up predominantly of people with backgrounds in chemistry, a trend that exists today in contemporary conservation laboratories as well, there was

also training for 'repairers and attendants' (Agrawal, 1963), indicating a diversification of roles within the lab.

The *Journal Conservation of Cultural Property in India*, Published by the Indian Association for the Study of the Conservation of Cultural Property, released its first volume in 1966. Pigment analysis of different artworks – textile, wall murals, paintings, and manuscripts – was becoming increasingly popular, as well the literature being published on pigments at the time. The increasing popularity of microchemical analysis of pigments is seen in articles like '*A Study of Four Polychrome Sculptures*' (Agrawal, et al., 1969), outlining the invasive testing of pigments and binders. Pigment analysis was not being undertaken for the purposes of pure research, as is evidenced by B.N Tandon publishing about '*Scientific Analysis and Preservation of a Tibetan Tankha*' (1966), where scientific analysis of pigments informed the steps to stabilization, disinfestation, and preservation, as well as in later studies of wooden polychrome objects (1975). Pigments were not being studied in isolation, '*Composition and Technique of a Miniature Painting of Malwa School, Dated 1640 A.D.*' (Agrawal, et. al., 1969) focuses on the techniques and processes of creating the artwork, directly informing conservation steps to be taken to preserve it, indicating the holistic study of the object, as a sum of its parts. V.V. Talwar writes on the '*Restoration of a 14th Century Painting*' (1979), noting not just the analytical data, but also the supporting mount, storage practices, and physical processes for conservation.

Wall paintings and murals were of particular interest at this time, though sometimes murals and wall paintings were shifted for analysis from their original locations to laboratories. This risked the condition and safety of the paintings, as well as removed them from their initial context – however, some of these movements were necessary after considering the in situ environment. O. P. Agrawal wrote extensively on wall paintings at the time, analysing pigments and binders to identify challenges in their conservation, and factors leading to degradation - '*Problems of Preservation of Ajanta*

Wall Paintings.' (1975), '*Moisture and Wall Paintings: A Study*' (1975). Other studies included wall-painting analysis in historic monuments, for example '*Analysis of Pigments and Plaster of the Paintings in the Sheesh Mahal, Nagaur.*' (Agrawal, et. al., 1989), which also acknowledged the importance of techniques used to create the artworks. Indian pigments were also being introduced to the international lexicon in various conferences, for example '*Indian Pigments and Their Problems of Preservation*' at the Symposium on Mural Paintings under the Aegis of Indo-US Subcommission on Culture (Tandon, 1980), using the Ajanta Caves as a case study.

The lockstep between scientific analysis and informed conservation interventions is evidenced in current day as well, as was heard from senior conservation scientists Girikumar and Sreekumar Menon (surveys). Similar to pigment analysis, the analysis of wood, ceramic, metals, and paper was happening in response to the need for better conservation practices. The challenges at this time were still that scientific equipment was cost-prohibitive, and too large to move off-site. Shifting murals and artworks was often high-risk and invasive analysis, while necessary in the absence of other options, was still the norm at the time. The inability to take scientific analysis to the site was, and continues to be, one of the main reasons conservation science research in India is a slow-growing field. While one can recognize the uptick in conservation post-independence, we also see the limitations, especially in comparison to international conservation science conventions in the 1980s-1990s. Many of the methods being used were the same, or very similar to those used in the 1930s-1940s, and while there was potential for exponential growth, it was still limited to a few laboratories in the country, with visibility through only a few publications.

Section III – 1990s – Present

In recent decades there has been significant growth in the field of Conservation Science in India, the most distinct being the fostering of alliances and cooperation between international and national conservation initiatives. Private funding and non-governmental organizations have entered the field, bringing resources to otherwise under-served areas and institutions. These changes have directly influenced the landscape of cultural heritage conservation in India, developing ethical and research frameworks that meet global standards, and encouraging the exchange of knowledge and experience across borders. While India's complex heritage and history have been recognized from the time of early archeological research initiatives in the 19th century, we are now acknowledging the pressing need for conservation of heritage sites and artifacts, especially due to climate change and industrialization. While the multidisciplinary nature of heritage conservation is increasingly obvious, India still faces challenges as many institutions work in silos, and there is a limited amount of conservation research being undertaken. Multidisciplinary interventions necessitate extensive infrastructural and resource networks, as well as innovative methodologies that bring together different fields and specializations. There is still a need for diversification within the conservation field as well, and a dearth of educational and mentorship opportunities for young conservators. The vastness of the country is also a challenge, with scientific equipment being largely immobile, and thus conservation

processes undertaken in lower-resource cities and towns are often under-informed by scientific analyses.

Moorti writes: “The cultural organizations the world over such as the International Council on Monuments and Sites (ICOMOS), and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) which are operating at the international level and the Archaeological Survey of India (ASI), the Indira Gandhi National Centre for the Arts (IGNCA), the National Museums of India (NM), the Indian Museum (IM), the National Archives of India (NA), the Indira Gandhi Rashtriya Manav Sanghralaya (IGRMS) the Centre for Cultural Resources and Training (CCRT), Indian Council of Historical Research (ICHR), the Indian National Trust for Art and Cultural Heritage (INTACH), Directorates Archives of various States of India, Central and State University departments, and associated cultural bodies as well as quite a few non-governmental organizations, active at the national and regional levels, are emphasizing the need for exigent measures for preserving and conserving the human as well as natural heritage before these are severely defaced.” (2008) The intention for collaborative work in the conservation field is increasingly obvious, but the challenges are demonstrably extensive. Conservation Science needs to be approached not as pure research, but as supporting the macro-frameworks of the cultural heritage field at multiple levels – from the practice of conservation, to impacting multiple fields including the development sector and education. Menon provides a counterpoint, “Formal systems are absent in India, which recognize the need for use of scientific tools for diagnosis and quantitative assessment of residual capacity before choosing repair or strengthening strategy” (2014) highlighting the contradiction of increasing awareness, with the lack of infrastructure and systems to address the magnitude of challenges present. Subbaraman articulates the hope that the lack of infrastructure will be addressed with increasing awareness, “Considering the importance of research in this field, it is an encouraging development that the Department of Science and Technology, Government of India, propose to evolve a national programme on the application of

science and technology in the conservation of cultural heritage, as part of their scheme to encourage research in frontline areas. It is hoped that more and more research scientists will start taking interest in this field, so that light may be thrown on hitherto unsolved problems and we may be able to conserve our heritage better." (1993)

Recognizing the Need for Scientific Analysis:

The example of Indian Bronzes spans the history of conservation science in India is a thread that is illustrative of the development of applied research in the field. In the 1930s Paramasivan popularized the electrolytic cleaning of Chola Bronzes in the Madras Museum, building one of the first conservation labs in the country. Over the next several decades the scope of applied metallurgical scientific principles in bronze conservation of idols and coins, as well as the diversification of scientific instruments used for analysis, expanded the scope of conservation practice. Recent challenges have emerged due to Bronze degradation, with traces of lead pitting sculptures and coins, necessitating scientific advancement. V.C. Sharma et.al. elaborate on the multiple analytical steps taken to assess and address damage due to the presence of lead:

> "An energy-dispersive spectrometer system (EDAX PV 9900) integrated with a scanning electron microscope (Philips SEM 515) was used at 20 kV for elemental analysis of the samples. To determine distribution of copper and lead in the matrix of the samples, an electron probe microanalyser (JEOL JXA-8600 MX) was used at 15 kV. An X-ray diffractometer (Philips PW 1710) with Cu tube and Ni filter at 40 kV was used to record XRD patterns in the 20 range of 8 to 1100. A Fourier transform infrared spectrometer (Shimadzu 8201 PC) was used to characterize the compounds and a thermal analyser (Perkin-Elmer TGA-7) was used to determine thermal stability. For pH measurements, an Orion Ross Sure-Flow combination pH electrode 81-72BN coupled to an Orion EA 940 ion meter

used. X-ray photoelectron spectroscopy (XPS) was employed to study the nature of the interaction of BTA with lead metal." (2003)

Pigment analysis of manuscripts and artworks has also increased significantly in the past three decades. The study and conservation of murals in the Ajanta caves has also followed the trajectory of the evolution of conservation science since the early 40s. Initial descriptive and analytical steps were rudimentary, running the risk of damaging the mural through invasive analytical methods. While invasive pigment sampling is still popular due to limited resources, and the limitations of non-invasive techniques, there has been marked improvement in safety standards of invasive steps. The importance of in situ conservation analysis and practice has also been highlighted in recent years, with removal of wall murals being carried out only in exceptional circumstances. M. Singh, Director General of the National Research Laboratory for Conservation of Cultural Property has worked on the Ajanta caves for several years, and carried out extensive structural, microclimatic, microbiological, and pigment analysis on the murals. "The pigments used at Ajanta have now been clearly identified with the help of non-destructive/destructive methods of analysis of micro-samples. The scientific studies on pigments of Ajanta at the preliminary stage were carried out with portable ED-XRF, portable microscope, UV light observations and spectro-colorimetry. The micro-chemical analysis of the micro-samples of pigment layers was conducted with a mineralogical microscope, SEM-EDX, micro-FTIR, XRD and micro-Raman spectroscopy. This has helped acquire information about pigments, succession of layers and state of conservation of Ajanta murals." (2011) Singh highlights the combination of invasive and non-invasive sampling techniques, as well as the combination of immovable and portable scientific equipment. The analysis of pigments requires a vast array of equipment to get comprehensive results, leading to this combination of non-invasive analytical instruments, and the need for invasive sampling methods.

Thus far, the global discourse on the study of pigments in manuscripts has largely focused on Western/European manuscripts and artworks. While the study of Indian pigments was slowly entering the lexicon of Pigment Studies and Art History in the years following Independence, the last few decades have seen a significant push towards pigment analysis in India at a global level. A significant portion of pigment analysis of Indian manuscripts and artworks – palm leaf, Indian miniatures, pre-Mughal and Mughal artwork - has occurred in museums in the UK and US, including at the Harvard Art Museums, and the Fitzwilliam Museum, Cambridge. A lot of the data on Indian pigments is thus removed from its immediate cultural context. Another limitation of pigment analysis not taking place in situ/ in a local context is that there is no comprehensive database or mapping of the distribution and evolution of pigments (and thus artworks) in India. Cultural Heritage and research organizations in India are gradually increasing capacity in response to the need to study pigments in the subcontinent. D. Sharma et. al. conducted pigment analysis on palm leaf manuscripts at the National Museum Institute, which has one of the most comprehensive conservation laboratory setups in the country.

“Pigments were also observed under the digital microscope (Dino-Lite Edge, 200×, 5 megapixels, AM7915M27 Series) to study their nature and composition. The element composition of selected colours was measured using a scanning electron microscope with energy-dispersive analyser (SEM-EDX; SEM FEI QUANTA FEG 250, EDX Analyser EDAX, Apollo-X Detector, EDX Software Genesis V.6.1). Measurements were made under low vacuum without sputtering. For further analysis, the pigments were powdered thoroughly and observed under polarized light microscope (PLM) (Nikon Eclipse ME 600 microscope fitted with digital camera Nikon Coolpix 990; 100 W halogen lamp). Pigments identification was carried out based on characterization of the morphological and optical properties under PLM.” (2019) Structural and chemical analysis of artworks has advanced significantly due to microscopy, which, in conjunction with other spectroscopic and non-invasive methods has given significant insight into the techniques of artworks, the molecular and chemical composition of pigments, and

curative and preventive steps for the conservation of palm-leaf, which is prone to degradation in India's largely tropical environment.

Pigments, inks, and dyes from further-flung regions, and otherwise low-resource areas, have also entered into scientific literature, due in large part to the diversification and improvement of analytical techniques in recent years. For example, Mahi, an ink used in manuscripts in Assam showed remarkable resistance to degradation and dicey environmental conditions, especially in comparison to other, more corrosive and fragile inks on palm leaf manuscripts. "Mahi, a unique herbal ink prepared with cow urine as extractant, was used for manuscript writing in early Assam. The ink had a deep and fast colour and was persistent on Sancipat manuscripts due to its resistance to aerial oxidation and fungi. It was also non-corrosive unlike the corrosive acidic iron gall ink of contemporary Europe. The present study was aimed at analysing the physico-chemical properties of Mahi, including its special properties. The study includes phytochemical analysis, antimicrobial assay, UV-visible with fluorescence analysis, iron and copper estimation and identification of some of the polyphenols by HPLC-UV." (Goswami et. al., 2017) Chemical analysis was conducted after recreating the traditional ink-production process, a comprehensive study bringing together art historical and scientific study, and considering production in a local context.

Multidisciplinary Approaches:

As previously mentioned, the multidisciplinary approach to conservation is not a new phenomenon – in the 1930s and 1940s there was a growing awareness about the need for curators and chemists to effectively run museums and laboratories. Subsequent decades saw the convergence of traditional studies of artifacts and local skills, art historical and contextual knowledge, and scientific inquiry. Even though historically we have established that there is a need for collaborative study, we still face significant challenges in the present day. Subbaraman writes, "It is (also) being realized

that a multidisciplinary approach is necessary because of the rather complex nature and composition of art objects and also because many different types of agencies are known to be at work in causing their deterioration. The study needs the help of chemists, physicists, biologists, etc., working in collaboration with archaeologists and art specialists. Environmental studies, receiving much attention these days, are of great importance in conservation science also because environmental pollution is one of the most potent causes of decay of art objects." (1993)

Cotte, in her extensive work on Thangka Paintings, observes the need for conservation processes on thangkas to be collaborative across different specializations, "Conservators need to cross boundaries and build bridges between their specialties to carry out treatments that respect the needs of the whole object." (2007) Ricciardi et. al., also discussing Tibetan paintings, observes "Knowledge of the painting materials and techniques used to decorate manuscripts and prints can provide a wealth of information on the skills and possibly the identity of the painter(s), the importance and the overall history of the object under study. It can also explain observed degradation phenomena, inform decisions regarding storage and conservation treatment, and allow for comparisons with contemporary artistic practice in other media and in other geographical areas. Despite major technical developments in recent years which allow reliable, non-invasive identification of many artists' materials…the technical analysis of works of art…remains an under-developed field."(2016)

Moorti, acknowledging both that scientific research has started to become multidisciplinary, and that multidisciplinary work needs to be encouraged, writes, "Bringing a refinement in the current research methodologies (aided by the state-of-the-art technology and other scientific facilities) with added emphasis on the modules relevant for the Indian situations and society, developing of a global outlook, identification of projects of national importance in the field of cultural studies, comprehensive and sound documentation procedures analogous with the requirements

of each discipline (or sub-branch of study), developing and promotion of qualitative expertise in all the fields focal to the cultural as well as natural heritage have been considered as some of the priority areas of the research agenda" (2008) Building on the growing awareness of the importance of multidisciplinary work at the academic, institutional, and government level is the current challenge facing conservation and conservation science.

International Collaboration and Knowledge-Sharing:

An extension of the awareness for collaborative work, international knowledge and resource sharing is expanding in India. Whether it is seen in the investment by Freer-Sackler in establishing the Udaipur City palace Museum Laboratory (Girikumar, survey interview), or in the Harvard University Mapping Colour in History project (Harvard University, Lakshmi Mittal South Asia Institute), international bodies are allying with Indian institutions and museums to expand on cultural heritage conservation initiatives. These alliances are critical, because, as Moorti puts it, "there are very few educational and research institutions in India which have the required scientific facilities to study and analyze the materials found in archaeological and other cultural contexts." (2008).

The benefits of collaborative study have been seen in the conservation of the Ajanta mural and other wall-murals across the country. Italian methodologies of Stacco a massello, De-stacco, and Strappo have informed the conservation of murals, especially those that had to be moved from the original site due to their fragility (M. Singh et. al., 2021). International studies of lime plasters have also informed conservation methods of wall murals, including in Ladakh (Sreekumar, survey interview). Subbaraman is somewhat cautious, however, stating that the current scenario is far from ideal when it comes to scientific analysis in India, "While this subject has engaged the attention of scientists in the West, the former Soviet Union and Japan in recent years, with some of the latest analytical tools being employed and a sizeable literature becoming available

on the work, there have not been many research inputs in this field in our country." (1993)

Mobile Laboratory:

Paramasivan, towards the end of his 40+ year career in conservation, had envisioned a mobile lab for the conservation of bronzes, specifically those that had to be repaired in situ because they could not be moved. This intention has been echoed by multiple conservation scientists over the years, but India is yet to have a mobile laboratory setup that can conduct high-level scientific analysis. MOLAB, a mobile laboratory initiative across Europe, has successfully studied many paintings and artworks in situ, with the founding intention being a lab that is movable and adaptable to different kinds of conservation and art historical research. One study conducted at the Fitzwilliam Museum, Cambridge, of a sixteenth century Persian manuscript, involved non-invasive pigment study involving Raman spectroscopy, Mid-FTIR spectroscopy, UV-Vis reflection and emission spectroscopy, and XRF spectrometry. (Anselmi et. al. 2015). Further, "The cross-disciplinary approach used by the joint MOLAB® -Fitzwilliam team was based on a close collaboration between scientists, conservators and art historians and proved invaluable in successfully addressing queries related to the manuscript' s decorative materials…Using a multi-technique spectroscopic in situ approach and portable, non-invasive instrumentation – including laser-based devices – this collaborative effort has produced a rare insight into the field of Persian manuscript painting." (2015). Another MOLAB project analyzed a Caravaggio painting "The Taking of Christ" was in 2016 in situ, where "Comprehensive, multidisciplinary and analytical (non-invasive) research was carried out…provided the MOLAB (mobile laboratory), which offers access to a portable set of advanced analytical equipment, for in situ non-invasive measurement." (Mancini, 2016)

In some cases for comprehensive analysis non-invasive *and* invasive pigment study is inevitable- “The sampling of wall paintings and the preparation of cross sections are fundamental for technical analysis. Light microscopy (under visible and UV light) and scanning electron microscopy are widely applied to the analysis of cross sections, more recently, nondestructive Fourier Transform Infrared Spectroscopy microscopy (micro-FTIR) has been introduced for the stratigraphic analysis of organic and inorganic materials in samples.” (Nevin et. al., 2015). Other studies are increasingly exploring the realm of non-invasive analysis of art objects, especially those delicate enough to potentially be irreparably damaged due to invasive sample-taking. “The scientific examination of pigments used in miniature paintings on paper has always presented problems. Their small size and fragility, the thinness and brittleness of the paint layers makes sampling undesirable and dangerous to the stability of the object. Sampling of undamaged areas is not acceptable on ethical grounds and sampling of previously damaged areas may lead to cracking of the adjacent gouache paint and subsequent losses.” (Isacco et. al., 1993)

Mobile laboratories address these concerns about destructive sampling, “Archaeometrical research has grown intensively during the last decades and a trend can be observed to minimize sampling, based on ethical reasons. Owing to the development of more sensitive equipment, sample size could be reduced. Moreover, recently, the wide development of non-destructive approaches using mobile instrumentation (Raman spectrometers, infrared devices, X-ray fluorescence equipment, etc.), allowing for in situ investigations, makes sampling often unnecessary…In situ methods are indispensable in the research of cultural heritage. Raman spectroscopy is a molecular spectroscopic approach that has many advantageous properties for the study of cultural heritage objects” (Lauwers et. al., 2016) The importance of careful scientific analysis and documentation of data during mobile laboratory research is highlighted, especially since reading on wall murals and other immovable paintings can render incorrect results if not documented properly

(Lauwers et. al., 2016). Issaco stresses the importance of mobile equipment for access, “Neither sample-taking nor heavy equipment being required, this new method can prove essential to the otherwise difficult scientific study of wall-paintings or when access to the original is difficult” (1993), when speaking of infrared photography and other photographic techniques, microscopic analysis, in conjunction with Energy-dispersive X-ray fluorescence spectroscopy (EDXRF).

Observations and experiences from across the world on the importance of mobile equipment and mobile laboratories should inspire similar initiatives in India, especially considering the current landscape and its limitations. Indian artworks and artifacts have been studied extensively in the UK and US using portable equipment, but that model is yet to be observed in India. The intention of knowledge and resource sharing across borders, in a world where conservation of cultural heritage is an increasingly interdisciplinary and international concern, should inform Indian conservation practice and conservation research, at all levels including government, educational institutions, museums, cultural heritage organizations, and all stakeholders who participate in preserving and protecting the diverse and challenging culture of the subcontinent.

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Appendix C.
Conservation Environmental Canvas Summary

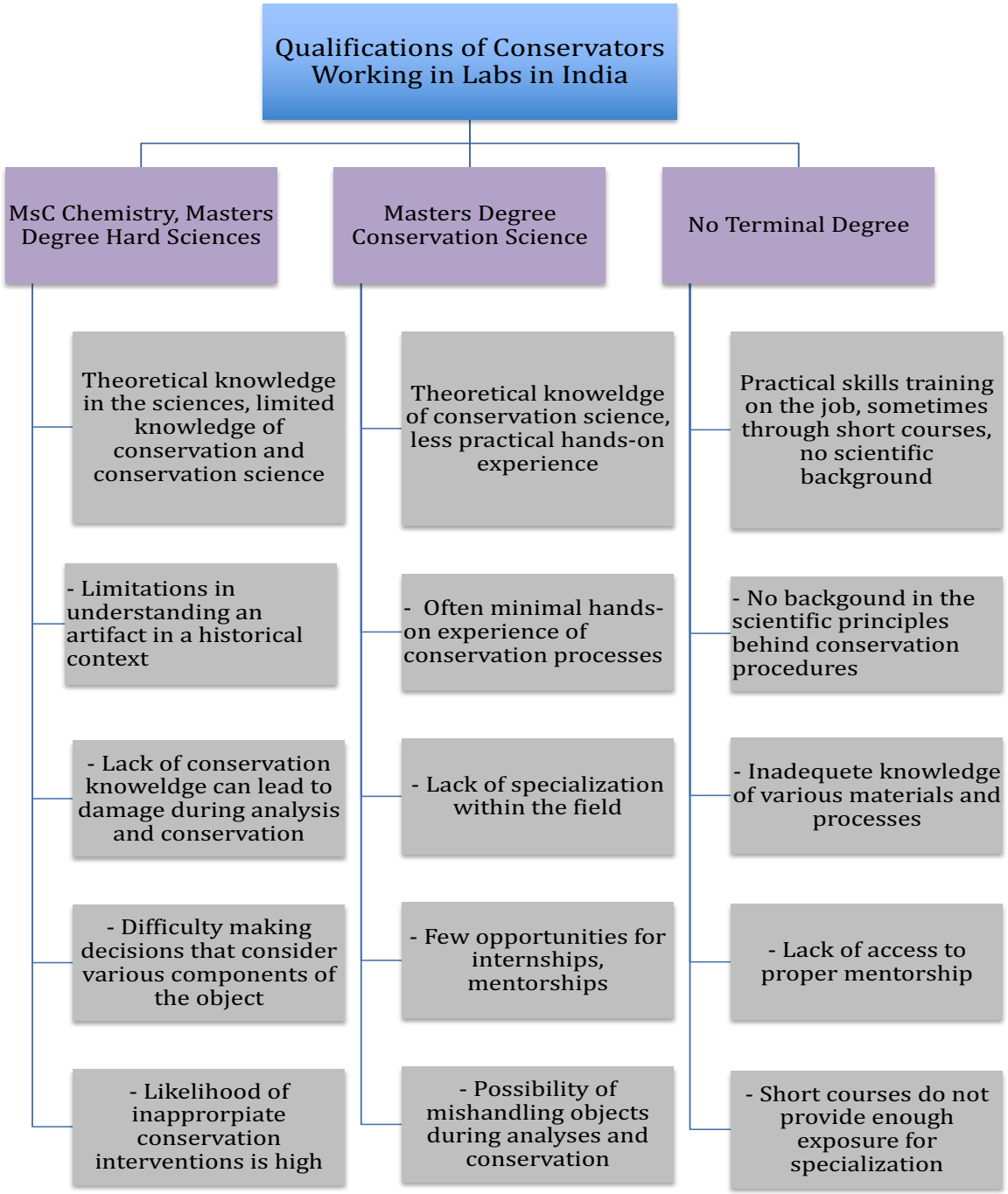


Table 1. Qualification of Conservators in India

Access to Scientific Analysis Equipment	•Most scientific equipment is incredibly cost prohibitive, especially for smaller institutions, or those in low-resource areas • Equipment is often housed permanently in larger institutions, with no structure in place for sharing or lending
Size of Available Equipment	•A lot of scientific equipment is large, often immovable, and cannot be shited between sites easily (Raman, FTIR, XRF) •Those that are portable often not actively loaned between institutions, or used to analyse multiple collections
Allocation of Funding	•If funding is aviable it is funnelled into either infrastructural changes (storage, building), or into growing conservation capacity •Funding is not explicitly sought out for scientific equipment, in part due to the needs of a conservation facility, in part because there is no culture of advanced scietiic enquiry
At the Management Level	•It is hard to justify high costs for scientific analytical equipment to management in institutions, the approach to funding is often to spend it all in infrastructural and non reseach activities •Projects in which results are not 'tangible', for example research-heavy projects, are usually not accepted over projects where one can see 'tangible' conservation results
Limitations Within Scientific Studies	•There is a stress on quantity over quality, if research is undertaken, a certain about of results/output is expected, and that takes priority over quality and depth of data •Scientific analysis often reports data without analysing and situating results while referencing other studies, and art historical background
Scientific Research Models	•The scientific research models followed are frequently those from the West, using similar parameters even though materials, contexts, and processes may be different •Results generated without adaprting research questions and parameters may misrepresent results

Table 2. Challenges to Scientific Analysis

Appendix D.

Guidelines for undertaking non-invasive pigment analysis for MCH

Introduction

The Mapping Color in History (MCH) is a digital humanities project directed by Dr. Jinah Kim, George P. Bickford Professor of Indian and South Asian Art, in the Department of History of Art & Architecture at Harvard University. The project aims to conduct noninvasive, scientific analysis on dated South Asian paintings and manuscripts and build a publicly accessible database of the materials and pigments comprising them.

Research and analysis on pigments in paintings and manuscripts should, like all other research, follow, the scientific method. A well-designed scientific investigation involves continual questioning and re-evaluation. Keeping in mind the basic process of the scientific method – observation, hypothesis, prediction, experiment – will ensure that the experiments being conducted remain focused on addressing a specific question. Asking "why" at every step will ensure that opportunities for new discoveries and insights are not missed. Further, bear in mind that the answer to "why" may require the use of different analytical techniques.

Another thing to bear in mind is that the strongest conclusions are made based on positive results. You can base conclusions on positive evidence, but you cannot prove something based on negative, or lack of, evidence. As is often stated: "absence of evidence is not evidence of absence." In the case of pigment analysis, depending on the technique, the absence of evidence can suggest the presence of materials that are not identified through that technique.

As with most analytical techniques, the tools suggested below are best used in combination with each other. This document aims to cover the basic analytical procedures that can be used for the non-invasive analysis of pigments. It is structured as a Q&A with a specialist on the questions that MCH team sought out to address in proposing the sequence and the process for analytical research of objects. Our aim is to give the reader suggestions on best practices that they can follow while using the various instrumentation and scientific equipment provided in the MCH Mobile lab.

I. Visual Examination and Microscopy

The preliminary stage in the technical examination of a painting or painted object usually involves the use of methods that do not necessitate the taking of samples. The first step in the analytical studies of works of art should be visual examination. This may begin with a close visual examination in normal light, followed by examination under magnification, and perhaps utilizing raking light. Raking light means the light source is shown on the object at an angle nearly parallel to the surface of the object. Much can be learned by inspection with the aid of a low-powered binocular microscope. These are the simplest and most reliable ways to evaluate the relative homogeneity or heterogeneity of specimens and to detect the presence of traces of materials that might otherwise be overlooked. Microscopic examination narrows down the possibilities quickly and inexpensively.

Observations should be recorded, and photographs used for documenting important observed phenomena can be useful and important for performing subsequent analysis on pigments.

Guidelines on assessing paintings using preliminary visual examination techniques[1]

- What are the various kinds of preliminary object-based data / analysis results that you collect and assess to begin with pigment analysis?
    - What kind of information do you try to get by examining the object (or its images) using the naked eye?
        - *Naked eye examination is the first step of any material (or for that matter any other) analysis. You want to start by looking at the object in visible light with a naked eye. If you find any spots that look interesting, whatever catches your eye – if you find two different shades of the same color, if you see a gap, some places where the ground is exposed, if you find an area where you can see the material on which everything is painted on, or places where gold leaf is applied.*
        - *You may not have constant access to the object. Reading and learning about the object's provenance especially where it's been, what's been done to it, i.e. treatment history, will help set up a plan for analysis. When you have a chance to look at the object, it is important to jot down ideas about where you want to begin your examination and this is where collaboration with curators and other specialists can be helpful. It's pretty much exploring, and looking for clues, and trying to figure out what may have happened to the object.*
    - What kind of information do you try to get from raking light images?

[1] Based on communication with anonymous project assistant, who has significant experience with microscopy for pigment analysis

- *I would throw in raking light in between naked eye examination and microscopic examination. Raking light can help you tell areas of loss. It goes well with UV examinations because they show a lot of the surface structure. So you can tell if there is varnish or something that's been applied or if there is a flaking. It also can help determine the method of pigment application and layers.*

- What kind of information do you try to get from microscopy images?

  - *Microscopy is an important second step of the visual/physical examination. Once you've identified spots that look interesting (2 different shades of the same color, places where the ground is exposed, etc) using naked eye examination and raking light, I would then look at them with a microscope and take photos. You can't really do too much in the way of microscopic examination. You can zoom around with it and take photos of the areas you find unusual and important. Once you have that you can go back and look at it, take some notes, see if you can come up with any ideas of what's going on. Maybe you see brushstrokes, maybe you see the grain size of the pigment. The grain size of the pigment can be a useful indicator of organic versus inorganic materials. Organic dye stuffs tend to be finer than mineral-based pigments. After microscopy, you can follow the procedures of the Multispectral imaging, taking photos using visible, UV, IR reflected, and UV induced luminescence.*

  - *At any point in this whole process if you discover anything new that's interesting, go back and do it all again – keep going back and repeat as many times as necessary until you have a good idea or you have a couple of good ideas about \ how the piece was made, and maybe what pigments are used. This stage of visual and microscopic examination can help provide a substantiating piece of secondary evidence to support any further findings.*

- How does using a Dinolite device for microscopy compare to using a table-top microscope?

  - *Dinolites are pretty good. I'm not sure if the table-top microscope is necessarily going to be that much better, because certain dinolites are really powerful. One should be mindful that Dinolites can be unstable due to their size and portability . So when you put them on their little plastic stand, if you bump them at all when you're at 100 magnification, it moves all over the place. It is delicate and one needs to be extremely careful in setting it up. It can be challenging to get a stable image when you capture through the dinolite capture software program.*

  - *The benefit of the bigger microscope is that it is a lot more stable and it can reach a lot further. So you're not just stuck doing investigations on the outer edges of an object or having to hang it vertically so you can investigate other points in the centre of the painting, which sometimes happens when using*

Dinolites. The little arm that extends for the Dinolite doesn't go out very far. So if you have a big microscope with a long arm on it you can have a very large painting and you can investigate spots in the middle while keeping it flat on the table so it doesn't put unnecessary stress on it.

- Can you identify pigments using these preliminary techniques?
    - *No, not just with these techniques. For certain pigments, you can make reasonable suggestions on what pigments might have been used, but to confirm an identification, you will need more techniques in most cases. *It is important to keep in mind the degrees of certainty that come with pigment identification.*

II. Multispectral Imaging

Non-invasive examination of paintings includes examination using selected ranges of wavelengths in the electromagnetic spectrum that include and extend beyond the capabilities of the human eye. This analytical technique, called multi- or hyperspectral imaging is a qualitative, non-invasive, portable analytical technique that enables the spatial localisation of specific materials or material types.

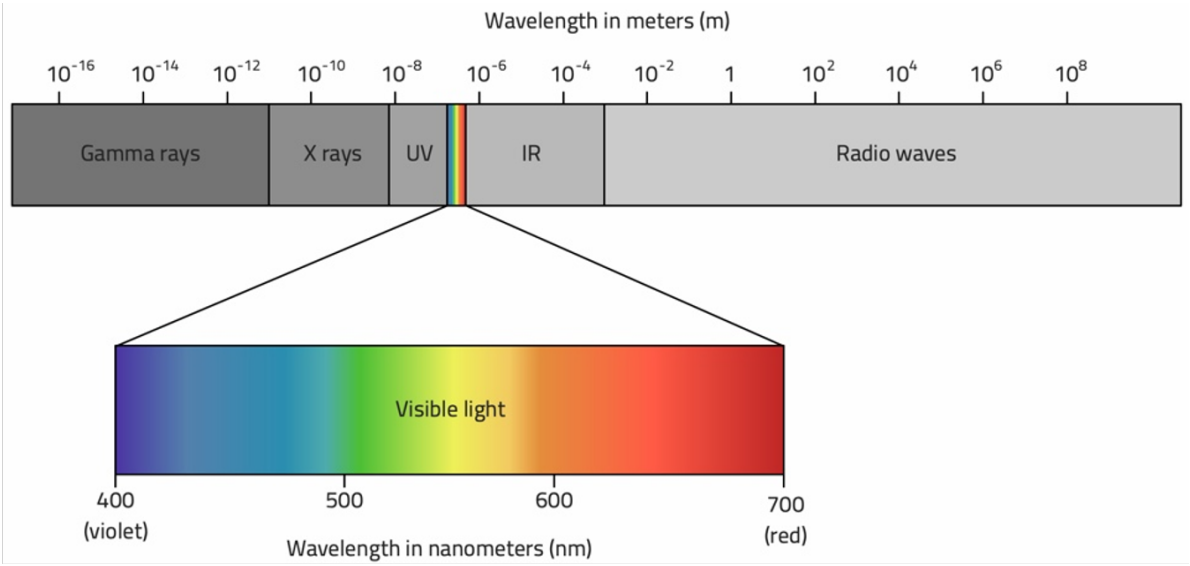


Image courtesy of radio2space.com

Spectral images provide essential clues about an artist's materials, techniques, and composition, past conservation interventions, and damage, to name just a few applications. Critically, examining data in image form often initiates and encourages dialogue among scientists, conservators, and curators. Multi- or hyperspectral imaging has proven useful in the

characterization of a number of organic pigments and in distinguishing classes of organic binding media in situ.

Personal communication with anonymous who has significant experience with multispectral imaging.

Guidelines on undertaking MSI, data interpretation and storage[2]

- Undertaking MSI

· What preparatory steps do you follow for doing MSI?

  o Any specific things to keep in mind while setting up the camera?

    § *Make sure your camera is white balanced. You can do this once at the beginning of your work and it doesn't need to be done repeatedly, unless you move to a different place for imaging.*

    § *Take a few photos of the object and make sure you're happy with it. Make sure you allocate quite a bit of time for doing this, especially the first few times you get into it. Make sure there's nowhere else you have to be for a while because you'll have to play around with it. Make sure you're not getting interrupted.*

    § *Bring all your notes with you.*

    § *If you're using flashes make sure you have spares charged because batteries go through pretty quick. Make sure you have an outlet nearby so you can plug in your computer.*

    § *Connect to a software on a computer to capture your MSI images.*

  o Any specific steps to keep in mind while setting up the object?

    § *You should have all your objects ready for imaging.*

    § *You should keep the object on a piece of plastazote – something that is not going to reflect at all.*

    § *Besides that, you must handle all your objects carefully, in most cases, working closely with the conservator following his/her suggestions.*

· Describe step by step the procedure followed to do MSI?

[2] Based on communication with anonymous project assistant, who has significant experience with multispectral imaging

- Could you briefly describe the MSI workflow, not the which filter goes where, but the general process?
    - *After you've completed setting up your camera and the object, you keep placing the filters on the flash and the camera lens and capturing each of the images. The camera settings will keep changing in each radiation. You can't set it all up at once, and use the same settings through each step. The white balance will be fine throughout, that can stay the same, but in terms of aperture, F-stop and other camera settings, you'll have to figure out what these settings will have to be for each filter. You will have to play around with it and see how it turns out. The flash brightness is also a big element – you will want to figure out how much flash you want for each radiation.*
- Do you always take all 6 images for all paintings? If we are not able to take all 6 images, which ones are absolutely essential for pigment analysis and why?
    - *I start with visible reflected image, then go into infrared reflected and UV reflected and then do UV induced luminescence. These first four settings are the most important ones to capture. After that any other settings are just a kind of bonus.*
    - *You don't get so much information out of visible induced luminescence in the IR range: for instance, this step only helps to see a limited number of pigments, like Han blue, Han purple and Egyptian blue. So if you have one of those pigments, then it will be incredibly useful and it would be very interesting to do that. Visible induced IR luminescence can also help see lake and cadmium based pigments. So if you think that there is a chance that these pigments can show up then you can definitely do this step, because that could end up being by far the most interesting analysis you do, but if you're looking at something that you think is in no way going to have Egyptian blue on it, which is absolutely rare in South Asian materials, it might not be the most productive use of energy and time.*
    - *As long as you know what you're looking for with each technique – try to think about what sort of observations does each technique permit and then look into each image with that in mind – UV for instance will show you the surface, IR will show you underdrawings. Just try to figure out what you're looking for in the object with each of the 6 MSI techniques.*
- Do you always keep both the color checker and spectralon standards in frame for all MSI images? Ok to keep a part of the color checker in view, since it is very big?
    - *It is important to keep the spectralon standards in all images.*

- *The color checker is important in visible, UV and IR reflected – those three – but I don't think you need any other ones besides that. I've only ever used it in the nip software for making false color images. Otherwise it's just a visual reference point.*

- *If the color checker is big and doesn't fit in your frame, you can have a part of it in your frame. As long as there are certain squares that you can pinpoint on it should be fine. We never really got into why we need these. We use them when we do color transformations but it's something you just throw in there because it will help somebody, someday. If you can have it in there it will be good.*

- What are the advantages of capturing by tethering over capturing using camera only? Which software do you use to capture images using the laptop? Are there any specific softwares we need to use for capturing MSI images?

  - *Micro USB to the camera should fine. Whatever software program is utilised by the camera – view NX2 if you're using a Nikon camera.*

  - *The only use to these programs is that it helps you store all your images in one place so you could scroll through the images and look at them and it could also export them from RAW into TIFF format. As long as a software can do those two things it should be fine, it doesn't have be a software specific to MSI.*

- What meta-data do you record (manually) while capturing the individual MSI images?

  - *ISO, aperture, shutter speed for each. Also, flash strength – so it can be 1/1, ½, ¼, 1/16 – and that will change with each technique.*

  - *I would also write down the observations. Not so much the settings because the setting will just be numbers just for you or someone else to use if they want to recreate the exact same image at any point.*

· What precautions do you take while doing MSI?

- What aspects do you check in an image after capture to confirm if the image is okay and does not need reshooting?

  - *I would mostly look at exposure – can you see everything in the image? That's mostly for visible, IR and UV reflected – is it super-overexposed or underexposed? Based off that you can change your settings and get it to where you can see everything evenly.*

  - *With luminescene if you can see the entire image luminescing then it's not really luminescence – so you want to make sure there is no luminescence out of the 99% reflectance standard in the corner, anything else you can see is actual luminescence. If you can see any light coming off that, if it's not totally black,*

then you have stray radiation. That is what's most important for any luminescing type images - you want to make sure your reflectance standard is dark so you don't have any stray radiation.

- *Other than that just make sure that your image looks nice and has included everything you want in your frame.*

- How do you avoid (what steps, precautions) you take to avoid ambient radiation? Or is it not a cause for concern with the short exposures?

  - *It does depend on your shutter speed. If you have a high enough shutter speed (anything faster than 1/250) it doesn't matter because you're not going to capture any ambient radiation at all. When you need a slower shutter speed, for whatever reason you didn't get the exposure you wanted, you will want it to be quite dark in the room.*

  - *If you do the MSI photography in a room with no windows, you don't have to worry about it ever. Doing MSI in a large storage room works really well. This helps make sure that the area is completely dark, pitch black.*

  - *Where paintings may exist on a site (eg. Wall paintings), you can also do nocturnal photography, or put up chart papers on windows to block off light.*

- Would you recommend wearing any PPE while doing this (and microscopy, raking light photography work?

  - *While working with UV, you will want to wear protective glasses because UV will stop when it hits any surface. Any sort of protection glasses you have should work. Besides that nothing else is needed.*

- Any recommendations/precautions to be taken while handling/storing/transporting MSI equipment??

  - *Handle the equipment carefully to prevent any physical damage.*

  - *Make sure you clean everything, wipe the filters and lenses and keep them clean so you don't have any smudges. It is not something that needs to be done regularly, if the filters look clean they are fine. It's just the smudges that you might need to get rid of.*

  - *Pack everything up very nicely every time.*

  - *And since the equipment is quite expensive I would find a nice place to lock it up, especially when it travels around the country.*

- Post processing, data storage and interpretation

· What post-processing is done for all images?

  o Comments about the Nip 2 software?

    § *Yeah that is the one that has been developed to process MSI images specifically, but it's a bit tricky to use and there is a learning curve to understand the various aspects of that software. But it is definitely useful to convert UV and IR reflected images to false color images.*

  o Adding the images to the MSI Reporting format?

    § *You can add the images to the reporting template with your notes and observations and a manual record of the camera settings that we discussed earlier.*

  o Is it recommended to play around with the brightness and contrast of MSI images?

    § *I wouldn't play around with those settings. You can if you think that will help to show a point that you will make, but raising the brightness is not really recommended. This is because you can't really tell what's luminescing and what's not - it all glows a little bit and you would have to look for what really glows and draw the line between what's really luminescing and what's not. It's fine if you have a totally dark image with just a bit of glow around the outline, because it then illustrates that there is no luminescence in that particular painting.*

  o Do you save your RAW and processed MSI images as well?

    § *I keep everything. I have a folder with RAW images. I have one folder that says 'visible reflected RAW', another 'UV reflected RAW'. I have a different folder for TIFF – visible TIFF, UV TIFF, IR TIFF. Sometimes it's also nice to have JPEGs for making power-points, but that's an optional step.*

  o What nomenclature system is followed for naming files and folders? What filing hierarchy is followed for each object?

    § *We do not have an established system yet, but I would just put them under the accession number of the object and then fill those folders with the separate MSI images.*

· How is all this data stored and backed up?

  o How many duplications of any collected data do you keep? On a hard drive or cloud based system? How is it kept up to date?

§ *The data is going to be stored on your camera SD card first. It should be stored on your computer also, but you are going to be deleting the camera's memory over and over again so it doesn't get full. I would have a secondary place besides the computer. A solid-state external drive is good, rather than trusting the cloud. I would also recommend having back-ups because it would be a huge shame if so much time and work was put in and it just went 'poof' one day. A solid-state drive is really good because if you drop them nothing happens to them – they're just a bit more expensive. You can also have a backup of the backup if you want, it's up to you and would depend on how much you trust yourself really.*

- Interpretation

· What steps do you follow for interpreting information from MSI images?

o Are there any specific images from your MSI image set you begin with to identify any specific things, relating to pigment identity?

§ *You must look through the images in the order you have taken them in - visible, IR reflected, UV reflected and then luminescence images. You will have to keep looking through them repeatedly because if you notice one thing in one image it might bring you back to another image to look at the same spot - it's a very iterative process. Having things open in different windows and scrolling back and forth through them works best for me.*

· Could you give some examples of the kind of information that one should be looking for in each of the MSI images?

§ *With all your MSI images, something notable will pop up immediately. You can zoom in and scroll around, but something will catch your eye.*

§ *With infrared the most important thing is to look for the under-drawings. If you can find the color notations, it might hint at what pigment was used or what color was supposed to be placed there. Color notations are markings that a master artist would have made inside the drawing – blue in some places, yellow in others – and are followed and filled up by the artists working under them. It's really great when you find that because you can tell what a particular was supposed to be, because sometimes the color notation refers to the color itself, and sometimes it refers to the pigment. Usually it's just the color, but sometimes you can get lucky and it can tell you what pigment is there. In some cases, if there has been some colour degradation over the years, these colour notations can give you a clue of what color was supposed to be there – perhaps some area used to be yellow but now it looks white.*

§ *UV reflected images can help you look for losses or later additions, varnishes/coatings on the surface of the painting.*

§ *With luminescence images (UV induced luminescence image in visible range and visible induced luminescence in IR range), either you have it or you don't. And if there is luminescence in the UV induced luminescence in visible range, that will tell you about where the organic pigments are present.*

- Are there any characteristic behaviours, tell tale signs of organic dyes/pigments in MSI? Eg. The bright UV induced luminescence of Indian yellow.

§ *Any organic pigment will luminesce quite brightly. It might also be the binder sometimes. If you have a general luminescence across the painting you could have something like an animal glue binder that's causing it to luminesce. Mostly if it is organic, it will luminesce. I'm not sure about some being brighter than others, I don't have enough experience to comment on that.*

· Do you interpret MSI images simultaneously while capturing them or is it better to do that after all images are taken?

- What are the pros and cons of both ways of working?

§ *It works best if you focus on taking all the images and then interpret them, but it is also good to take a quick peek at them while doing the imaging.*

§ *There are advantages to looking at it on the spot also because if you notice something interesting you can take a close up of that while you're still there. You might also be in a place where you only have access to those paintings for only a day, so you need to make sure you are getting the most out of it.*

§ *There's advantages to both, it depends on what your time frame looks like, how much time you have to work with.*

- MSI in relation to the larger pigment analysis process

· Do you think MSI can help with identifying pigments by itself? – without the use of any other analytical techniques? If yes, which pigments?

§ *It will never be a means to identify pigments on its own. It's only a supporting technique. It paves the way for further techniques with more substantial evidence, but you can never make final interpretations about pigment identity just on the basis of MSI.*

· How is MSI data associated and interpreted with the other analytical data (microscopy and raking light images, pXRF data, etc.) of that particular object?

  - *It is good to have one location where all information about the object is stored. Creating a profile for the object can help anyone who wants to reference it in the future. If they want to do further work on this object they can build up on what we've already done.*

  - *MSI is great because it will tell us about what has been done to the painting, it will tell a lot about areas of weakness. In microscopy as well it will show us where and what kind of flaking the painting might have, whether there is a varnish and if there is craquelure on top – things to look out for that might help with future treatments. There are plenty of other uses of MSI besides pigment identification.*

  - *It helps to move on to XRF because it might tell you more information about spots you find interesting. If you find a spot that's luminescing, it might be fun to try and use XRF, but if it's organic it probably will not show a signal using XRF. You could therefore avoid the luminescing spots while doing XRF, or try them and see if it's a mixed pigment.*

  - *However, time ends up being the most constraining factor. It would be fun to do a million XRF points, but that might not be the best use of one's time.*

  - *And all of this, like I said earlier, is an iterative process. At any point in this whole process if you discover anything new that's interesting, go back and do it all again.*

· Where do we incorporate interpretation from the data that cannot be included in any of the reporting formats? What is the best way to record this information?

  - *Yeah, I would have a word document full of your thoughts and notes. It's always good to have one extra document of things that might have been left out somewhere. And you can store this document along with the other information that you've acquired from the object.*

· What would you say is the best suggested sequence of analysis?

  - Considering we have at our disposal a Dinolite (with visible and UV light), a microscope with articulated arm and polariser, an MSI kit, pXRF available for rent.

    - *I would start with naked eye examination – just take a look at the painting.*

    - *Then I would do raking light and microscopy – those go around the same time. Since you have a UV function in the Dinolite I would use that at this stage as well.*

§ *I would then start photographing – Visible, UV, IR, UV induced luminescence and any other MSI imaging.*

§ *After all this, you'd have to sit down and choose points you want to look at using an XRF. At this stage you'd also want to have a sheet to annotate the images to be able to do XRF of those points.*

§ *And then after all that do XRF.*

III. X-ray fluorescence

X-ray fluorescence spectroscopy relies upon the detection and examination of characteristic fluorescent X-rays that correspond to the unique electronic orbital structure of each atomic element. It can thereby be used to determine the elemental composition of materials and can therefore give us direct evidence on the identity of the inorganic pigments present on a painting. The handheld models of XRF machines allow one to undertake this analysis without needing to mount samples in a sample compartment, and allowing the portable XRF machine to be transported and used in situ.

There is more to conducting an XRF study than simply collecting the spectra. Advance preparation regarding the object under study, as well as the physical presentation of the collected spectra, is key to a successful analysis. The following interviews provide practical tips on ways to prepare, set up, interpret, and report the data generated through XRF.

Personal communication with an anonymous conservation scientist

Guidelines on XRF analysis procedure and data storage[3]

· Could you please explain the step-by-step process you follow for undertaking the pXRF analysis of paintings?

§ *We get paintings out from the storage area. The paintings in our collections are all mounted on a mountboard and are therefore easily set up vertically on an easel for pXRF analysis.*

· Setting up pXRF machine

o What are the steps followed to set up the pXRF machine before you start analysis??

§ *We connect the pXRF machine to a laptop. It can also be connected with an overhead display, which is mounted on the XRF machine. We use S1 pXRF software, which is an online software that you use to see the spectra while*

[3] Based on communication with anonymous conservation scientist

doing analysis. After connecting the machine to computer, we switch on the machine and open the software. We then set up the analysis parameters in the pXRF - 40Kev, 8uA, no filter, 60 seconds.

- Do you attach the pXRF machine to the stand (instead of using it in handheld mode while analysing flat paintings). How much distance do you maintain between XRF machine window and painting while analysis?

  - *We use the machine in handheld mode. We do not use a stand while doing the analysis, but we keep the machine on its stand in between analysis, while saving the data, marking peaks, etc.*

  - *The machine that we have needs to be kept in complete contact with the paint surface to be analysed. So there is no distance between the machine and the analysed surface.*

- Do you use any kind of covering material (with a hole where X-rays are released) on the nose of the instrument?

  - *Since the pXRF model that we have needs to be kept in direct contact with the surface/point we want to analyse, we keep a melinex sheet between the folio and the XRF. Since this is organic in composition it doesn't get counted in the XRF spectrum. No hole is made in the melinex sheet where analysis is being done.*

· Carrying out analysis

- Could you briefly outline the steps you follow in order to do the pXRF analysis of paintings?

  - *We first analyse the back mountboard signal in each case so that any elements included in that can be identified and accounted for while interpreting the XRF results. We then analyse the annotated points in which the background paper in a painting or manuscript is always the first point that is analysed, so that it can be overlaid with other pigments' spectra while interpreting them.*

  - *Labelling of the sample ID happens before we go for analysis - before I pull the trigger I have to put in the name of the file, the path of the file where it will be saved.*

  - *After that I click the trigger and we usually get a graph in the first 20 seconds itself. But* it takes *60 seconds in order to get the final graph, since that is the collection time we have set in the initial stages.*

- What do you check to determine if the quality of the spectrum taken is good enough?

- *We always check for noise in the graph (visible on the computer software) as noise can prevent the peaks from being seen clearly in the graph. If there is noise, we take the graph again. To reduce the noise, we make sure that the machine is properly aligned and in close contact with the point we are analysing on the folio.*

- What is the process that you follow for marking the peaks on the collected spectrum?

  - *We detect the elements and mark the peaks on the spectrum using the software. We have to detect the elements manually using the periodic table that is provided within the software. After we do this the graph saves automatically by the name and in the location that we mentioned before we started collecting the spectrum.*

- What are the formats in which we can get the raw data from this pXRF machine?

  - *We are saving it in the raw form - PDZ file. This can be opened in any XRF software (ARTAX software of Bruker as it is compatible with PDZ format; ARTAX can also be used for analysis). If the data is in the text form (numbers with 2 columns – the count and the energy) then it can be opened by any other softwares as well.*

- Do you record any other metadata or any observations on paper while doing analysis?

  - *I go with a print out of the annotated image that tells me which points I need to analyse. Once the analysis of any point is done, I tick it out. We don't record anything else, but if we need to, any additional data gets recorded on a word file.*

· Are there any other recommendations to be followed while doing pigment analysis using pXRF machine on paintings?

  - *You should have a good background of information about pigments of all the eras so you don't get confused. You should also have information about the object - historic data about the object, so that the information you get from the graphs doesn't confuse you.*

  - *Standard Operating Procedures are very clear on how to handle XRF, but the interpretation requires experience.*

  - *Some filters are required in some cases. We mostly use them for detection of heavy metals or pigments of lower concentration. Lower atomic weight elements will also need vacuum to detect them.*

Guidelines on identification of points for XRF analysis, analysis procedure, data interpretation and storage[4]

- Before you begin pXRF

· What information do you need to have in hand before you start with pXRF?

  o What kind of object-based analysis and interpretation takes place before you identify and finalise points for pXRF? What things about the materiality of the object do you aim to understand before starting pXRF?

    § *Ideally it is nice to have the visible and the UV fluorescence photograph and raking light, if possible. For selecting the points for XRF analysis it is nice to have a microscope that you can use to look at the object and have an assessment about whether some areas have been overpainted, in which case you can stay away from those areas, if you want to look at the original materials.*

    § *While deciding which points to analyse using the XRF, it is always good to have the first point be the paper itself or the substrate itself. Then I try to choose two different selections of what visually looks the same like white, yellow, red, blue, green – the basic colors. If there is a pink, a purple or a light blue, something that you don't find very often, you take one analysis point of it. But I try to analyse 2 areas and hopefully they're the same, and if they are then I start to question whether they visually look the same or if they are different materials.*

    § *UV light images are helpful because some of the organic reds and definitely the Indian yellow will fluoresce under UV. Two yellows can look the same in visible light, but in UV light they can be distinctly different.*

    § *Raking light helps you see if there's a tear that's been repaired, if there's over paint, or if the paint is flaking – sometimes just the whites tend to flake and such cases the raking light can help you understand the stability of the paint.*

    § *As far as any art historical information is concerned a curator or conservator needs to explain to me what is important to them before I start the analysis, so I know what to analyse.*

- Details about pXRF machine used for analysis

[4] Based on communication with Dr. Michele Derrick (Retired Conservation Scientist, Museum of Fine Arts, Boston)

· Details of the pXRF machine used at Harvard (Brand, model, x-ray source, detector, element detection range).

  - § *The Bruker ARTAX instrument that has the arm with a camera on it, so it's not really that portable even though it is on wheels. I've never taken it to the gallery, I bring the objects to the instrument. The Bruker Tracer, the handheld XRF is used when we need to go to the storage room to look at objects or if we need to go to the gallery to look at objects, particularly big things that we can't bring to the lab.*

· What are the minimum specification requirements of a pXRF machine to be able to use it for pigment analysis?

  - o Can you use mode-based machines (such machines automatically select filters etc.)? Aperture size? Minimum elemental range of the instrument?

    - § *I would definitely like there to be the option of no filters. We have tried filters especially when they recommend it for looking at glass or metals and I don't like it. The problem is you need the specific standards to do the analysis to set up with each filter and we have metal standards but we don't have glass standards or ceramic standards. So I would just rather not use any filter, and if I have to I would be worried if my assignments are accurate. The filters can shift the maximum analysis area to different regions, whereas without a filter you get one thick envelope where the maximum peaks are in the area of copper, zinc, lead, arsenic, mercury, that region. Unfortunately the lower end of the spectrum - the silicon, sulphur, chlorine, calcium, potassium, has very little energy, so when we need that area to be visible in the spectrum I do use a helium purge. With a handheld instrument, because there is less air space for the beam to travel through, that is a little more sensitive for the lighter elements than the ARTAX instrument.*

    - § *As far as changing the aperture size I don't think that's incredibly important unless you are working with areas that are really tiny or unless the machine has a big aperture - it doesn't really matter whether it is 0.5mm or 1.5mm. You will get less peak intensity with the smaller aperture, but you'll have to be more careful when you'll select a paint area if you're at 1.5mm to not include and record the spectrum from adjacent areas. I don't think there is much difference in the ability to interpret what you're looking at with either 0.5mm or 1.5mm aperture.*

  - o Can we use machines with a gold X-ray source instead of Rh – or will the tube output spectrum interfere with the detection of these elements in painted surfaces?

    - § *I usually plot the spectrum just past the rhodium peak (we collect 0-30 Kev, but I usually only plot about 2-25 Kev).*

- *If you use a machine with a gold X-ray source, you won't be able to detect gold, but also the gold comes very close to the mercury peak and the copper peak - that would be a problem. The reason Rhodium is nice as an X-ray source is because its peaks are stuck out there where not much else occurs.*

- Analysis procedure

- What kind of setup do you use?
  - Do you prefer doing pXRF analysis with the object lying down flat or in a vertical position?
    - *I generally do the analysis with the object lying down flat on the table, but if you're putting the object up on an easel, you're going to have to make sure flakes aren't going to fall off when you prop it in a vertical position.*
  - What are some other setup requirements to do pXRF of paintings?
    - *I always use an archival board underneath the painting, but that's just for cleanliness and to separate the painting from the tabletop that I have underneath, because I think the archival board has fewer elements in it.*
    - *On some scrolls we use little bean bags to hold the scroll open so we can analyse those safely, but mostly with folios you'll come across flat objects.*
    - *With books that are mounted we have a book cradle made out of plexiglass. Plexiglass sheet is also a nice backing to have underneath things while doing pXRF analysis. It's important that the surface be flat and plexiglass helps ensure that to some extent.*
    - *In an easel the nice thing is you can probably have air behind it in which case you don't have a problem.*
    - *Some people use a melinex sheet in between the pXRF nose and the painting because with the handheld XRF you wouldn't want to put it against the painting surface, so it's nice to have the protective melinex barrier. It is fine to do this as long as you do a background spectrum with the melinex because it shouldn't interfere with your pigment spectrum.*
- What is the step-by-step procedure followed for doing pXRF analysis?
    - *I have a printout image of the object where I record where on the painting I do each analysis. I save each file after I run it because our software doesn't automatically save it. Our instrument has a camera mounted on it, and because we are a centimeter off the sample, we use that camera to focus and get it at the right height and the right orientation, if there is a curved surface*

that we are looking at. Using this camera we can take an image of each analysed point, so I also take an image and save it with the data file.

- *I take 2 minute runs on the ARTAX machine, but sometimes when we have the handheld machine, we can only do 30 seconds or a minute at the longest because your arms gets really tired holding that instrument.*

- *The general parameters we use for analysing paintings using the pXRF machine are 40 kV, 8 µA, no filter and 60 sec*.

· What do you check to make sure the graph you get is of a good enough quality?

- *I check for the noise level of the baseline. If its incredibly noisy I either wasn't at the correct focus or some kind of movement happened while taking the graph. If the spectrum is really noisy then I run it again, and since our instrument is on the arm, I can run for 5 minutes and make it less noisy if it's some type of material that's not giving a very good emission or a very good signal.*

- *There is another thing, but this happens only with metals. I generally run with 40 Kev for pigments, but sometimes with metals the peaks can be too strong rather than noisy. And with metals we often want to do quantitative analysis, so I need to make sure the peaks are not getting saturated. So sometimes I have to turn the intensity down to 25 Kev to make sure that my peak heights are accurate and quantitatively representational. But this is with metals and quantitative analysis. With pigments you want as much emission as you can get, which means you use either 40 Kev or 50 Kev.*

· Are there any specific pigments/elements that are difficult to detect and need careful analysis to enable their identification through pXRF?

- *If you really suspect that there's ultramarine on your painting, it would be good to analyse a reference sample of ultramarine (synthetic ultramarine is not going to give the same response as natural ultramarine) painted out on paper under the exact same experimental conditions and use that for comparison. Ultramarine and the clays are usually the ones where I don't rely on the XRF and I want a different type of analysis to confirm their presence. They are easy to detect with infrared and Raman spectroscopy. FORS can also give an ultramarine spectrum.*

- *Just like ultramarine and clay, if you're analysing glass materials, anything with silicon in it, ceramics, glazes, it's nice to have that type of reference to compare it to.*

· Do you ever use vacuum to detect any particular pigments? Or any other analytical parameters (other than the general ones) to detect any particular pigments? In what case are they used?

  - *We don't really use vacuum for paintings, but for photographs we usually use the helium purge. But not for paintings, even though that would probably be nice if there was really ultramarine there on the painting.*

· Do you use and PPE or follow any precautions while using the pXRF machine?

  - *In the US we are required to wear radiation badges. With the handheld XRF instead of a badge we have a dosimeter ring just because it is more possible that your hands might get exposure from X-rays.*

  - *Before I handle the paintings I rely on the conservators to tell me if they want me to use cotton or nitrile gloves, or ask me to make sure that my hands are washed and dried properly. Since many of our paintings are mounted, I only have to touch the mounts and not the paintings themselves.*

  - *With the ARTAX and the handheld XRF we were also told that as long as you're standing behind it, it's okay, but don't stand to the right side of it because if any X-rays are going to get diffracted they are going to come out on that side. But that depends on the instrument you have and they should give you that information when you buy it.*

  - *With the big ARTAX instrument if I have somebody in the room with me, I tell them to not get closer than 6 feet. We have a Geiger counter to detect radiation and we've only observed radiation exposure about 6 inches from the beam, which is why we tend to keep 6 feet away from the machine beam. This is more pertinent with our ARTAX machine where we do 2 minute runs, and people may approach the machine without realising that it is running.*

- Interpretation of the collected pXRF graphs

· Do you prefer to interpret pXRF graphs as you go or collect all data and then interpret?

  - *I just read what I'm getting as I go. I have a screen to show the spectra as it's collecting. But I usually don't fully interpret the results until I can sit down later and compare it to the background and mark the peaks and see if it makes sense. Because even with the instrument assigning the peaks it can be easy to miss things or misinterpret, whereas if I am doing that later I can do it with a better focus on just interpreting, when my attention is not diverted by the operation and running of the XRF machine.*

· What are the kind of things (other than XRF graphs) that you need for interpretation of XRF data?

- Software used – ARTAX. How do you overlay spectra?
- High resolution annotated images?
- MSI images (that could have been taken before XRF)?
- Magnified images (maybe of specific areas that need clarification while interpreting XRF results) that could have been taken before/after XRF?

    - *The first two are absolutely necessary. But if we have all this, that would be really nice, but it isn't always possible to get all this. In any case it's hard to know if there are multiple layers of paint because the X-ray will, especially at 40kEV, go through the first and second and third layer and pick things up from all the layers. That is another reason to go down to lower energy so that the beam would not penetrate as much. If you're really concerned about getting just the surface, you can use a little lower energy.*

· What is the procedure for overlaying the pigment spectrum over the background spectrum?

- *With the Bruker software it is easy to overlay even upto 20 spectra and compare them and look at them. I only usually like to plot the pigment spectra over the background, so that it is easier to compare the two visually and mark the peaks of elements in the pigments. The software has the little periodic table - so if there is cobalt and I'm curious about whether there is tin to go with it (if you have cobalt and tin together it corresponds to smalt), so I can always click on tin in the periodic chart if I don't remember where the peaks are on the spectrum and it will show me those, and I can check if its there in my sample or not. It's nice to be able to turn on and turn off the markers to see if I'm accounting for all the peaks or if there are some peaks that I've missed or if there are some peaks that aren't right. So it's nice to be able to use the XRF software due to all these features, which is something you cannot do if you plot your graphs in MS Excel.*

· After you've finished interpreting it, in what form do you save your data?

- As RAW individual graphs? Or as overlaid spectra? Can overlaid spectra be saved in the RAW format?

    - *I save the RAW files as well as overlaid spectra files. The RAW data is always in individual files, so I don't think I can save the overlaid spectra as RAW and I generally export them, but I've never tried.*

- *I export the overlaid spectra and make reports in power-point or PDF form because that would be the easiest for anyone to read and access.*

· What written format do you generally use to save the interpretations you make from the XRF spectra? Eg. here we are using format developed by the MCH project team.

- *I write data reports, with peaks in general labelled major, minor and trace. In this I include power-points along with the overlaid graphs displayed alongside the image of the point analysed. Its usually a one-page report that has the analysis area, the elements I found and then it has possible interpretations.*

- *The reporting format that the MCH project team has developed is also a good one as it covers all the important data that one needs to have.*

· What is the best way to store XRF data and interpretations for the long term?

  - Hard disk backups?

  - Cloud based backup systems?

    - *We don't allow any of our computers that are attached to instruments to be networked because they don't trust it if they haven't installed security files etc.*

    - *We have hard drives in which I would back up the data from each instrument once a month. So on the first day of each month I connect it to each instrument and set it up to download. And because I keep all files by dates I usually just download the new data.*

· What order of analysis do you suggest?

  - Overall microscopy, MSI, pXRF, microscopy where needed, FORS, Raman?

    - *With these Indian paintings, if I think there is an organic yellow - the Indian yellow, I would do UV fluorescence on it, or if there is an organic red, I will try the UV fluorescence, the EEM. If there is an organic blue like Indigo, I would do FORS and visible reflectance, because that is an easy, fast, confirmation method. However, I don't tend to analyse all of the points using these techniques – so I might do the organic reds and organic blues, but I am not going to do the inorganic points. So unfortunately if there is organic mixed with inorganic, I might totally never figure that out.*

    - *At some institutions paintings are analysed using Raman spectrometry because they don't have FORS or UV fluorescence. I would probably save Raman to the very last because there is a chance that you can burn a hole in the object. So if I couldn't get the information by FORS or UV fluorescence, I would do FTIR. If there's a white and we aren't sure whether it's Gypsum, or calcite or chalk I*

would also do FTIR reflectance because it would be easy to tell the three apart from each other using this technique.

- Microscopy after pXRF

· Can you see any morphological characteristics of pigments (when applied on objects, without sampling) using microscopy? What magnification range is used? Any characteristic of some pigments that help in identifying them using high magnification images?

  - § *If you do microscopy beforehand, it's to get a general idea of the condition. If you have a polarising light microscope and beforehand you can go 10x, 20x, maybe 50x.*

  - § *If you take samples and go to 400x you can tell the difference between indigo and ultramarine. I don't like taking samples, but with ultramarine and indigo it's easy to tell the difference using microscopy. This is something that can be done after XRF, if you really have a question to define a specific area so you don't have to take a lot of samples.*

- o Is it any use going to very high magnifications without taking samples? Will that tell you anything?

  - § *Maybe if you've looked at a lot of them and trained your eye you would be able to tell things apart from each other. Our stereo binocular microscope can only go upto 200x, I've never tried to go over that - so I don't know, but it might. Certainly you can see azurite crystals at that point (50-100x). I'm not sure about ultramarine because its pretty small, but indigo is even smaller, so you might be able to tell them apart. It all depends on how its prepared. If azurite is ground too small, it does not give a very intense blue, so azurite tends to be relatively big for a pigment so that you get a good color.*

- o Does polarisation help in analysis of pigments non-invasively, when pigments are applied on paintings?

  - § *Polarisation is a transmitted analysis. You have to take out a tiny sample. You can use a needle to take a sample and put it on a slide and disperse it and look through it under a polarised light microscope. You can compare various morphological behaviors of pigments with available pigment monographs to identify pigments in this way.*

- o How frequently do you use reference pigment samples to aid pigment analysis? How important is it to have a reference pigment collection?

§ *It's very important to have references for comparison but they can be digitized references. For example, we have large libraries of FTIR, Raman and HPLC references spectra that we can search for identification of unknowns. For XRF, references are only needed if you are trying something unusual, such as detecting ultramarine blue or if you want to do quantitative analysis.*

· What are some of the things that one should keep in mind while doing pigment analysis? Any words of advice?

§ The main thing is you pick up tricks and techniques as you go. The more you do it the more comfortable you'll be doing it.

IV. Systematic recording of collected analytical data

All types of scientific analysis must be clubbed with proper interpretation and storage of the interpreted data, in a form that is easily understood by people who have not been directly involved in the analysis process. Translating the RAW analysis data collected using the methods identified above to create a concise and easy-to grasp report can improve the accessibility and readability of the data, and can help the non-scientist cultural heritage professionals draw various conclusions that relate to the art historical importance of the analysed objects.

The MCH project team has developed a reporting format and controlled vocabulary that can be used to record the interpretations made using various analytical techniques. Following Q&A explains the goals and the purpose of systematic reporting and data recording and rationale behind the proposed reporting template developed and tested by the MCH team.

Guidelines on using the MCH reporting format to record and interpret analytical data[5]

- Reporting formats

· What was the reason the reporting format and controlled vocabulary was developed for MCH? What does it aim to achieve, especially for an international collaborative project like MCH?

§ *At the inception of the project in 2018, I was asked to bring lots of different analyses from lots of different analysts from publications or just some very rough notes that were shared with us. I had to standardise the information, and put it in an excel spreadsheet to begin with. We had a brainstorm session*

[5] Based on communication with Francesca Penty, Research Assistant, MCH

at the beginning about controlled vocabulary and how to structure the data compilation with the types of data that the PI had in mind, and it was determined that we must have what might seem an arbitrary set of controlled vocabulary on visible colors to organize the data.There is a great need for controlled vocabulary for a database project like this. For example, different reports have scientists and analysts using different terms for pigments. We had to refine and standardize the pigment names used in the database. After several brainstorm meetings with conservation specialists, scientists, and data science specialists, we've also decided to introduce certainty level to the pigment identification, which helps to capture the degree of certainty that can be subject to further research and analysis.

- *We held an international workshop in 2019 which brought together conservation scientists ,conservators, and South Asian art historians/curators to discuss the types of information that might be useful and important for them in a database project like the MCH.*

- *In the controlled vocabulary I think we have about 40 pigments. We have added all the pigments that we have found in the paintings on which we have analytical information.*

- *Other than the science side of the database, there is also the artwork information. As the PI always emphasizes, a database is as good as the data within it, and without concrete historical and geographic information, the MCH project won't work. Unfortunately, a lot of the South Asian materials lack concrete historical and geographic information. We have a team of research assistants under the direction of the PI working on art historical research to improve our understanding of each object that is included in the database.* ·

  Could you please give me an outline of the procedure of using the reporting format along with the controlled vocabulary?

- *We created this word document so it can be printed out and used to collect necessary information even when the internet connection is not present or unstable given the electricity and resource precarity in India. This reporting format is based on the template that we used initially for creating a spreadsheet but it is also designed with the goal of capturing the data in the most concise and condensed manner while in the field, so it can be directly entered into the database. We also put together the User guide that includes an example of a filled-out reporting, so anyone can follow that to fill up the blank version of the reporting format.*

· What all types of data can the reporting format incorporate?

  - Where in the reporting format can we insert microscopy images, raking light images?

- § *The microscopy, MSI, raking light images will have to be shared with us as individual labelled files because the reporting format does not include a place to upload the files as of yet. The reporting format is designed in a way that information and interpretations from those images are used to populate the table of the reporting format. We also have a separate rudimentary form for MSI imaging report if a researcher in the field has access to a computer and can include the images in a word document.*

- o Is there scope for the reporting format to include information from Raman, FTIR, microscopy and MSI? Or are those subsidiary techniques whose information is supposed to support the pXRF data that goes into the reporting format?

  - § *We do have a column for other analysis, other than XRF from, be it Raman or FTIR. But also, these are secondary techniques that one is supposed to use after the microscopy, MSI, pXRF data is used to narrow down on the identity of the pigment.*

· Is this same format used for reporting pigment analysis results in other institutions in the US as well?

  - § *We get different types of reports from scientists. We often get enough information from the scientists to translate the data for the database but it is not exactly formatted in the way that the database is designed. Sometimes, we have to go back and ask them for more relevant information for the database. So we hope to recommend the usage of this new reporting template for future research.*

  - § *The MCH project also takes the data from published studies. In publications the data reporting format is not standardized either. Often times, the data is not as granular and specific as our project seeks to capture We now have a consulting conservation scientist on the MCH team and we are lucky to collaborate with her in translating the data when it is not as detailed or fuzzy .§ As long as the necessary information is there, it doesn't really matter what format it is in. Our reporting template helps to standardise the data collection so that the most important information required for the database is included.*

· What are the key aspects that need to be included while developing / using any kind of reporting format? What is it that is absolutely essential to record?

  - § *Everything; all of the categories on our template. Another way you can record your analysis data may be that you label the annotated image map, the pigment and elements identified, and write the information*

on this annotated image. iThis method can get quite messy and hard to read, depending on the number of points on the surface, especially if it's handwritten. But as long as all the information is there it can be in another format.

- Data storage and dissemination

· How do you envision receiving data from different institutions in India in a systematic way in the future of this project?

  o Via email? Or Uploaded on a shared drive or dropbox that allows things to be easily uploaded from Indian end and accessed by you?

    § *At the moment we've had a mixture of scientists sending us data on google drive or dropbox – different formats.. How to collect and compile the raw data generated in analytical studies elsewhere is something we are actively thinking about. We don't anticipate having a standardized way forward at the moment - we will keep using the readily available cloud tools for raw data collection, whichever tool works best for the group in India. We will keep looking for an alternate solution for raw data collection and storage.*

· Do you follow any image/file nomenclature system to ensure data can be easily retrieved?

  o If yes, could you please share that with us? So we can label files in the correct way, reducing workload at your end?

    § *We have everything, the UV images, graphs, in an object-based folder (as accession number) on the drive under each institution.*

    § *I would do accession number_methodolgy, that's how I would save the labelled map.*

· Is all this data part of the back end user base of the MCH database OR will they be made available online? Will all MSI images, graphs, microscopy images be put on the MCH website? Will some be put online?

    § *We take information from the tables and other data you share with us and add it to the back end interface of the database. Here we also have an image of the painting, its title, its date and place of production, the collection it belongs to and the accession number of the object. We also*

have the various analysis dates and information about where the analysis was done.

- § *The first step is adding a visible color. We can also add pigment condition. We also have fields for description and notes to add any relevant information about that particular color or point.*

- § *After choosing the visible color, we enter the pigments and select the certainty level. There is also a section on methodology so we can have multiple methodologies associated with a color marked in this section.*

- § *So even on the front end it looks very similar to the table you are filling out – it has visible color, pigment identity, elements, analysis point location and analytical technique used.*

- § *At this point we do not anticipate storing microscopy, and MSI images on the MCH project database. What is recorded is the analysis methodology, which will also help document the history of conservation science and the development of different analysis techniques.*

· How do we factor in limitations of analysis in India (for example all analytical equipment not being available) into the database? Results obtained from low quality or preliminary analytical techniques may not be accurate?

- § *I think that would be accounted for through the certainty level. It depends on how uncertain, there is an element of speculation. For example, we were discussing having organic blue in the database. But then we decided that instead of having organic blue of a certainty level 1, it's probably indigo – so we decided to have indigo with certainty level 2. So there is an element of speculation. But I think as long as there is a certainty level related to that), it should be accounted for.*

Mapping Colour in History Project and Pigment Analysis in India[6]

- A large amount of research relating to pigments and characterization of the unique behaviours of pigments (even those used in Indian paintings) is coming from research conducted outside India, mainly in the West. In what way can this model of research be adapted in India?
    - *There is something to differentiate between the data that we know about pigments - history of pigment usage is mainly based on European materials, versus*

[6] Based on communication with Dr. Jinah Kim, Principal Investigator, MCH

the methodology developed to analyse the pigments. Analysing pigments and actually seeing what's on the surface takes many iterations and different approaches to understand it - it's not going to be like you put in A, and B comes out as the answer. It doesn't work that way. And no amount of methods followed in the west are going to be like a cookie cutter and fit exactly the same way in India.

- *Given the low resource setting in the Indian subcontinent, there are methods that one can use and are more adaptable in that setting. For example, the low budget approaches or those that do not require high tech equipment, those that are mobile - those are the three things one needs to consider when recommending what kind of techniques can be used to get maximum output using the minimal resources. That's what we have learnt from interviews with conservators and people currently working in the field in India: people manage to work with what is available. That is also what shows up when we see artists working with these materials (that we are trying to analyse), they are very clever about how to use the resources that are most commonly available.*
- *I think it is also important to recognize that these high-tech methods are great, but there are also certain limitations to being able to apply these techniques. That is why we have proposed doing multispectral imaging of paintings, because that is a relatively low-tech analytical method that can be used. It cannot replace the high-tech analysis, but it can complement them and provide some kind of data that can simulate the kind of data that one can get, for instance, from Raman spectroscopy. There have been studies that talk about how the use low-budget techniques can get similar answers.*
- *It is also useful to collaborate because you can ask scientists elsewhere who have more reference materials or more resources to help you analyse and understand similar objects in their collections. The pandemic actually opened the possibility of collaboration across the globe and made this possible virtually.*

- Would you recommend any literature sources for a person who is undertaking analysis on Indian pigments and paintings?
  - *See, for example, the entire series of Artists' Pigments: A Handbook of Their History and Characteristics, from the National Gallery of Art in the US, now freely available for download: https://www.nga.gov/research/publications/pdf-library/artists-pigments-vol-1.html*
  - *"Conservation & Art Materials Encyclopedia Online (CAMEO)." n.d. Accessed February 6, 2020. http://cameo.mfa.org/wiki/Main_Page.*

Following is just a small selection of literature. The MCH database will also feature a curated bibliography for further research - curating and hosting bibliographic resources will probably come together in the next stage of the database development.

- *Purinton, Nancy, Richard Newman, and Cincinnati Art Museum. 1985. "A Technical Analysis of Indian Painting Materials (Appendix 1)." Pride of the Princes: Indian Art of the Mughal Era in the Cincinnati Art Museum, 107–83.*
- *Isacco, Enrico, and Josephine Darrah. 1993. "The Ultraviolet-Infrared Method of Analysis, a Scientific Approach to the Study of Indian Miniatures." Artibus Asiae, 470–91.*
- *Knipe, Penley, Katherine Eremin, Marc Walton, Agnese Babini, and Georgina Rayner. 2018. "Materials and Techniques of Islamic Manuscripts." Heritage Science 6: 40.*
- *Bisulca, Christina, and Christopher Foster. 2018. "Perfection of Wisdom—a Spectroscopic and Microscopic Analysis of a Twelfth-Century Buddhist Sūtra." Bulletin of the Detroit Institute of Arts 92 (1–4): 68–79. https://doi.org/10.1086/701459.*
- *Bayerová, Tatjana. 2017. "Buddhist Wall Paintings at Nako Monastery, North India: Changing of the Technology Throughout Centuries." Studies in Conservation. https://doi.org/10.1080/00393630.2017.1327111.*
- *Reiche, I., Ralf Britzke, Gregor Bukalis, Uwe Reinholz, H.-P. Weise, and R.D. Gadebusch. 2005. "An External PIXE Study: Mughal Painting Pigments." X-Ray Spectrometry: An International Journal 34: 42–45.*
- *Purinton, Nancy, and Mark Watters. 1991. "A Study of the Materials Used by Medieval Persian Painters." Journal of the American Institute for Conservation 30 (2): 125–44.*
- *Smith, Gregory Dale. 2017. "Cow Urine, Indian Yellow, and Art Forgeries: An Update." Forensic Science International 276: e30–34.*
- *Van Dyke, YANA. 2009. "Sacred Leaves: The Conservation and Exhibition of Early Buddhist Manuscripts on Palm Leaves." The Book and Paper Group Annual 28: 83–97.*

- What are some of the barriers to pigment analysis and research in India

- *As mentioned before, one of the basic barriers is access to scientific equipment and resources.*
- *Realistically, bureaucracy is also another barrier, which is basically anywhere you go in the world. I think there are a lot of good administrators who want to support this type of research work, but it is also about following the protocols, the rules. It has a history to it and it was all done to maximise access in a systematic way, but that also means that one has to go through so much more paperwork.*
- *Another challenge is the siloed lines of communication, especially in museums, where conservators and curators often talk, but there are these channels of communication that are not easily flowing. We need to have open communication and open mindedness. Again, the pandemic has opened up the possibilities of communication across the board and one needs to really cultivate this instead of being siloed.*

- Has the research done under the aegis of the Tata grant for the MCH project helped establish the answer to some research questions? For instance your questions about the effect of Mughal ateliers on the indigenous painting techniques.
  - *That is to be seen because we do not have a lot of data. There is a lot of research that has been done in the west, but it's still limited.*
  - *I also wanted to know if there are certain environmental factors in India, and how they affect the deterioration and condition of the pigments, that was one of the original visions for the Tata-trust funded project as well. But I don't have any observations to share as of yet because we don't have a lot of data to go on due to the pandemic. But I think we can find things by comparing earlier materials, and further analysis can bolster certain observations about earlier materials, like what kind of palette was used.*
  - *I was hoping that there is usage of zinc white somewhere, or copper-based blue like we have seen in some of the analysed paintings that belong to the earlier centuries than what is widely accepted early usage of each pigment. But we will keep looking and hope to find the answers to these questions as more data is generated and collated onto the MCH database.*

MAPPING COLOR IN HISTORY

Pigment Analysis Data Collection
User Guide for Database Entry

Contents

About Mapping Color in History

Mapping Color in History [henceforth MCH] is a Digital Humanities project that brings together the scientific data drawn from existing and on-going material analyses of pigments in Asian painting in a historical perspective. As a knowledge common, MCH aims to help chart how, when, and why specific colors were used in artistic practices in specific regions. The MCH digital platform hosts a searchable database with mapping capacity to track the appearance and usage of pigments across time and space. It takes an object-based entry method for data collection instead of a pigment-based organization scheme. It also records the historical and technical information on the analysis, providing valuable data on the history of analytical methods. On MCH, each piece of pigment analysis data is associated with the analyst(s), and each contributing analyst/institution can see their data in comparative terms and locate their objects in the historical and geographic spectrum.

Required Documents Checklist

For each artwork being analysed, please include the following documents (see example filled in sheets on the subsequent pages):

1. **'Analysis and Artwork Information'** sheet (sheet_001), to note general information about the artwork (title, date, location, repository etc.), and the analysis (analyst name, date of analysis, methods of analysis etc.). In the case of a manuscript or an album, create an entry sheet for each folio/page.
2. '**Pigment Analysis**' table (sheet_002), to record pigment analysis findings. Please check notes on the bottom of the sheet, and refer back to the 'Controlled Vocabulary Guide: Pigments' in order to maintain a consistent use of vocabulary throughout the project.
3. **Analysis Points Map**, a copy of the image with numbered analysis point labels, either in an A4 print-out or digital format (please convert to PDF when complete). These numbered analysis points should relate back to the 'Analysis Point' column on the 'Pigment Analysis' table. If available, append any additional images of XRF and Raman spectrums.

Analysis and Artwork Information

MAPPING COLOR IN HISTORY

Analyst Information

Name of analyst:

Job title:

Institution:

Project number*:

Date(s) of analysis:
(mm/dd/yyyy)

Methods of analysis:

Analysis method model*:
(e.g. Bruner Artax XRF)

Artwork Information

Title:

Artist*:

Repository:

Accession number:

Related artworks:
(by accession number)

Classification*:

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:

Location:

***Fields marked with an asterisk are optional.**

sheet_001

Style*:
(e.g. Rajput)

Size:
(H x W cm)

Medium:
(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*:
(exhibition name, location and year)

Publication history*:
(Chicago style: Firstname Surname. *Publication Title*. (Place: publisher) Year: page number.)

Notes*:

***Fields marked with an asterisk are optional.**

sheet_002

Pigment Analysis

MAPPING COLOR IN HISTORY

Accession number: Project Number: Name: Date:

Visible color*	Pigments**	Certainty level †	Elements			Location point and description		Notes
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	
Green	*Orpiment*	*1*	*As, S*			*1, tree*	*1, tree (raman)*	
	Indigo	*1*						

*Choose from controlled color vocabulary: red, yellow, blue, purple, pink, green, orange, grey, black, white, brown, or metallic (i.e. gold or silver).

**Please refer to 'Controlled Vocabulary Guide: Pigments'. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record 'pigment condition: unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

sheet_002

Accession number: Project Number: Name: Date:

Visible color*	Pigments**	Certainty level †	Elements			Location point and description		Notes ‡
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	

* Choose from controlled color vocabulary (red, yellow, blue, purple, pink, green, orange, grey, black, white, brown) or metallic (gold, silver).

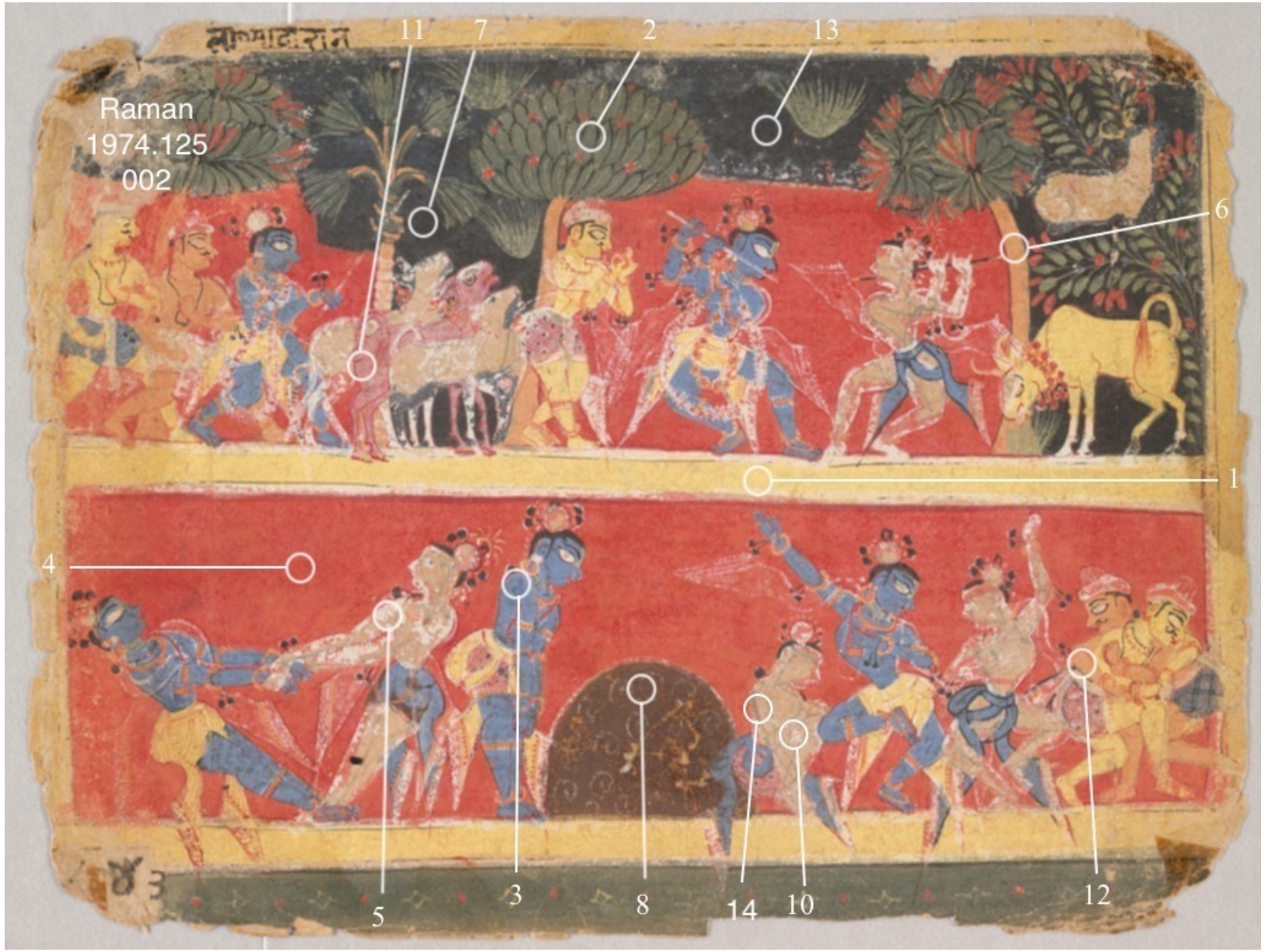
** **Please refer to ‘Controlled Vocabulary Guide: Pigments’. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record ‘pigment condition’: unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

MAPPING COLOR IN HISTORY

CSMVS Acc. No. 55.65, fol 47v, annotated XRF map

MAPPING COLOR IN HISTORY



Raman Map of Harvard Art Museums, 1974.125. Raman Analysis by Dr. Katherine Eremin

Controlled Vocabulary Guide: Pigments

MAPPING COLOR IN HISTORY

Color	Preferred term[1]	Related terms[2]	Elemental composition[3]
Reds	Vermilion	vermilion red; vermillion; vermiculus; cinnabar; Chinese red; red mercuric sulfide, mercuric sulfide	HgS
	Realgar	Red orpiment; red arsenic sulfide; arsenic sulfide; arsenic disulfide; jalde; roseaker; sandaraca	AsS
	Red lead	lead tetroxide; orange lead; burnt white lead; mineral red; mineral orange; orange mineral; false sandarach; Paris red; saturine red; Saturn red; minium (mineral)	Pb_3O_4
	Lac dye	Lac dyes; lac-dye; lack dye; lac; lac colorant; lac-lac; laccaic acid; lac (resin); lac insects	C20H14O11
	Lac dye (cochineal)	Carmenic acid; carmine lake; carmine (lake); carmin (lake), Karmesin lake; new red lake; Kugel lake; Parisian lake; Munich Lake; Venetian lake; Dactylopius Coccus	
	Red ochre	Red ocher; ocher, red; ochre, red; red earth; miltos; burnt	Fe2O3

[1] Prefered pigment term according to the MFA CAMEO Materials Database, to be used throughout MCH project (unless otherwise stated).
[2] Related terms according to the Getty Art and Architecture Thesaurus Online and to be retained in search terms. Purple highlights related concepts/compositional terms.
[3] Elemental composition according to CAMEO (as the Getty Thesaurus doesn't include this information)

		ocher; iron oxide red; hematite; haematite; iron ochre	
	Organic red	Organic red pigments; pigment, organic red	
	Madder		
	Insect dye	Cochineal, lay dye, kermes (not in Indian painting)	
	Pararealgar		
Yellows	Orpiment	Yellow orpiment; sunflower yellow; orpigment; auripigmento; auripigmentum; arsenblende; arsenikon; king's yellow; arsenic trisulfide	As2S3
	Indian yellow	Yellow, Indian; snowshoe yellow; gaugoli; gogili; Hardwari peori; Monghyr puril; peoli; peori; peri rung; pioury; piuri; puree (Indian yellow); purrea arabica; purree; pwree	C19H16O11Mg.5 H2O
	Yellow ochre	Yellow ocher; ochre, yellow; yellow ochre; chamois; yellow earth; Italian ocher; French ocher; Italian ochre; ocher, yellow; minette; Chinese yellow; Mars yellow	
Blues	Ultramarine	Lapis lazuli blue; natural ultramarine blue; natural ultramarine; genuine ultramarine; ultramarine; royal blue; lazuline blue; lapis lazuli ultramarine; lapislazuli; azur; ultramar; artificial ultramarine blue; lazurite; new blue; Oriental blue; soluble blue;	3Na2O.3Al2O3. 6SiO2.2Na2S

		steel blue (Prussian blue); Turnbull’s blue	
	Artificial ultramarine	synthetic ultramarine blue; synthetic ultramarine; artificial ultramarine; permanent blue; French blue; French ultramarine; Gmelin’s blue; Guimet’s blue; ultramarine blue	3Na2O.3Al2O3.6SiO2.2Na2S
	Organic blue	Organic blue pigments; pigment, organic blue	
	Indigo	Natural indigo; anil nilah; stone indigo; rock indigo; Indian blue; intense blue; nil; indego; indico; indicoe; indicum; Indigofera tinctoria	C16H10N2O2
	Azurite	Azurite (mineral); bleu cendres; blue bice; Bremen blue; copper blue; mountain blue; copper carbonate	2CuCO3-Cu(OH)2
	Smalt	Dumont blue; Saxon blue; starch blue; azure blue	K, Al, Co silicate
	Cobalt	cobalt; cobalt blue; azure cobalt; olympia blue; Thénard's blue; Hungary blue; Vienna ultramarine; Vienna blue; bleu de cobalt; new blue; Oriental blue; soluble blue; steel blue; Turnbull’s blue	CoO.Al2O3
Greens	Malachite	Hungarian green; Olympian green; malachites; mountain green;green bice; green verditer; copper carbonate	CuCO3-Cu(OH)2
	Verdigris	Copper basic acetate; Montpellier green; Van Eyck green; basic copper acetate	Cu(C2H3O2)2-2Cu(OH)2

	Emerald green	Schweinfurt green; schweinfurt green; Paris green (name refers primarily to the product used as an insecticide); English green; Schweinfurter Grün; Schweinfurtgrün; verde di Schweinfurt; verde di Schweinfurt; Veronese green	Cu(C2H3O2)2.3 Cu(AsO2)2
	Copper green	Green, copper; copper salts	
	Atacamite	Copper oxychloride	Cu2Cl(OH)3
	Green earth	holly green; stone green; verdetta; green stone; Belgian earth; Hessian earth; Rhenish earth; Saxon earth; celadonite; glauconite;; Veronese green	
	Chrome green	bronze green; verde chrome; verte de chrome; oil green; Victoria green, viridian	
Blacks	Carbon black	Black, carbon; carbon-black	C
	Lampblack	Lamp black; oil black; Lampenschwarz; lamp-black	C
	Organic black	Organic black pigments; black pigments, organic	
Whites	Titanium white	White, titanum; titanium dioxide white; titanox; titanium dioxide; anatase; rutile	TiO2
	Lead white	White, lead; cerussa; cerusa; ceruse; Cremnitz white; flake white; hydrocerussite; Kremnitz white; Kremserwiess; Krems white;	2PbCO3.Pb(OH)2

		London white; Nottingham white; Roman white; silver white; slate white; snowflake white; Vienna white; blanc de plomb	
	Tin white	Ceruse of tin; stannic oxide; tin dioxide; cassiterite; tin oxide	SnO or SnO2 - xH2O
	Clay white	Kaolin; kaolin; China clay; China-clay; Devonshire clay; kaolinite, clay white	Al2Si2O5(OH4)
	Calcite	White pigment, calcium carbonate; calcite; whiting; chalk; shell white	$CaCO_3$
	Gypsum	Terra alba; calcium sulfate dihydrate; mineral white; anhydrite	CaSO4-2H2O
Metallic	Mica	Muscovite	
	Gold	Au	Au
	Silver	Ag	Ag
	Tin		Sn

Appendix F. Sample Pigment Analysis-analytical report

MAPPING COLOR IN HISTORY

The Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)'s art conservation centre conducted XRF analysis on a list of 30 objects in the CSMVS collection prepared and curated by PI using their pXRF equipment. The appendix provides a sample pigment analysis report based on this collaborative research on one object (the analytical information on one folio of a manuscript, Acc. No. 55.65). It consists of the following documents:

a. Annotated point map of the object prepared by Jinah Kim, PI
b. MCH Analysis and Artwork information template prepared by the CSMVS team (Nikhil Ramesh, Omkar Kadu, B. Pownthurai under the direction of Anupam Sah)
c. MCH analysis data reporting template prepared by Anjali Jain, MCH India consulting conservator with corrections by Dr. Derrick
d. XRF data from CSMVS plotted by Michele Derrick, MCH consulting Scientist

MAPPING COLOR IN HISTORY

CSMVS collaboration project

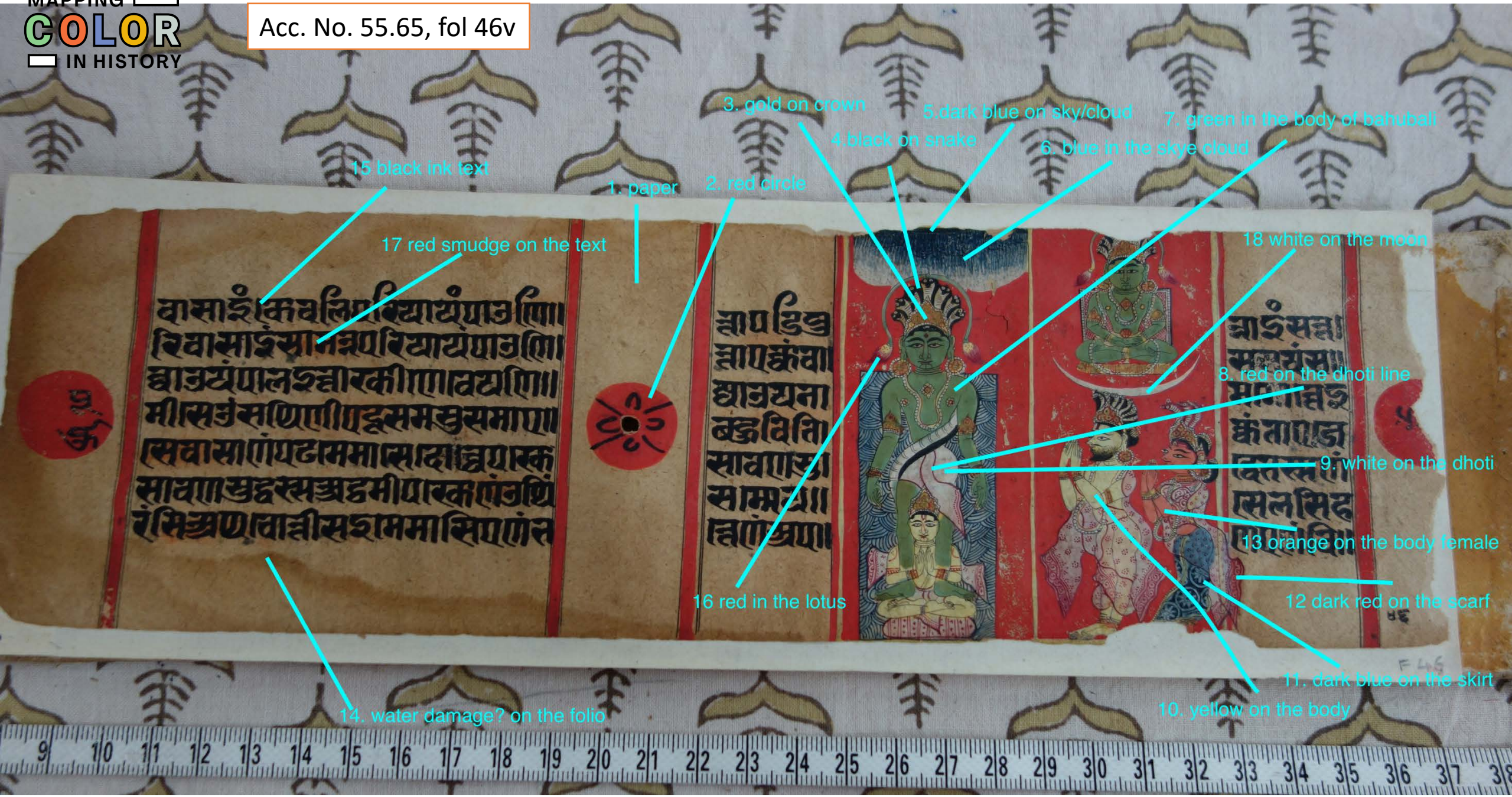
Object 1 Acc. No. 55.65*
Kalpasutra and Kalakacharya katha, Western India, c. 1375, folio :30x8.6xm, illustrations 41, folio 106, 7 lines of text per page

Folio 46v (painting: 8.3x8.6cm)
Folio 47v
Folio 50v
* Folio 28 v (if time permits, see the note)
~~Folio 90 (painting: 8.2x8.6cm)~~
~~Folio 37 (painting: 7.7x 8.6cm)~~

Folio 46v

MAPPING COLOR IN HISTORY

Acc. No. 55.65, fol 46v



Folio 47v

MAPPING COLOR IN HISTORY

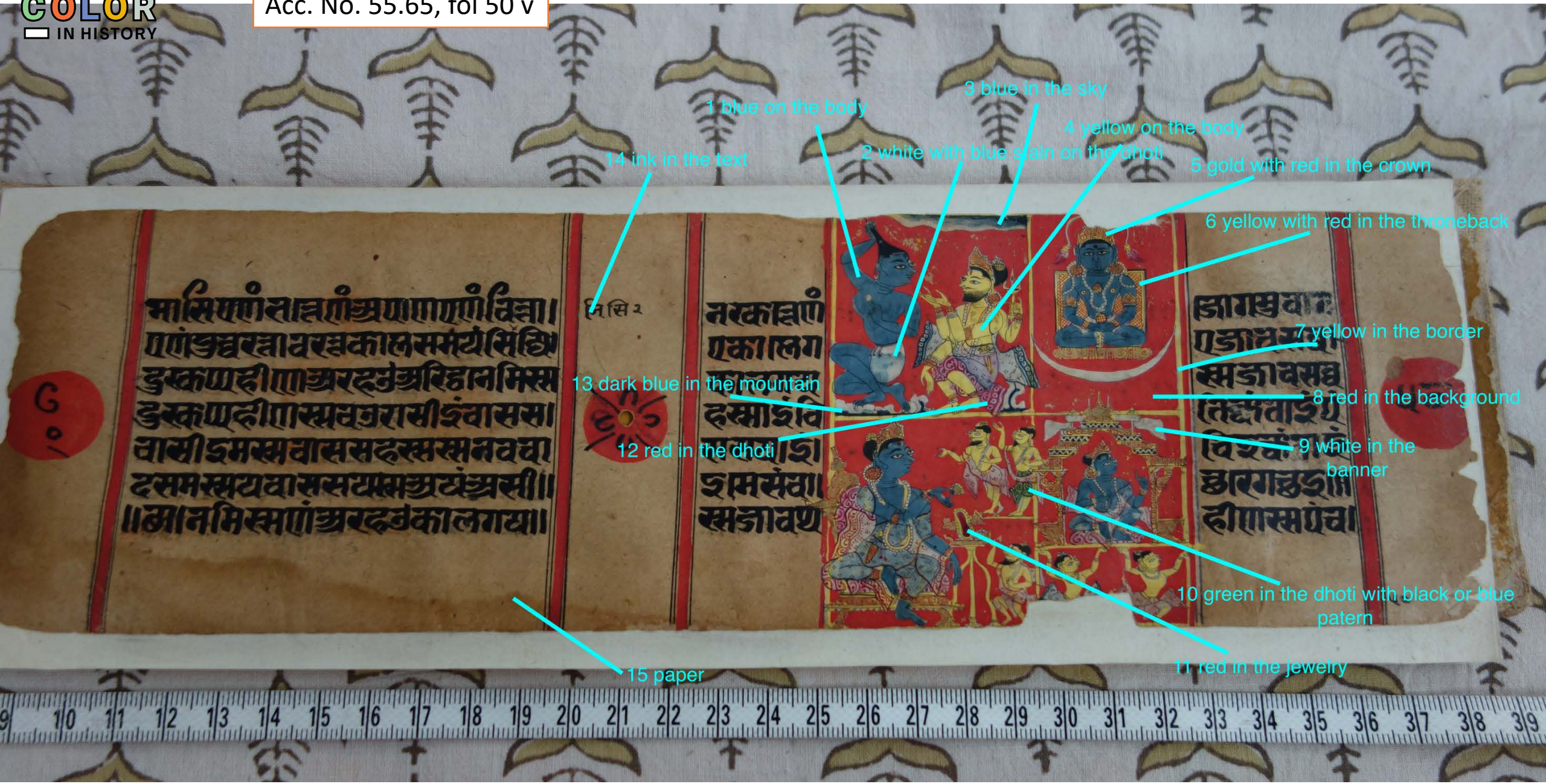
Acc. No. 55.65, fol 47v


मासिएणंसाहणंअणाएणंविन्ना।
एणंउच्चत्तावरत्तकालसमयंसिद्धि
दुक्कण्हीणाअरद्धंअरिहानमिस्स
दुक्कण्हीणासयगरासीइंवाससा।
वासीइमासवाससहस्ससनवचा।
दसमसयवाससयसमइयंगओ॥
॥मानमिसणंअरद्धंकालगया॥
निसि २
नरकाइणं
एकालग
कालगय
दसमाइंवि
ससयाइं।
इमसंता।
समजावश
जागसवा
एजावसव्व।
समजावसव्व
तिक्खंताइंगं
विश्वंताइं
छारगछइ॥
हीणासएंच।
५०

Fol.50v

MAPPING COLOR IN HISTORY

Acc. No. 55.65, fol 50 v



MAPPING COLOR IN HISTORY

If time permits, this is an additional page to confirm what's on other pages. If no time, can skip, would appreciate knowing what's in #3 skin color.

#6 & #7 can help understand the gold/yellow relationship in painting – determine whether yellow is under all gold application.

Fol.28v

Analysis and Artwork Information

MAPPING COLOR IN HISTORY

Analyst Information

Name of analyst: Omkar Kadu; B Pownthurai

Job title: Conservator; Scientist

Institution: Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

Project number*:

Date(s) of analysis: 04/12/2021
(mm/dd/yyyy)

Methods of analysis: pXRF

Analysis method model*:
(e.g. Bruner Artax XRF)

Artwork Information

Title: Folios Folio 46 rev. Austerities of Parshvanatah (Parshva as Siddha)
47 rev. - Birth and lustration of Arishtanemi
91 rev. Shahi king and a soldier before Kalakacharya

Artist*: not known

Repository: CSMVS, Miniature painting collection

Accession number: 55.65

Related artworks: total folio 106 and illustration 41 and illustrated folios 36
(by accession number)

Classification*:

Album Page ☐ Manuscript Folio ☐ Painting ☐

Mural ☐ Painted Textile ☐ Book cover ☐

Other (please specify) ☐

Folio number*: 46,47, 91

Parent work*: Folios from an illustrated manuscript of Kalpasutra and Kalakacharya Katha
(e.g. 'From a Bhagavata Purana series')

Date:*c.*1375 CE

Location: Western India

***Fields marked with an asterisk are optional.**

sheet_001

Style*: Western India
(e.g. Rajput)

Size: Folio: 8.6 x 30.0 cms
(H x W cm)

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

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

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

Exhibition history*: - travelled to Los Angeles county museum for Jain art exhibition in 1996. Presently stored in the storage.

(exhibition name, location and year)

Publication history*: *: Kalpana Desai. Jewells on the Crescent, Masterpieces of Chhatrapati Shivaji Maharaj Vastu Sangrahalay. Mumbai. published by CSMVS in association with Mapin Publishing Pvt. Ltd. 2002 (catalogue no. 70-72, page no. 260-261)
(Chicago style: Firstname Surname. *Publication Title*. (Place: publisher) Year: page number.)

Notes*:

THE earliest surviving illustrated paper manuscripts in India are the Jain canonical texts of the *Kalpasutra* and *Kalakacharya Katha*. The *Kalpasutra* is the biographical account of Mahavira and other Tirthankaras. It is generally read or recited by the devotees during their days of fasting, known as *Paryushana*. The main emphasis, of course, is on the *Pancha-Kalyanaka* or the five most auspicious events in the life of a Tirthankara. These are Birth, Lustration, Renunciation, Enlightenment and *Nirvana*. The oldest surviving illustrated paper manuscript was in the collection of Shri JinaVijayaji dated V.S. 1424=A.D. 1367, which as recorded in the colophon, was presented by one Dehada to Sanga Tilaka.Though the present manuscript is contemporary, it bears greater resemblance to the illustrations of the palm leaf *Kalpasutra* dated 1370 A.D. in the Ujamphoini Dharmashala, Ahmedabad. The paintings emit a certain freshness and though the style is well defined, exaggeration in rendering is yet to set in. As described by Motichandra, "in the treatment of human figures it is marked by fine linear draughtsmanship, distortion of the later period is avoided, and the limbs are delineated with easy grace." The paintings are the work of some master artist as is evident by the elegant draughtsmanship, excellent finish and minute but clear detailing of the pattern of textiles and decoration of celestial bodies. The natural colours, available at that time such as red, yellow, white, green, indigo, blue and others are used except the ultramarine. The pagination done on the margins are both in the numerals as well as letters.

***Fields marked with an asterisk are optional.**

Literature: 1. *Chandra Moti, Bulletin, P.O.W.M., 1953–54, pp. 40–48 and plates.* 2. *Doshi S.V., 1995, pp. 129–30.* 3. *John Guy in The Peaceful Liberators, 1994, pp. 203–204, cat. #82.*

***Fields marked with an asterisk are optional.**

sheet_002

Pigment Analysis

MAPPING COLOR IN HISTORY

Accession number: 55.65_47v Project Number: Name: Anjali Jain Date: 19/04/2021

Visible color*	Pigments**	Certainty level †	Elements			Location point and description		Notes
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	
Background		*1*		*Ca, Ti*	*Ni, Fe*	*1, paper, top-centre*		*Ti, Ca either from paper or from board under painting*
Yellow	*Orpiment*	*1*	*As*	*S*		*5, yellow body*		
Green	*Orpiment*	*1*	*As*		*S, Hg*	*9, dark green on blouse*		*Microscopic analysis to find if mixed or layered*
	Indigo	*1*						
Red	*Vermillion*	*1*	*Hg, As*	*Fe*	*S*	*11, red on pattern*		*Vermillion likely applied over orpiment*
	Orpiment	*1*						
Blue	*Orpiment*	*1*	*As*	*Fe, Ti, Fe*	*S, Ca, Ni*	*14, blue on the baby*		
	Indigo	*2*						*Organic blue likely applied over orpiment*

*Choose from controlled color vocabulary: red, yellow, blue, purple, pink, green, orange, grey, black, white, brown, or metallic (i.e. gold or silver).

**Please refer to ‘Controlled Vocabulary Guide: Pigments’. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record ‘pigment condition: unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

sheet_002

Accession number: Project Number: Name: Date:

Visible color*	Pigments**	Certainty level †	Elements			Location point and description		Notes ‡
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	
Red	*Orpiment*	*1*	*As*	*Fe, Ti*	*Ca, S*	*15, red (point not annotated)*		*Red ochre likely applied over orpiment; annotation not found - inconclusive*
	Red ochre	*3*						

* Choose from controlled color vocabulary (red, yellow, blue, purple, pink, green, orange, grey, black, white, brown) or metallic (gold, silver).

** **Please refer to ‘Controlled Vocabulary Guide: Pigments’. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record ‘pigment condition’: unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

sheet_002

Accession number: Project Number: Name: Date:

Visible color*	Pigments**	Certainty level †	Elements			Location point and description		Notes ‡
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	

* Choose from controlled color vocabulary (red, yellow, blue, purple, pink, green, orange, grey, black, white, brown) or metallic (gold, silver).

** **Please refer to ‘Controlled Vocabulary Guide: Pigments’. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record ‘pigment condition’: unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

sheet_002

Accession number: Project Number: Name: Date:

Visible color*	**Pigments****	**Certainty level †**	**Elements**			**Location point and description**		**Notes ‡**
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	

* Choose from controlled color vocabulary (red, yellow, blue, purple, pink, green, orange, grey, black, white, brown) or metallic (gold, silver).

** **Please refer to 'Controlled Vocabulary Guide: Pigments'. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record 'pigment condition': unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.

sheet_002

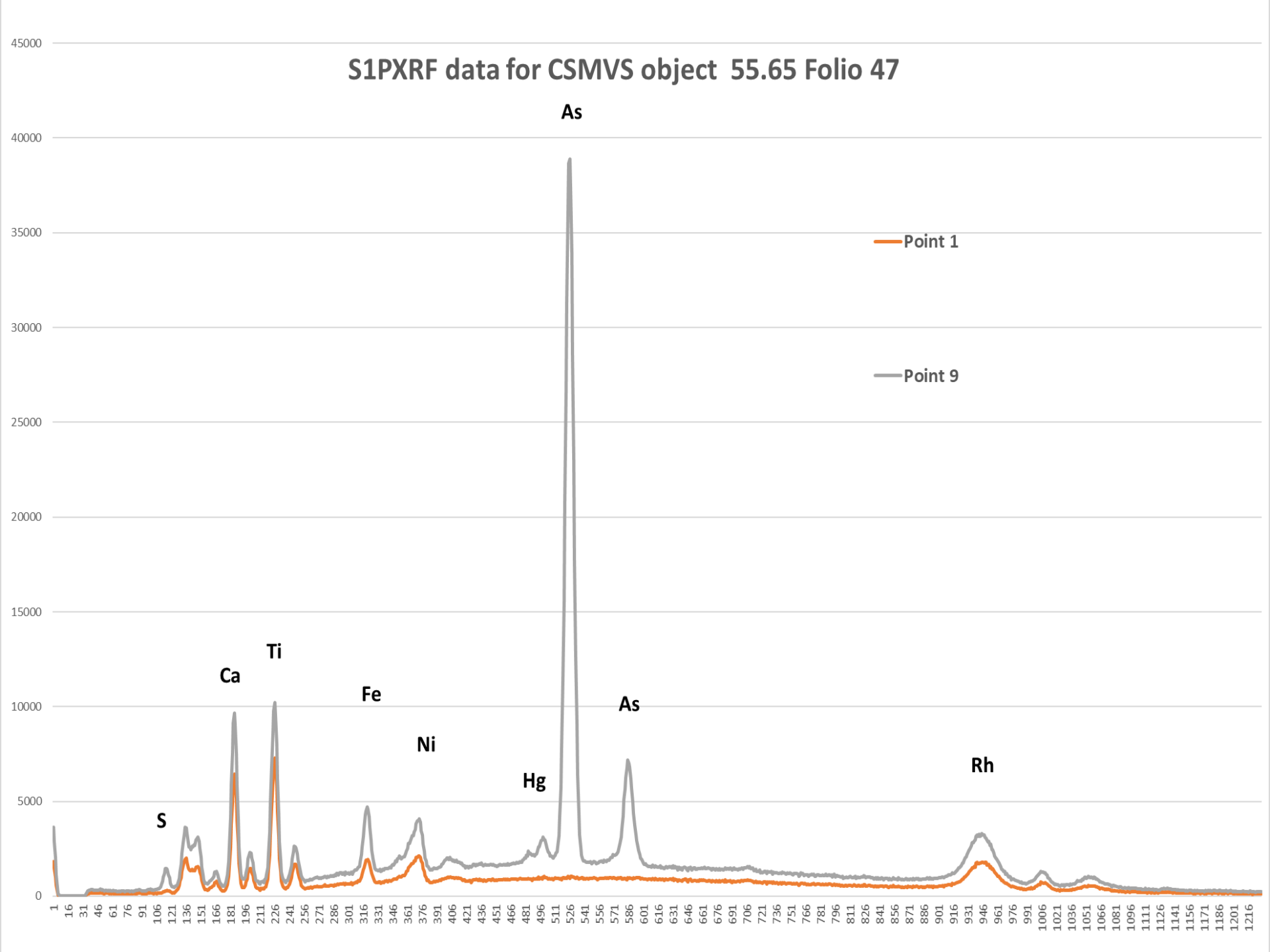
Accession number: Project Number: Name: Date:

Visible color*	**Pigments****	**Certainty level †**	**Elements**			**Location point and description**		**Notes ‡**
			Major	*Minor*	*Trace*	*XRF*	*Other (please specify)*	

* Choose from controlled color vocabulary (red, yellow, blue, purple, pink, green, orange, grey, black, white, brown) or metallic (gold, silver).

** **Please refer to 'Controlled Vocabulary Guide: Pigments'. † Certainty level: certain = 1; possible = 2; unlikely/uncertain = 3.

‡ For general notes, and to record 'pigment condition': unknown = 1; discoloration = 2; flaking = 3; cracking = 4; powdery = 5; underdrawing = 6; stable = 7; overpainting= 8.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As
Point 1
Point 9
Ti
Ca
Fe
Ni
Hg
As
S
Rh
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5000
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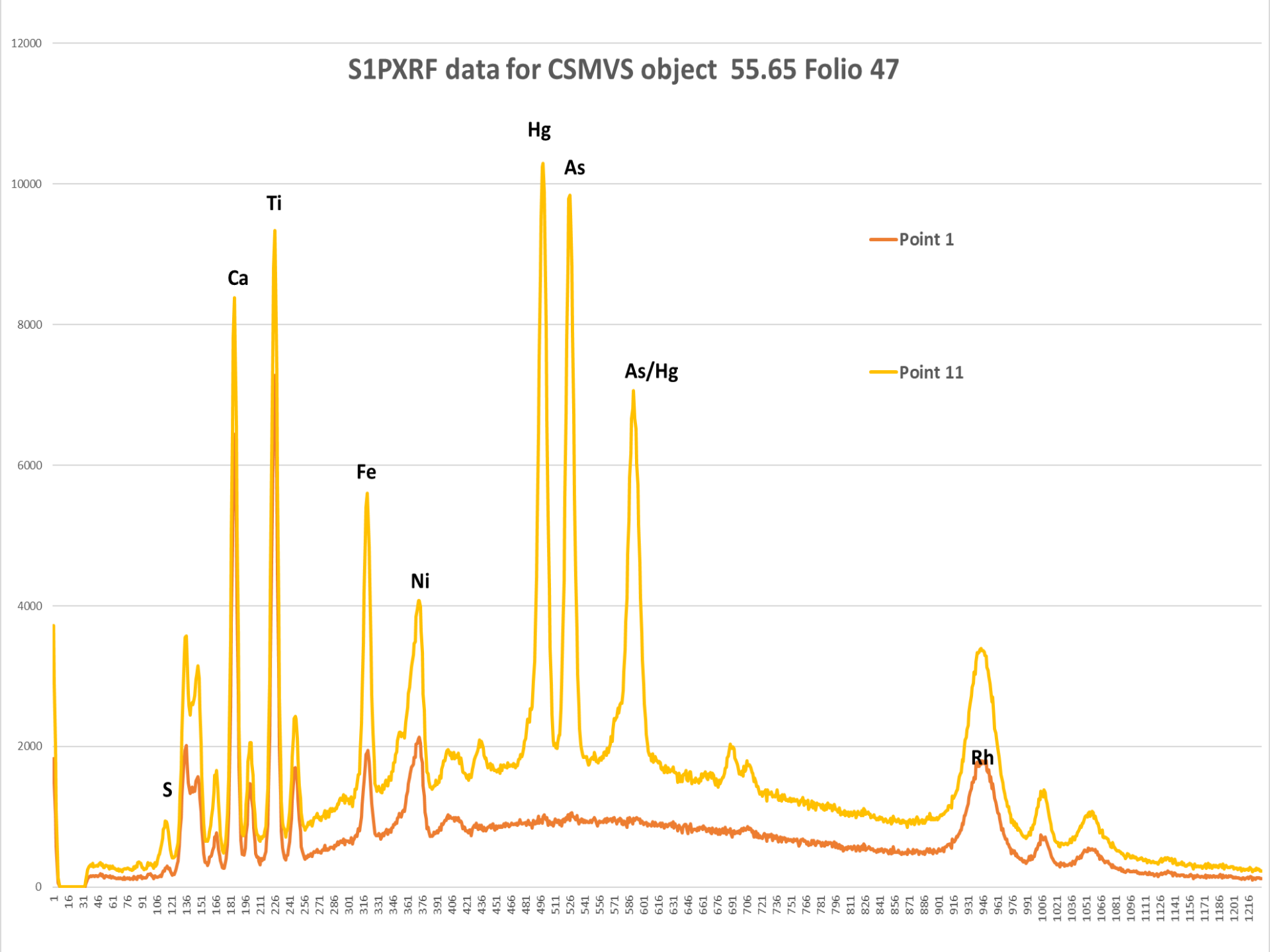
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Point 1
Point 11
S
Ca
Ti
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As
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Rh
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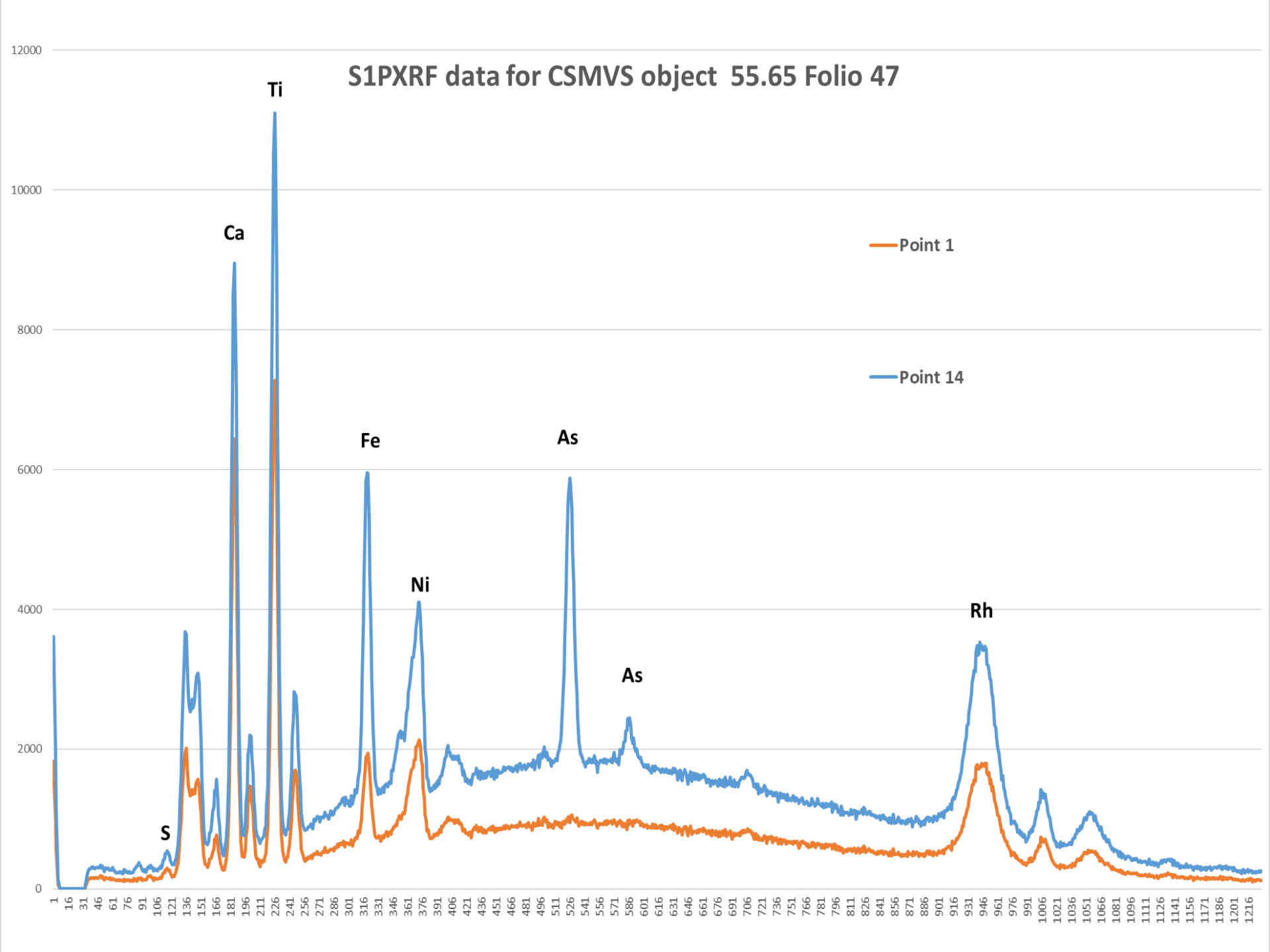
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4000
2000
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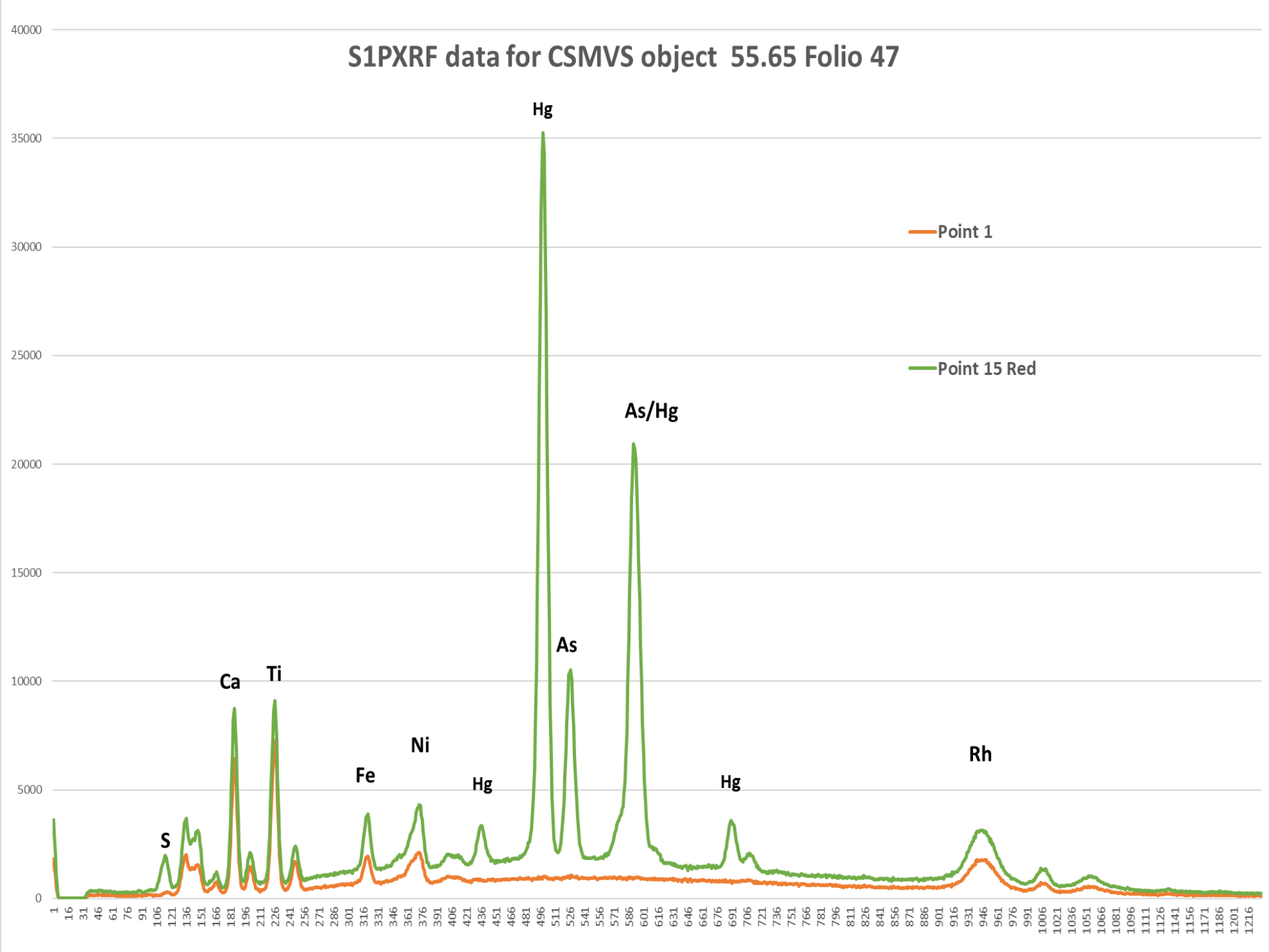
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Point 15 Red
S
Ca
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30000
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15000
10000
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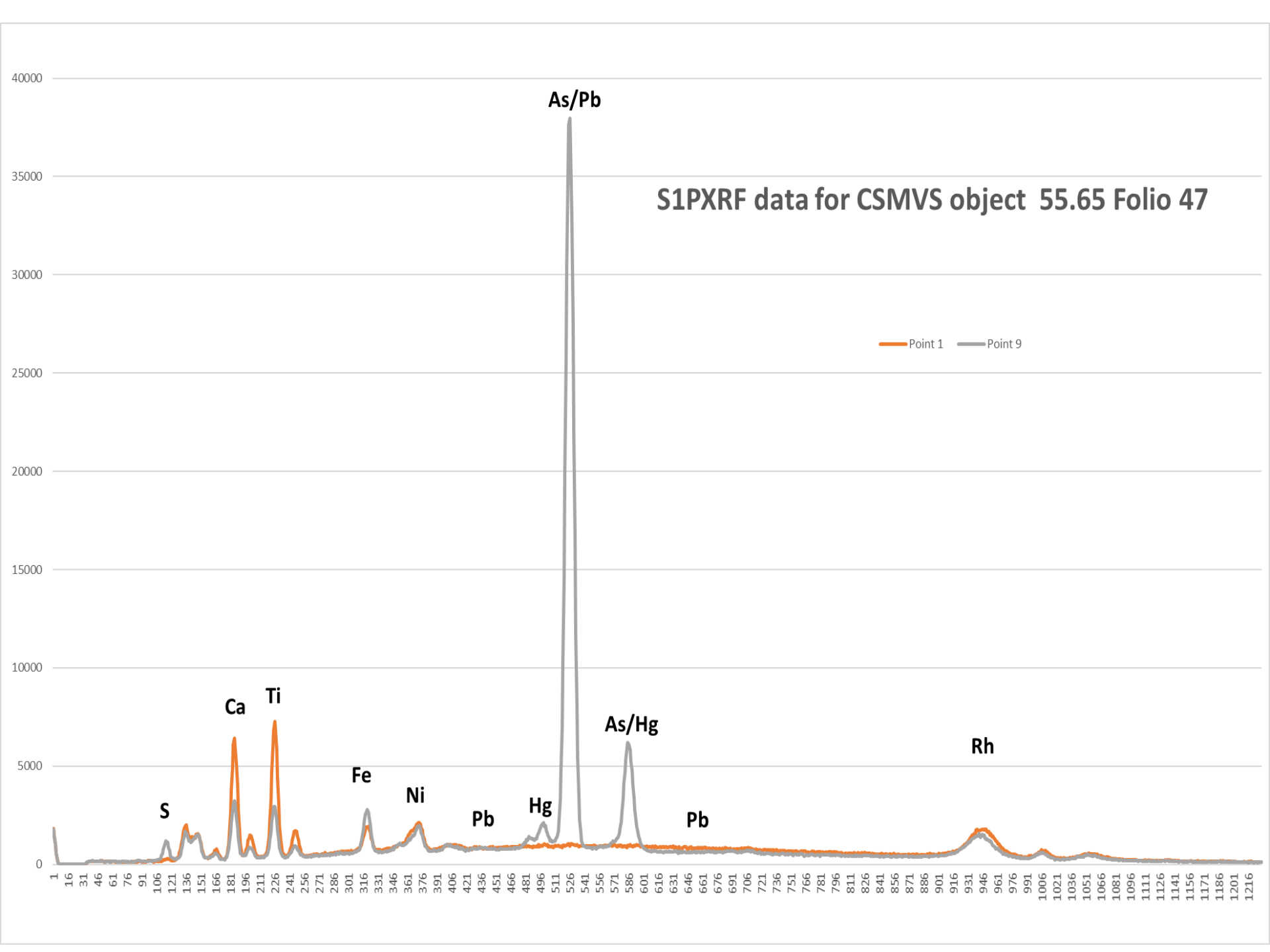
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As/Pb
Ca
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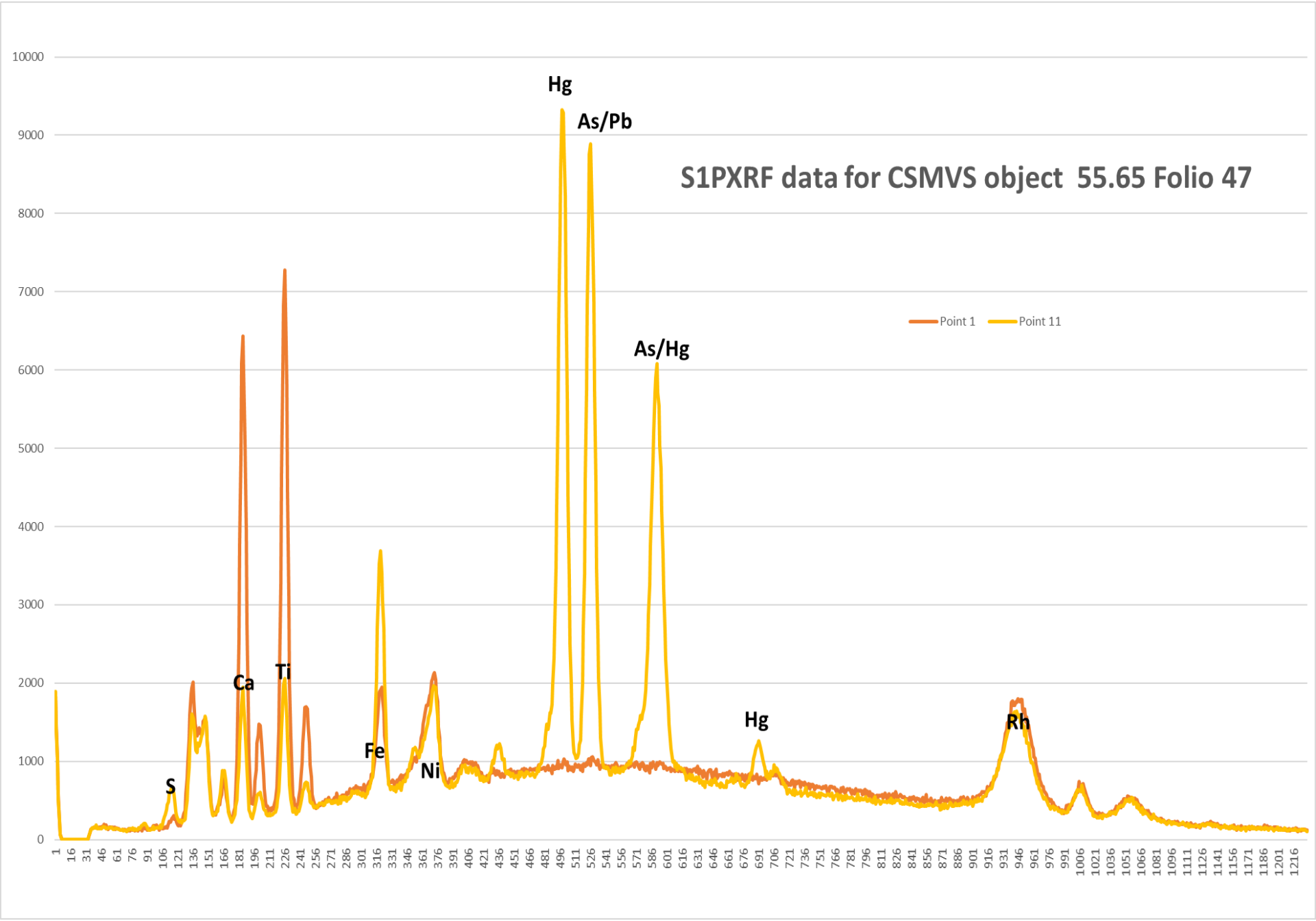
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Point 1
Point 11
Hg
As/Pb
As/Hg
Hg
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Ti
Fe
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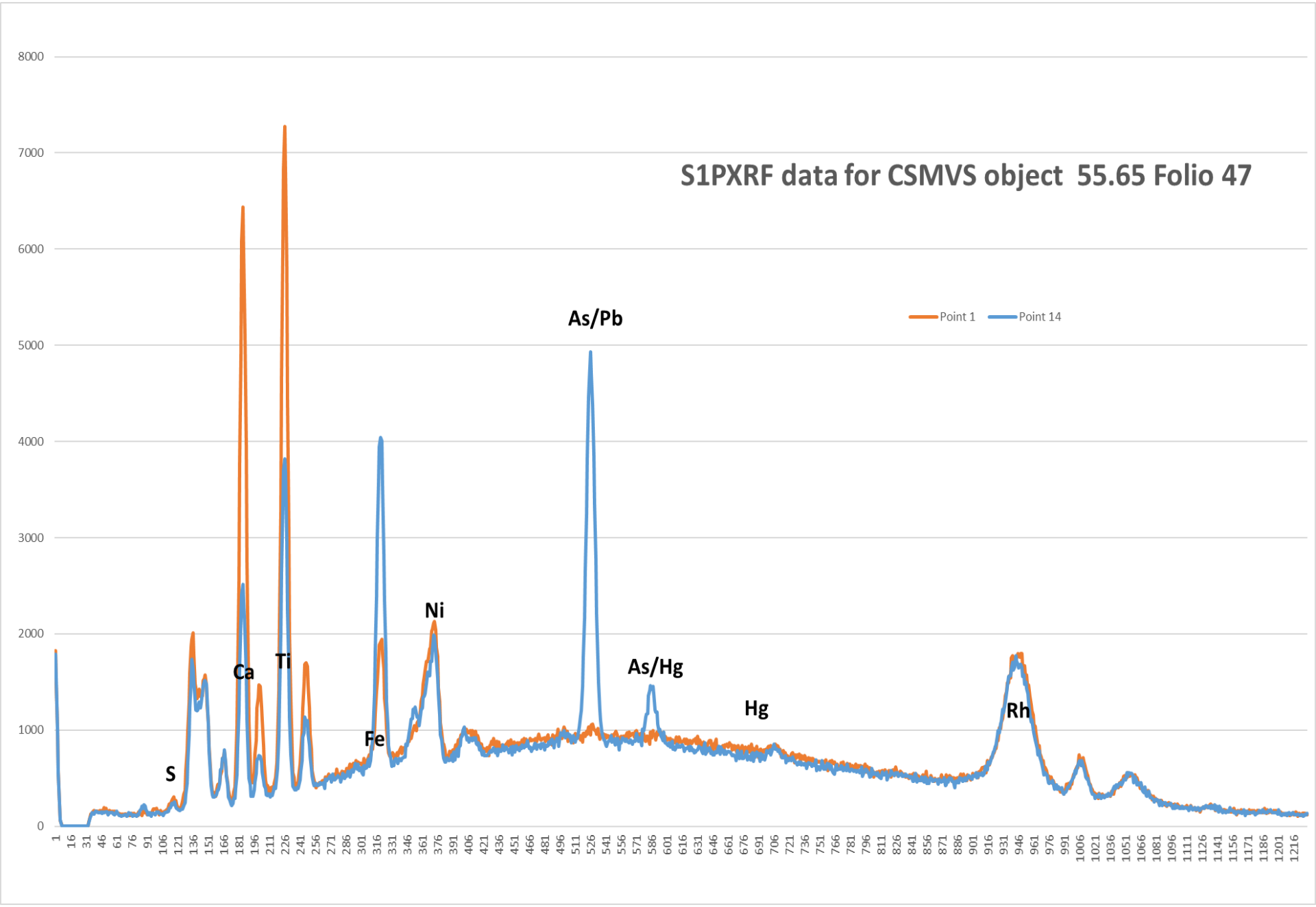
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Point 1
Point 14
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Ca
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Fe
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As/Pb
As/Hg
Hg
Rh
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7000
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3000
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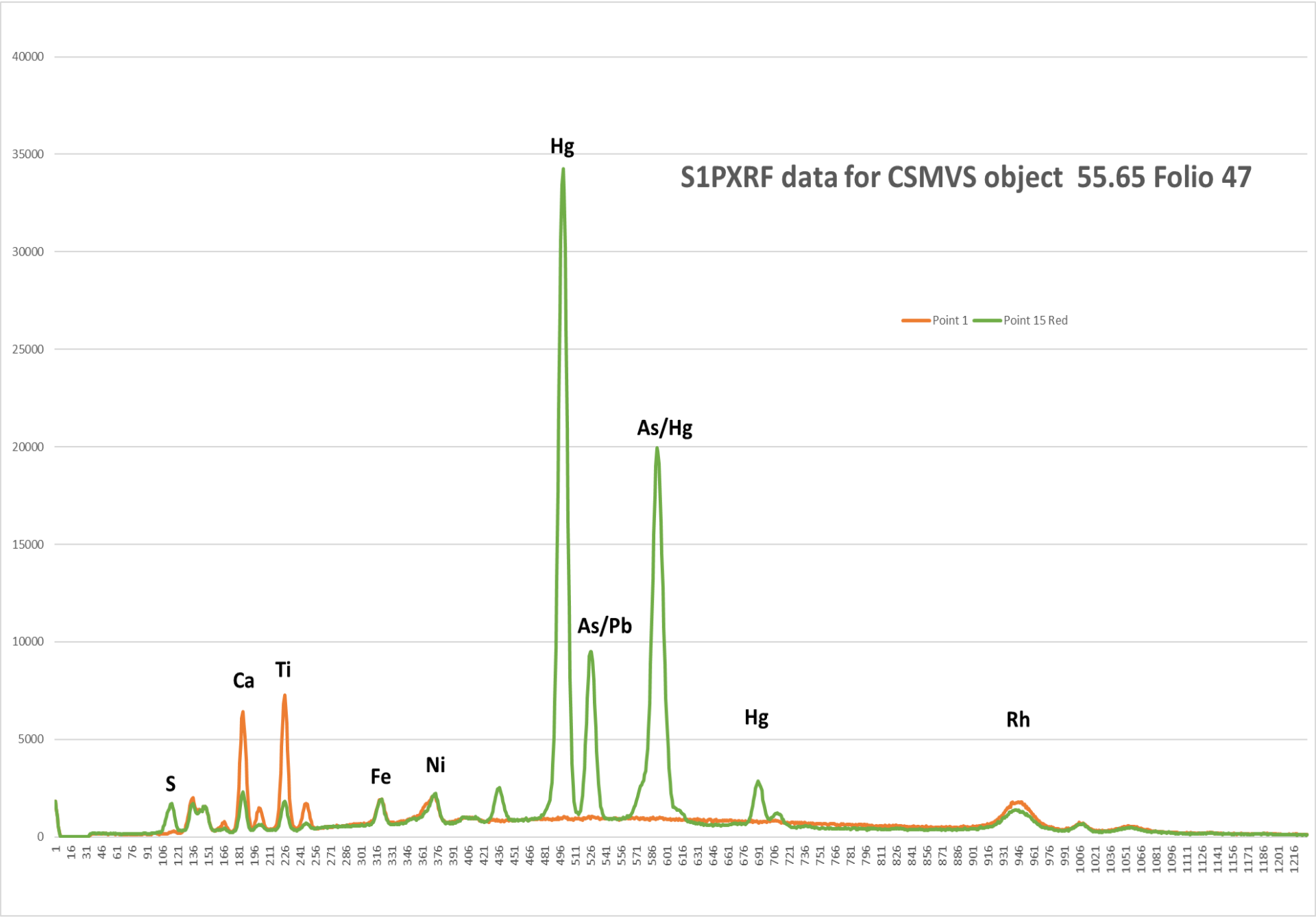
S1PXRF data for CSMVS object 55.65 Folio 47
Point 1
Point 15 Red
Hg
As/Hg
As/Pb
Hg
Rh
Ca
Ti
Fe
Ni
S
40000
35000
30000
25000
20000
15000
10000
5000
0

Appendix G.

MAPPING COLOR IN HISTORY

MCH Mobile Lab Equipment List (as of June 2021)

1. **Dinolite**
   - The dinolite is a portable digital microscope that is generally used in a handheld mode. It enables you to view and capture magnified images (20x-200x) instantly on a computer/laptop by means of the USB cord.
   - The stand and flexible arm can be used to hold the Dinolite still while trying to capture images and will prevent camera shake.
   - It is a low cost tool and has limitation of resolution and magnification, but can give sound preliminary results.
   - Relevance for MCH project
     - The high magnification mode of Dinolite can help view the surface morphology of pigment particles on painted surfaces and can guide their identification.
     - This particular model of Dinolite allows illumination of the area of interest using visible and UV LEDs, which can help view the UV fluorescence of materials (pigments, varnishes, binders) under high magnification and can help identify and/or differentiate them and their mixtures.

2. **Euromex microscope**
   - The Euromex microscope is a tabletop microscope that enables one to view magnified images (65x – 550x) of a higher resolution than that obtained using the Dinolite.
   - The attached camera in the microscope can be used to capture these high resolution, high magnification images.
   - The articulated arm can help move the microscope over large paintings and aid in their examination.
   - The polariser accessory includes two rotating polarizing filters which can be used to characterise the optical properties of particles
   - The depth of field of this equipment is very good, and that will allow us to have in sharp focus the relief work in the miniature paintings.
   - Relevance to MCH
     - This microscope can be used to carry out examination of paintings and capture very high magnification images of painted surfaces. Thus, particle morphology of pigments can be examined in magnifications upto 550x, helping aid their identification.

- It can also be used to carry out polarised light microscopy (PLM), which can be used to measure the refractive index, determine extinction coefficients, and examine birefringence, helping in the identification and characterization of pigments.

3. Multispectral imaging kit

- Multispectral imaging is a digital imaging technique where multiple images of the same object are obtained across different wavelengths of the electromagnetic spectrum. Different incident radiation (UV, visible, IR) is used to illuminate the object of interest and the reflected or luminescing radiation generated from the painted surface is captured.
- The set of images thus obtained can reveal the spatial distribution of similar or different pigments across the painted surface.
- Relevance to MCH
  - Capturing each painting using different incident radiation can help identify pigments with characteristic reflectance or luminescence behaviours, as well as the spatial distribution of pigments behaving in similar or dissimilar ways.
  - Images captured using the longer IR wavelengths of the electromagnetic spectrum (which penetrate most surface pigments) can reveal charcoal or graphite underdrawings, the underlying initial stages of a composition.

4. X-ray fluorescence

- X-ray fluorescence is a non-destructive analytical method used to qualitatively and semi-quantitatively determine the elemental content of materials. The x-ray spectrum emitted from each element has a unique set of energies that are related to the type and amount of atoms present in the sample.
- The portable model of the XRF can be used in the handheld mode to conveniently maneuver over and analyse various pigments on the surface of paintings.
- Relevance to MCH
  - Understanding the elemental composition of various pigments in dated manuscripts and miniature paintings can help map the chronological and geographical distribution of pigments used in historic objects.

5. Photography equipment

- Camera and associated accessories like tripods, lights, triggers, transmitters can be used for documentation of paintings in any museum collection
- Relevance to MCH
  - They can be used to capture high resolution images of those collections which have not been documented