

Schists and Pigments from Ancient Swat (Khyber Pukhtunkhwa, Pakistan)

Mariottini, Francesco; Vignaroli, Gianluca; Mariottini, Maurizio; Roma, Mauro

Source / Izvornik: **ASMOSIA XI, Interdisciplinary Studies on Ancient Stone, Proceedings of the XI International Conference of ASMOSIA, 2018, 793 - 804**

Conference paper / Rad u zborniku

Publication status / Verzija rada: **Published version / Objavljena verzija rada (izdavačev PDF)**

<https://doi.org/10.31534/XI.asmosia.2015/07.04>

Permanent link / Trajna poveznica: <https://um.nsk.hr/um:nbn:hr:123:727601>

Rights / Prava: [In copyright](#)/[Zaštićeno autorskim pravom.](#)

Download date / Datum preuzimanja: **2025-02-16**



Repository / Repozitorij:

[FCEAG Repository - Repository of the Faculty of Civil Engineering, Architecture and Geodesy, University of Split](#)





ASMOSIA XI

Interdisciplinary Studies on Ancient Stone

PROCEEDINGS

of the XI ASMOSIA Conference, Split 2015

Edited by Daniela Matetić Poljak and Katja Marasović



Interdisciplinary Studies on Ancient Stone
Proceedings of the XI ASMOSIA Conference (Split 2015)

Publishers:

ARTS ACADEMY IN SPLIT
UNIVERSITY OF SPLIT

and

UNIVERSITY OF SPLIT
FACULTY OF CIVIL ENGINEERING,
ARCHITECTURE AND GEODESY

Technical editor:
Kate Bošković

English language editor:
Graham McMaster

Computer pre-press:
Nikola Križanac

Cover design:
Mladen Čulić

Cover page:

Sigma shaped mensa of pavonazzetto marble from Diocletian's palace in Split

ISBN 978-953-6617-49-4 (Arts Academy in Split)

ISBN 978-953-6116-75-1 (Faculty of Civil Engineering, Architecture and Geodesy)

e-ISBN 978-953-6617-51-7 (Arts Academy in Split)

e-ISBN 978-953-6116-79-9 (Faculty of Civil Engineering, Architecture and Geodesy)

CIP available at the digital catalogue of the University Library in Split, no 170529005

Association for the Study of Marble & Other Stones in Antiquity

ASMOSIA XI

Interdisciplinary Studies of Ancient Stone

Proceedings of the Eleventh International Conference of ASMOSIA,
Split, 18–22 May 2015

Edited by
Daniela Matetić Poljak
Katja Marasović



Split, 2018

Nota bene

All papers are subjected to an international review.

The quality of the images relies on the quality of the originals provided by the authors.

CONTENT

PRESENTATION	15
NECROLOGY: NORMAN HERZ (1923-2013) by Susan Kane	17
1. APPLICATIONS TO SPECIFIC ARCHEOLOGICAL QUESTIONS – USE OF MARBLE	
Hermaphrodites and Sleeping or Reclining Maenads: Production Centres and Quarry Marks <i>Patrizio Pensabene</i>	25
First Remarks about the Pavement of the Newly Discovered Mithraeum of the Colored Marbles at Ostia and New Investigations on Roman and Late Roman White and Colored Marbles from Insula IV, IX <i>Massimiliano David, Stefano Succi and Marcello Turci</i>	33
Alabaster. Quarrying and Trade in the Roman World: Evidence from Pompeii and Herculaneum <i>Simon J. Barker and Simona Perna</i>	45
Recent Work on the Stone at the Villa Arianna and the Villa San Marco (Castellammare di Stabia) and Their Context within the Vesuvian Area <i>Simon J. Barker and J. Clayton Fant</i>	65
Marble Wall Decorations from the Imperial Mausoleum (4 th C.) and the Basilica of San Lorenzo (5 th C.) in Milan: an Update on Colored Marbles in Late Antique Milan <i>Elisabetta Neri, Roberto Bugini and Silvia Gazzoli</i>	79
Sarcophagus Lids Sawn from their Chests <i>Dorothy H. Abramitis and John J. Herrmann</i>	89
The Re-Use of Monolithic Columns in the Invention and Persistence of Roman Architecture <i>Peter D. De Staebler</i>	95
The Trade in Small-Size Statues in the Roman Mediterranean: a Case Study from Alexandria <i>Patrizio Pensabene and Eleonora Gasparini</i>	101
The Marble Dedication of Komon, Son of Asklepiades, from Egypt: Material, Provenance, and Reinforcement of Meaning <i>Patricia A. Butz</i>	109
Multiple Reuse of Imported Marble Pedestals at Caesarea Maritima in Israel <i>Barbara Burrell</i>	117
Iasos and Iasian Marble between the Late Antique and Early Byzantine Eras <i>Diego Peirano</i>	123

Thassos, Known Inscriptions with New Data <i>Tony Kozelj and Manuela Wurch-Kozelj</i>	131
The Value of Marble in Roman <i>Hispalis</i> : Contextual, Typological and Lithological Analysis of an Assemblage of Large Architectural Elements Recovered at N° 17 Goyeneta Street (Seville, Spain) <i>Ruth Taylor, Oliva Rodríguez, Esther Ontiveros, María Luisa Loza, José Beltrán and Araceli Rodríguez</i>	143
<i>Giallo Antico</i> in Context. Distribution, Use and Commercial Actors According to New Stratigraphic Data from the Western Mediterranean (2 nd C. Bc – Late 1 st C. Ad) <i>Stefan Ardeleanu</i>	155
<i>Amethystus</i> : Ancient Properties and Iconographic Selection <i>Luigi Pedroni</i>	167
2. PROVENANCE IDENTIFICATION I: (MARBLE)	
Unraveling the Carrara – Göktepe Entanglement <i>Walter Prochaska, Donato Attanasio and Matthias Bruno</i>	175
The Marble of Roman Imperial Portraits <i>Donato Attanasio, Matthias Bruno, Walter Prochaska and Ali Bahadır Yavuz</i>	185
Tracing Alabaster (Gypsum or Anhydrite) Artwork Using Trace Element Analysis and a Multi-Isotope Approach (Sr, S, O) <i>Lise Leroux, Wolfram Kloppmann, Philippe Bromblet, Catherine Guerrot, Anthony H. Cooper, Pierre-Yves Le Pogam, Dominique Vingtain and Noel Worley</i>	195
Roman Monolithic Fountains and Thasian Marble <i>Annewies van den Hoek, Donato Attanasio and John J. Herrmann</i>	207
Archaeometric Analysis of the Alabaster Thresholds of Villa A, Oplontis (Torre Annunziata, Italy) and New Sr and Pb Isotopic Data for <i>Alabastro Ghiaccione del Circeo</i> <i>Simon J. Barker, Simona Perna, J. Clayton Fant, Lorenzo Lazzarini and Igor M. Villa</i>	215
Roman Villas of Lake Garda and the Occurrence of Coloured Marbles in the Western Part of “Regio X Venetia et Histria” (Northern Italy) <i>Roberto Bugini, Luisa Folli and Elisabetta Roffia</i>	231
Calcitic Marble from Thasos in the North Adriatic Basin: Ravenna, Aquileia, and Milan <i>John J. Herrmann, Robert H. Tykot and Annewies van den Hoek</i>	239
Characterisation of White Marble Objects from the Temple of Apollo and the House of Augustus (Palatine Hill, Rome) <i>Francesca Giustini, Mauro Brilli, Enrico Gallochio and Patrizio Pensabene</i>	247
Study and Archeometric Analysis of the Marble Elements Found in the Roman Theater at Aeclanum (Mirabella Eclano, Avellino - Italy) <i>Antonio Mesisca, Lorenzo Lazzarini, Stefano Cancelliere and Monica Salvadori</i>	255

Two Imperial Monuments in Puteoli: Use of Proconnesian Marble in the Domitianic and Trajanic Periods in Campania <i>Irene Bald Romano, Hans Rupprecht Goette, Donato Attanasio and Walter Prochaska</i>	267
Coloured Marbles in the Neapolitan Pavements (16 th And 17 th Centuries): the Church of <i>Santi Severino e Sossio</i> <i>Roberto Bugini, Luisa Folli and Martino Solito</i>	275
Roman and Early Byzantine Sarcophagi of Calcitic Marble from Thasos in Italy: Ostia and Siracusa <i>Donato Attanasio, John J. Herrmann, Robert H. Tykot and Annewies van den Hoek</i>	281
Revisiting the Origin and Destination of the Late Antique Marzamemi 'Church Wreck' Cargo <i>Justin Leidwanger, Scott H. Pike and Andrew Donnelly</i>	291
The Marbles of the Sculptures of Felix Romuliana in Serbia <i>Walter Prochaska and Maja Živić</i>	301
Calcitic Marble from Thasos and Proconnesos in Nea Anchialos (Thessaly) and Thessaloniki (Macedonia) <i>Vincent Barbin, John J. Herrmann, Aristotle Mentzos and Annewies van den Hoek</i>	311
Architectural Decoration of the Imperial Agora's Porticoes at Iasos <i>Fulvia Bianchi, Donato Attanasio and Walter Prochaska</i>	321
The Winged Victory of Samothrace - New Data on the Different Marbles Used for the Monument from the Sanctuary of the Great Gods <i>Annie Blanc, Philippe Blanc and Ludovic Laugier</i>	331
Polychrome Marbles from the Theatre of the Sanctuary of Apollo Pythios in Gortyna (Crete) <i>Jacopo Bonetto, Nicolò Mareso and Michele Bueno</i>	337
Paul the Silentiary, Hagia Sophia, Onyx, Lydia, and Breccia Corallina <i>John J. Herrmann and Annewies van den Hoek</i>	345
Incrustations from Colonia Ulpia Traiana (Near Modern Xanten, Germany) <i>Vilma Ruppiniè and Ulrich Schüssler</i>	351
Stone Objects from Vindobona (Austria) – Petrological Characterization and Provenance of Local Stone in a Historico-Economical Setting <i>Andreas Rohatsch, Michaela Kronberger, Sophie Insulander, Martin Mosser and Barbara Hodits</i>	363
Marbles Discovered on the Site of the Forum of Vaison-la-Romaine (Vaucluse, France): Preliminary Results <i>Elsa Roux, Jean-Marc Mignon, Philippe Blanc and Annie Blanc</i>	373
Updated Characterisation of White Saint-Béat Marble. Discrimination Parameters from Classical Marbles <i>Hernando Royo Plumed, Pilar Lapeunte, José Antonio Cuchí, Mauro Brillì and Marie-Claire Savin</i>	379

Grey and Greyish Banded Marbles from the Estremoz Anticline in Lusitania <i>Pilar Lapuente, Trinidad Nogales-Basarrate, Hernando Royo Plumed, Mauro Brilli and Marie-Claire Savin</i>	391
New Data on Spanish Marbles: the Case of <i>Gallaecia</i> (NW Spain) <i>Anna Gutiérrez García-M., Hernando Royo Plumed and Silvia González Soutelo</i>	401
A New Roman Imperial Relief Said to Be from Southern Spain: Problems of Style, Iconography, and Marble Type in Determining Provenance <i>John Pollini, Pilar Lapuente, Trinidad Nogales-Basarrate and Jerry Podany</i>	413
Reuse of the <i>Marmora</i> from the Late Roman Palatial Building at Carranque (Toledo, Spain) in the Visigothic Necropolis <i>Virginia García-Entero, Anna Gutiérrez García-M. and Sergio Vidal Álvarez</i>	427
Imperial Porphyry in Roman Britain <i>David F. Williams</i>	435
Recycling of Marble: Apollonia/Sozousa/Arsuf (Israel) as a Case Study <i>Moshe Fischer, Dimitris Tambakopoulos and Yannis Maniatis</i>	443
Thasian Connections Overseas: Sculpture in the Cyrene Museum (Libya) Made of Dolomitic Marble from Thasos <i>John J. Herrmann and Donato Attanasio</i>	457
Marble on Rome's Southwestern Frontier: Thamugadi and Lambaesis <i>Robert H. Tykot, Ouahiba Bouzidi, John J. Herrmann and Annewies van den Hoek</i>	467
Marble and Sculpture at Lepcis Magna (Tripolitania, Libya): a Preliminary Study Concerning Origin and Workshops <i>Luisa Musso, Laura Buccino, Matthias Bruno, Donato Attanasio and Walter Prochaska</i>	481
The Pentelic Marble in the Carnegie Museum of Art Hall of Sculpture, Pittsburgh, Pennsylvania <i>Albert D. Kollar</i>	491
Analysis of Classical Marble Sculptures in the Michael C. Carlos Museum, Emory University, Atlanta <i>Robert H. Tykot, John J. Herrmann, Renée Stein, Jasper Gaunt, Susan Blevins and Anne R. Skinner</i>	501
3. PROVENANCE IDENTIFICATION II: (OTHER STONES)	
Aphrodisias and the Regional Marble Trade. The <i>Scaenae Frons</i> of the Theatre at Nysa <i>Natalia Toma</i>	513
The Stones of Felix Romuliana (Gamzigrad, Serbia) <i>Bojan Djurić, Divna Jovanović, Stefan Pop Lazić and Walter Prochaska</i>	523
Aspects of Characterisation of Stone Monuments from Southern Pannonia <i>Branka Migotti</i>	537

The Budakalász Travertine Production <i>Bojan Djurić, Sándor Kele and Igor Rižnar</i>	545
Stone Monuments from Carnuntum and Surrounding Areas (Austria) – Petrological Characterization and Quarry Location in a Historical Context <i>Gabrielle Kremer, Isabella Kitz, Beatrix Moshhammer, Maria Heinrich and Erich Draganits</i>	557
Espejón Limestone and Conglomerate (Soria, Spain): Archaeometric Characterization, Quarrying and Use in Roman Times <i>Virginia García-Entero, Anna Gutiérrez García-M, Sergio Vidal Álvarez, María J. Peréx Agorreta and Eva Zarco Martínez</i>	567
The Use of Alcover Stone in Roman Times (<i>Tarraco, Hispania Citerior</i>). Contributions to the <i>Officina Lapidaria Tarraconensis</i> <i>Diana Gorostidi Pi, Jordi López Vilar and Anna Gutiérrez García-M.</i>	577
4. ADVANCES IN PROVENANCE TECHNIQUES, METHODOLOGIES AND DATABASES	
Grainautline – a Supervised Grain Boundary Extraction Tool Supported by Image Processing and Pattern Recognition <i>Kristóf Csorba, Lilla Barancsuk, Balázs Székely and Judit Zöldföldi</i>	587
A Database and GIS Project about Quarrying, Circulation and Use of Stone During the Roman Age in <i>Regio X - Venetia et Histria</i> . The Case Study of the Euganean Trachyte <i>Caterine Previato and Arturo Zara</i>	597
5. QUARRIES AND GEOLOGY	
The Distribution of Troad Granite Columns as Evidence for Reconstructing the Management of Their Production <i>Patrizio Pensabene, Javier Á. Domingo and Isabel Rodà</i>	613
Ancient Quarries and Stonemasonry in Northern Choria Considiana <i>Hale Güney</i>	621
Polychromy in Larisaeon Quarries and its Relation to Architectural Conception <i>Gizem Mater and Ertunç Denктаş</i>	633
Euromos of Caria: the Origin of an Hitherto Unknown Grey Veined Stepped Marble of Roman Antiquity <i>Matthias Bruno, Donato Attanasio, Walter Prochaska and Ali Bahadır Yavuz</i>	639
Unknown Painted Quarry Inscriptions from Bacakale at <i>Docimium</i> (Turkey) <i>Matthias Bruno</i>	651
The Green Schist Marble Stone of Jebel El Hairech (North West of Tunisia): a Multi-Analytical Approach and its Uses in Antiquity <i>Ameur Younès, Mohamed Gaied and Wissem Gallala</i>	659
Building Materials and the Ancient Quarries at <i>Thamugadi</i> (East of Algeria), Case Study: Sandstone and Limestone <i>Younès Rezkallah and Ramdane Marmi</i>	673

The Local Quarries of the Ancient Roman City of <i>Valeria</i> (Cuenca, Spain) <i>Javier Atienza Fuente</i>	683
The Stone and Ancient Quarries of Montjuïc Mountain (Barcelona, Spain) <i>Aureli Álvarez</i>	693
<i>Notae Lapidinarum</i> : Preliminary Considerations about the Quarry Marks from the Provincial Forum of <i>Tarraco</i> <i>Maria Serena Vinci</i>	699
The Different Steps of the Rough-Hewing on a Monumental Sculpture at the Greek Archaic Period: the Unfinished Kouros of Thasos <i>Danièle Braunstein</i>	711
A Review of Copying Techniques in Greco-Roman Sculpture <i>Séverine Moureaud</i>	717
Labour Forces at Imperial Quarries <i>Ben Russell</i>	733
Social Position of Craftsmen inside the Stone and Marble Processing Trades in the Light of Diocletian's Edict on Prices <i>Krešimir Bosnić and Branko Matulić</i>	741
6. STONE PROPERTIES, WEATHERING EFFECTS AND RESTORATION, AS RELATED TO DIAGNOSIS PROBLEMS, MATCHING OF STONE FRAGMENTS AND AUTHENTICITY	
Methods of Consolidation and Protection of Pentelic Marble <i>Maria Apostolopoulou, Elissavet Drakopoulou, Maria Karoglou and Asterios Bakolas</i>	749
7. PIGMENTS AND PAINTINGS ON MARBLE	
Painting and Sculpture Conservation in Two Gallo-Roman Temples in Picardy (France): Champlieu and Pont-Sainte-Maxence <i>Véronique Brunet-Gaston and Christophe Gaston</i>	763
The Use of Colour on Roman Marble Sarcophagi <i>Eliana Siotto</i>	773
New Evidence for Ancient Gilding and Historic Restorations on a Portrait of Antinous in the San Antonio Museum of Art <i>Jessica Powers, Mark Abbe, Michelle Bushey and Scott H. Pike</i>	783
Schists and Pigments from Ancient Swat (Khyber Pukhtunkhwa, Pakistan) <i>Francesco Mariottini, Gianluca Vignaroli, Maurizio Mariottini and Mauro Roma</i>	793
8. SPECIAL THEME SESSION: „THE USE OF MARBLE AND LIMESTONE IN THE ADRIATIC BASIN IN ANTIQUITY”	
Marble Sarcophagi of Roman Dalmatia Material – Provenance – Workmanship <i>Guntram Koch</i>	809

Funerary Monuments and Quarry Management in Middle Dalmatia <i>Nenad Cambi</i>	827
Marble Revetments of Diocletian's Palace <i>Katja Marasović and Vinka Marinković</i>	839
The Use of Limestones as Construction Materials for the Mosaics of Diocletian's Palace <i>Branko Matulić, Domagoj Mudronja and Krešimir Bosnić</i>	855
Restoration of the Peristyle of Diocletian's Palace in Split <i>Goran Nikšić</i>	863
Marble Slabs Used at the Archaeological Site of Sorna near Poreč Istria – Croatia <i>Đeni Gobić-Bravar</i>	871
Ancient Marbles from the Villa in Verige Bay, Brijuni Island, Croatia <i>Mira Pavletić and Đeni Gobić-Bravar</i>	879
Notes on Early Christian Ambos and Altars in the Light of some Fragments from the Islands of Pag and Rab <i>Mirja Jarak</i>	887
The Marbles in the Chapel of the Blessed John of Trogir in the Cathedral of St. Lawrence at Trogir <i>Đeni Gobić-Bravar and Daniela Matetić Poljak</i>	899
The Use of Limestone in the Roman Province of Dalmatia <i>Edisa Lozić and Igor Rižnar</i>	915
The Extraction and Use of Limestone in Istria in Antiquity <i>Klara Buršić-Matijašić and Robert Matijašić</i>	925
Aurisina Limestone in the Roman Age: from Karst Quarries to the Cities of the Adriatic Basin <i>Caterina Previato</i>	933
The Remains of Infrastructural Facilities of the Ancient Quarries on Zadar Islands (Croatia) <i>Mate Parica</i>	941
The Impact of Local Geomorphological and Geological Features of the Area for the Construction of the Burnum Amphitheatre <i>Miroslav Glavičić and Uroš Stepišnik</i>	951
Roman Quarry Klis Kosa near Salona <i>Ivan Alduk</i>	957
Marmore Lavdata Brattia <i>Miona Miliša and Vinka Marinković</i>	963
Quarries of the Lumbarda Archipelago <i>Ivka Lipanović and Vinka Marinković</i>	979

Island of Korčula – Importer and Exporter of Stone in Antiquity <i>Mate Parica and Igor Borzić</i>	985
Faux Marbling Motifs in Early Christian Frescoes in Central and South Dalmatia: Preliminary Report <i>Tonči Borovac, Antonija Gluhan and Nikola Radošević</i>	995
INDEX OF AUTHORS	1009

SCHISTS AND PIGMENTS FROM ANCIENT SWAT (KHYBER PUKHTUNKHWA, PAKISTAN)

Francesco Mariottini¹, Gianluca Vignaroli², Maurizio Mariottini³ and Mauro Roma⁴

¹ Buildings Performance Institute Europe, Brussels, Belgium (francesco.mariottini@gmail.com)

² Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche (IGAG-CNR), Rome, Italy (gianluca.vignaroli@igag.cnr.it)

³ Istituto superiore per la conservazione ed il restauro, Rome, Italy (maurizio.mariottini.geo@gmail.com)

⁴ Istituto superiore per la protezione e la ricerca ambientale, Rome, Italy (mauro.roma@isprambiente.it)

Abstract

Since the earliest agricultural communities settled in the greater Indus basin in the 7th millennium BC, rocks and minerals have had an important role in the local processes of social evolution in order to signal the superior status of elites, as Italian excavations and surveys demonstrated in numerous projects (IsMEO-IsIAO and National Museum of Oriental Art in Rome, MNAO).

This paper presents results from mineralogical-petrographic analysis carried out from sculptures exposed in MNAO, with the aim of better understanding their context and provenance. The petro-textural characters have implications for both the conservation of the sculptures and reconstruction of the provenance history of the raw materials from the Swat Valley. A set of brightly coloured particles made of different raw materials (pigments and gold leaf) was also analysed. These precious materials were probably placed in the reliquary alongside a few cremated bones in the frame of a highly symbolic, ritual setting.

Keywords

schist, ancient Swat, reliquary, pigment, gold leaf

Introduction

In the framework of an ongoing study on the collection of Gandharan stone sculptures at the National Museum of Oriental Art (MNAO), Rome, renewed attention is being paid to the characterisation of the raw materials and the state of conservation of some artworks. The new investigations follow several excavations (Fig. 1) performed after insights arising from pioneer studies and geological surveys¹ at the Swat District of the Khyber Pukhtunkhwa province (northern Pakistan).

The Gandhara sculptures from the MNAO are carved from metamorphic rocks belonging to the ophiolite sequence of the Indus Suture Zone. Although these rocks are commonly given general term of “schists”, they include a large variety of metamorphic lithotypes with different mineral assemblages and different petrographic fabrics. The identification of the petrographic properties of these sculptures is crucial for understanding the lithology and for providing insights into the provenance of the raw material. Whereas the scientific characterisation of ancient marbles is one century old², the first mineralogical investigations on the “metamorphic schists” used in Gandharan sculptures begun less than 50 years ago³. Therefore, identifications are still scarcely supported by a specialised geological know-how. New information on the lithotypes on record is considered in the light of the local outcrops and the general archaeological and cultural contexts of the sculptural complexes.

Geological setting

The geological history of Pakistan⁴ is connected with the continental collision between the Indo-Pakistani and the Eurasian plates, starting from the Cenozoic⁵. The continental collision after the consumption of the former interposed Tethyan oceanic floor⁶ resulted in a prolonged phase of tectonic stacking of oceanic-derived units. The southern margin of the Neo-Tethyan seaway, which rimmed the Indo-Pakistani subcontinent, was incorporated into the Indus Suture Zone, together with major island arcs (such as the Kohistan island arc terrane)

1 FACCENNA 1974, 126-176; DI FLORIO *et al.* 1993a.

2 MARIOTTINI 1998, 23-35.

3 CURTOIS 1962, 107-113.

4 GAETANI *et al.* 2004, 56.

5 MOLNAR *et al.* 1977, 30-41.

6 KHAN *et al.* 2009, 366-384.



Fig. 1. Snapshots of excavations (elab. by B. Mazzone)

and volcano-sedimentary orogenic wedges⁷. The Khyber Pakhtunkhwa Province of Pakistan is dominated by the Kohistan-Ladakh tectonic complex (Fig. 2), a segment of the Indus Suture Zone developed during the northward underthrusting of the thick Indo-Pakistani shield lithosphere, with southward piling of the tectono-metamorphic units⁸. The metamorphic units include a heterogeneous sequence of intermingled HP/LT (mainly in the blueschist facies) and MP/LT (in the greenschist facies) rocks characterised by specific mineralogical assemblages⁹. All these lithotypes are presently exposed along the Indus Suture Zone. In the Swat District, decametric- to hectometre-thick lenses of talcschists and serpentinites are interdigitated with epidote-rich greenschists, magnetite and muscovite-bearing chloritoschists, marbles and phyllites. The top of the sequence generally includes a metapelitic unit (the Saidu Unit) composed of garnet-kianite-staurolite micaschists, paragneiss, amphibolites, prasinites and chloritoid-bearing calcschists¹⁰.

Presently, the structural setting of the region, including the structural boundaries between the tectono-metamorphic units, is defined by the brittle

deformation network, which consists of the imbricate thrust splays along which the considerable crust shortening was produced.

Material and quarries

In the Swat District, several quarries are localised in the immediate proximities of sacred areas¹¹. These quarries correspond to the exposures of the ophiolitic rocks from the Indus Suture Zone. The large variety of lithotypes from the ophiolite sequence represented a great wealth of available materials adopted for both carving and building construction. These lithotypes mainly correspond to chloritoschists, talchists, and serpentinites. These rocks are characterised by plano-laminated foliation that provides preferential cleavage planes to the rock that can be well worked during carving. Chloritoschists and talchists were used for many sacred sculptures and petroglyphs coming from the Gandhari-an sacred areas¹². The talcschist lithotype, with its finely schistose fabric, was used at least in a lion sculpture in the Butkara site. The wall blocks of this site were built with the same talcschist. It comes from many mines situated in several valleys of Khyber Pakhtoonkwa, like Jamrud, Hazara, Shangla, Parachinar, etc., even also

7 DI PIETRO *et al.* 2008, 1428-1440.

8 PETERSON 2010, 287-327.

9 KAZMI, JAN 1997, 554.

10 TAHIRKHELI 1982, 1-51.

11 DI FLORIO *et al.* 1993a; DI FLORIO *et al.* 1995.

12 OLIVIERI, VIDALE 2004, 121-180.

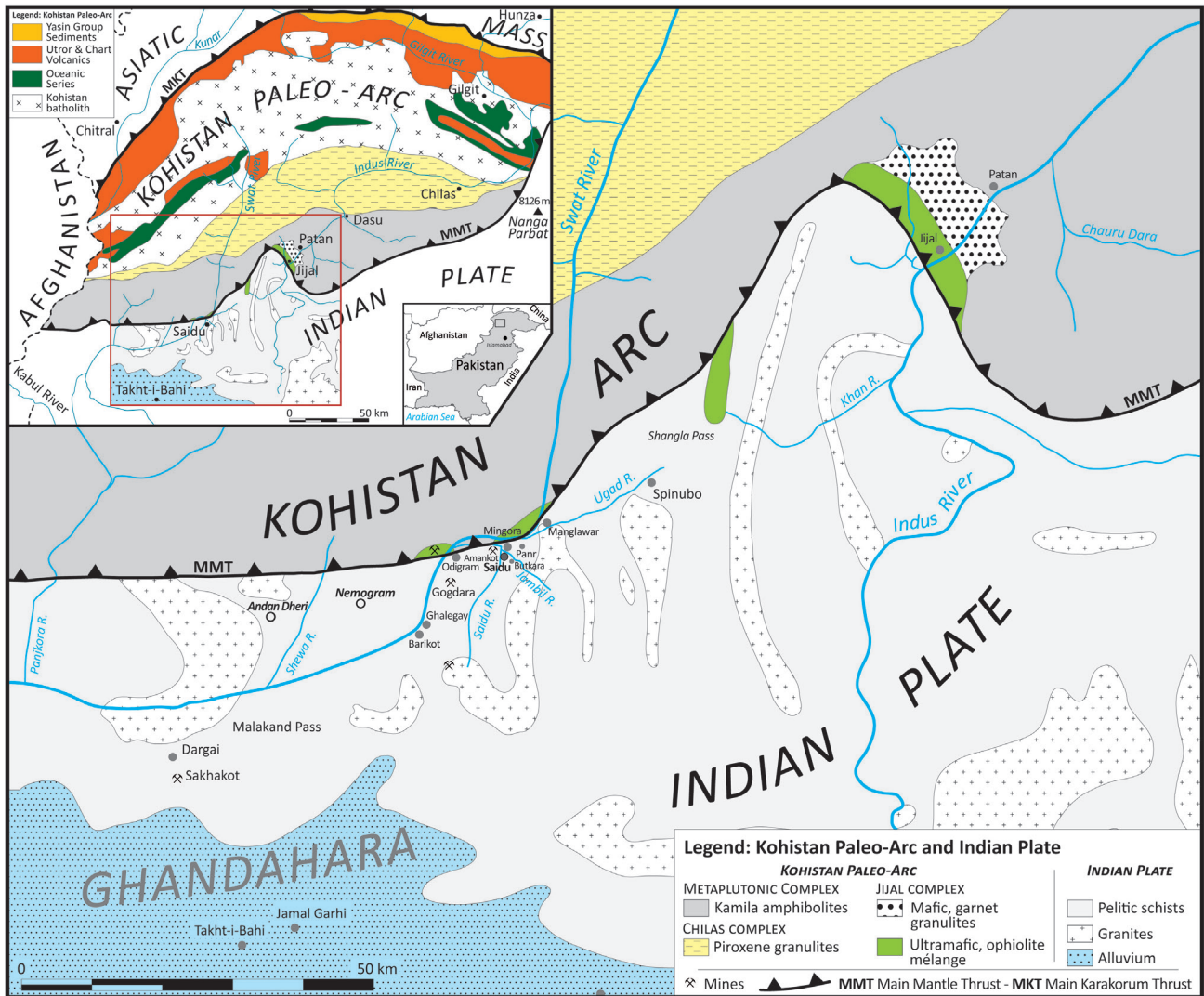


Fig. 2. Tectonic map of the Swat Valley (after FACCENNA *et al.* 1993, 257-270). The geodynamic scenario shown in the inset is after TAHIRKHELI (1982, 1-51) and PETERSON (2010, 287-327)

used for the stability of the pigments or for simple cosmetics as in the centres of Hindu¹³.

In addition to sculpturing, the ophiolitic rocks were also used as quarrying material for building. The ophiolitic rocks of Mingora were identified as the extraction area on the right side of the Swat Valley, but also on the left side of the same valley, opposite the town of Saidu Sharif. However, just up the more recent hills, intense modern mining for emeralds has cancelled every trace of excavations¹⁴.

In sacred areas, particular containers were found during archaeological surveys. These containers, having a shape similar to small cups, were probably devoted to multiple uses, like to prepare plasters or “stucco”, to crush materials, or as cavities for food preservation. In

many cases, these containers were used for baking lime in sacred areas, as observed in Butkara, Saidu Sharif, Panr and more recently in Amluk-dara¹⁵.

In ancient time the reliquaries contained relics of Buddha with a shape like a ‘stupa’ as in the Swat Region at Kanishka (Peshawar), Barikot, which recalls the function of the objects. Hindu and many other religions exhibit reliquaries in shrines or temples. Often organs or bone fragments of ‘saints’ can be separated from the main burial site and recovered in holders engraved with precious metals and rare stones. Not only do the colours have a high symbolic significance, but a stupa is an important form of a reliquary in Buddhism. Finally, there are also many sources of gold over all the area¹⁶.

13 VIDALE, KENOYER 1992, 92-95.

14 SNEE *et al.* 1989, 93-123.

15 OLIVIERI 2006, 137-155.

16 KHAN 2004, 27-40.

<i>Samples</i>	<i>Petrographic classification</i>
MAO4423, MAO2464, MAO2158, MAO4059, MAO2244, MAO1117, MAO4172, MAO2158, MAO4153	Serpentinite
MAO1304	Serpentinite with calcite
MAO4244, MAO1169, MAO4152, MAO2519, MAO1134	Schistose serpentinite
MAO 2080	Talcschist with antigorite

Table 1. List of selected samples and petrographic classification

Petrography of selected samples

The Gandhara finds were preliminarily analysed¹⁷ under the supervisor of the ISMEO. Within this section, we report on a list of the main petrographic characteristics of selected artefact samples stored at MNAO, by focussing on (i) the description of the main micro-structural rock properties, (ii) the definition of principal and secondary mineralogical aggregates, and (iii) the petrographic classification of the samples.

The petrographic analyses were performed on 16 polished thin sections (30 µm thick) taken from the sculpture samples (Table 1). Observations were made using an optical transmitted light microscope equipped with 2x, 4x, 10x, 20x, and 40x magnifications and digital camera acquisition.

At the sample scale, most of the samples have a homogeneous green-grey colour over the entire surface of the investigated thin section. By contrast, sample MNAO2080 shows a homogeneous whitish colour. From a textural point of view¹⁸, these samples show either a sub-millimetric-thick foliated fabric or a massive fabric.

The petrographic characteristics unravelled at micro-scale allow classifying the serpentinite as the predominant lithotype, with schistose serpentinite and talcschist as subordinate lithotypes.

Serpentinite samples are characterised by a dominant massive fabric defined by the random orientation of the main mineralogical assemblage (Fig. 3a). The massive fabric is often crosscut by a system of microveins not showing a systematic trend. Antigorite is the main mineralogical constituent, providing up to 60% of the main fabric investigated at the thin section scale. Antigorite grows both as lamellar and fibrous-acicular crystals. Fibrous antigorite occurs dominantly in the investigated samples (e.g., samples MNAO2464, MNAO 2158). Fibres appear either isolated or in aggregates to form fan structures. Secondary mineralogical species are mainly represented by white mica (crystals having up to 1 mm in length), calcite (fine-grained crystals in micro-veins together

with antigorite), and chlorite (very fine-grained crystals within the groundmass). In detail, white mica appears as single crystal that is (i) either incorporated by the antigorite groundmass, or (ii) superimposed on the antigorite groundmass. In the first case, white mica crystal shows irregular habitus, folded cleavage, and faint chemical alteration along the crystal rims; however, in the second case, white mica presents well-defined, unaltered, habitus. Accessory minerals are magnetite and epidote (up to 20 µm in size), chloritoid (up to 70 µm in length), and rutile. Chloritoid occurs as single tabular crystal with corroded shape (sample MNAO 1117). Rutile appears as mineralogical relict mantled by the antigorite groundmass.

Sample MNAO 1304 corresponds to a serpentinite with massive fabric and diffuse crystallisation of calcite aggregates. Antigorite (and subordinate, very fine grained chlorite) is the main mineralogical constituent. Calcite crystal has a size over 100 µm and does not show relation of textural equilibrium with antigorite crystals, suggesting that calcite is a late mineralogical phase developed after the antigorite groundmass.

Schistose serpentinite samples show an internal fabric consisting of penetrative, few µm-thick foliation (Fig. 3b). The foliation is made of aligned fibrous antigorite, up to 300 µm in length (Fig. 3c). Within the foliation, secondary and accessory minerals are dispersed. These correspond to rutile, magnetite, chlorite, and white mica up to half a millimetre in size. Rutile and magnetite often show corroded rims, while white mica may appear with regular habitus.

Talcschist is characterised by the development of an incipient foliation defined by faint alignment of talc crystals (Fig. 3d). Talc crystals are acicular to lamellar in shape, up to 100 µm in length. Foliation is up to 30 µm in width, with local deformation in microfolds. Within the foliation, acicular to fibrous antigorite occurs as a relict mineralogical phase transposed by the main foliation containing talc.

Also the inquiries with the investigations at the scanning electron microprobe (SEM-EDS) scale confirm the petrographic observations, evidencing the occurrence of mineral phases rich in Al₂O₃ (chloritoid) besides quartz and oxides of Ti (especially rods of rutile and aggregates of ilmenite), Fe (magnetite), often associated with minimal quantities of Mn, Cr and V. Most of the analysed

17 FACCENNA *et al.* 1993, 257-270.

18 SPRY 1969, 350.

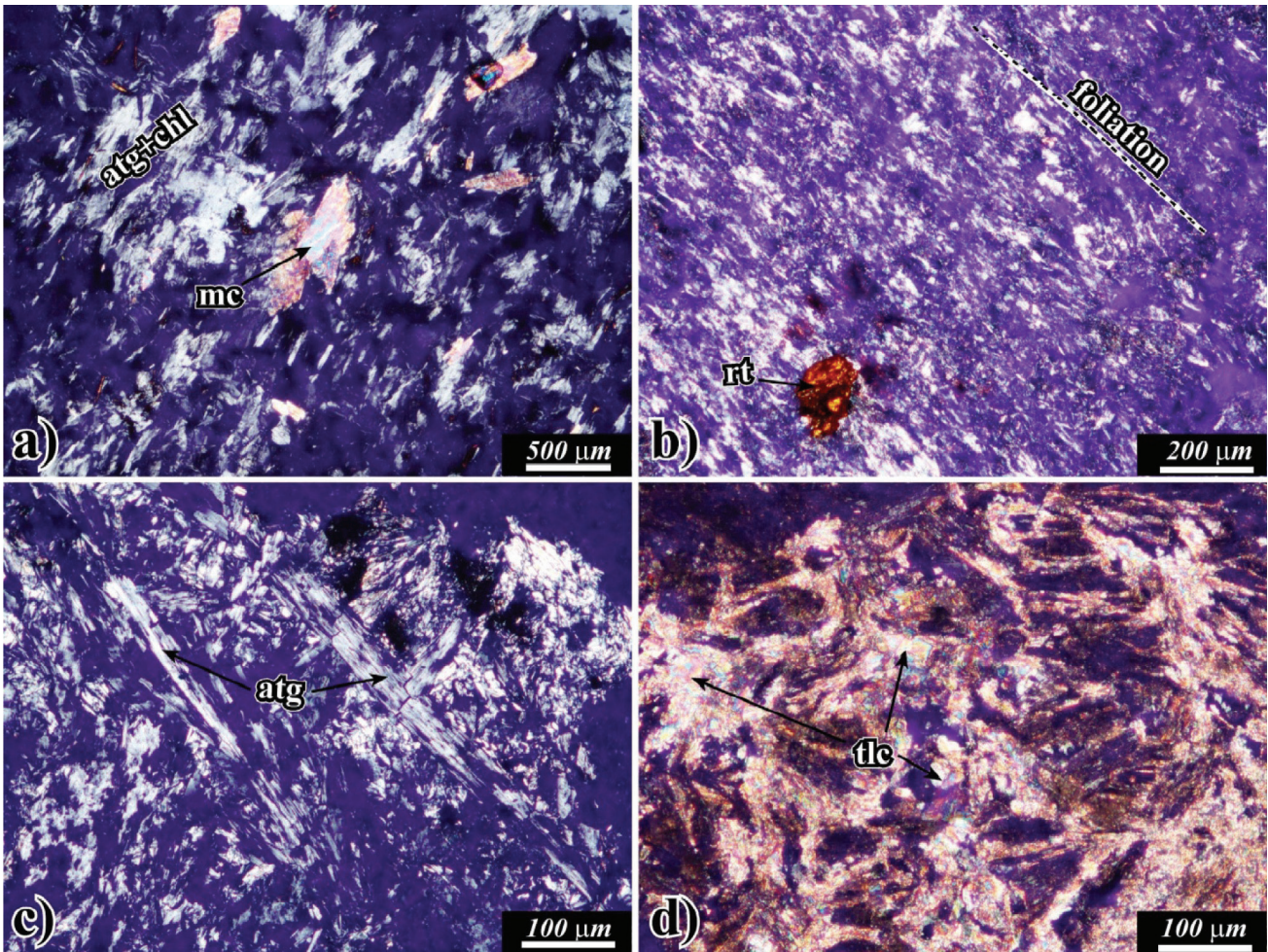


Fig. 3. Petrographic features of selected samples at thin section scale. (a) serpentinite with massive fabric defined by antigorite (atg) and fine grains of chlorite (chl) in the groundmass, with late crystallised grains of white mica (mc); (b) serpentinite schist characterised by penetrative foliation marked by aligned fibrous antigorite incorporating relict mineralogical phases like rutile (rt); (c) detail of the serpentinite schist fabric evidencing fibrous antigorite; (d) talc aggregates (tlc) in microfolded fabric of talcschist. All pictures have been taken at crossed polars

samples show the occurrence of Zr and REE such as lanthanoids (Sm, Gd, Dy, Er, ecc.). The image and its spectrum of the section of the sample MNAO 2158 (Fig. 4) show also the presence of a granule cerium, neodymium and lanthanum, to be referred to monazite-(Ce): $(\text{Ce, La, Nd, Th})\text{PO}_4$. Further, it is possible to find small grains with variable amounts of zirconium (zircon), titanium (rutile), or iron (flaky or platy of ilmenite) forming single acicular crystals or frequently giving forms at a sharp angle, called knee-shaped twins. In some findings, the zircon and the rutile have plaques of ilmenite and magnetic alteration with hematite (Fig. 5, sample MNAO 1148.). The silico-aluminate phases also have problems of chemical and textural alteration (i.e. decussate texture) regarding the antigorite, the chloritoid, epidote and muscovite.

Finally, according to the examinations done at the microprobe scale, SEM-EDS analyses give information about the chemical characteristics of the groundmass. In particular, it has been possible to verify that

approximately the same concentration percentage in weight of the elements (Mg, Al, Si, Fe) occurs between grains and the surrounding groundmass.

Painting and pigments

Analysis of schists¹⁹ provides reliable and significant data on the nature of the colours, the preparation layer and about the manufacturing process.

Following the previous stereoscopic microscope and UV/vis observations²⁰, XRD analysis integrated with SEM-EDS show that natural pigments (e.g. red and white) were readily available in the areas surrounding the stone workshop.

19 Based on an unpublished report from MARIOTTINI 2014, 7.

20 STERLING GLEASON 1960, 244.

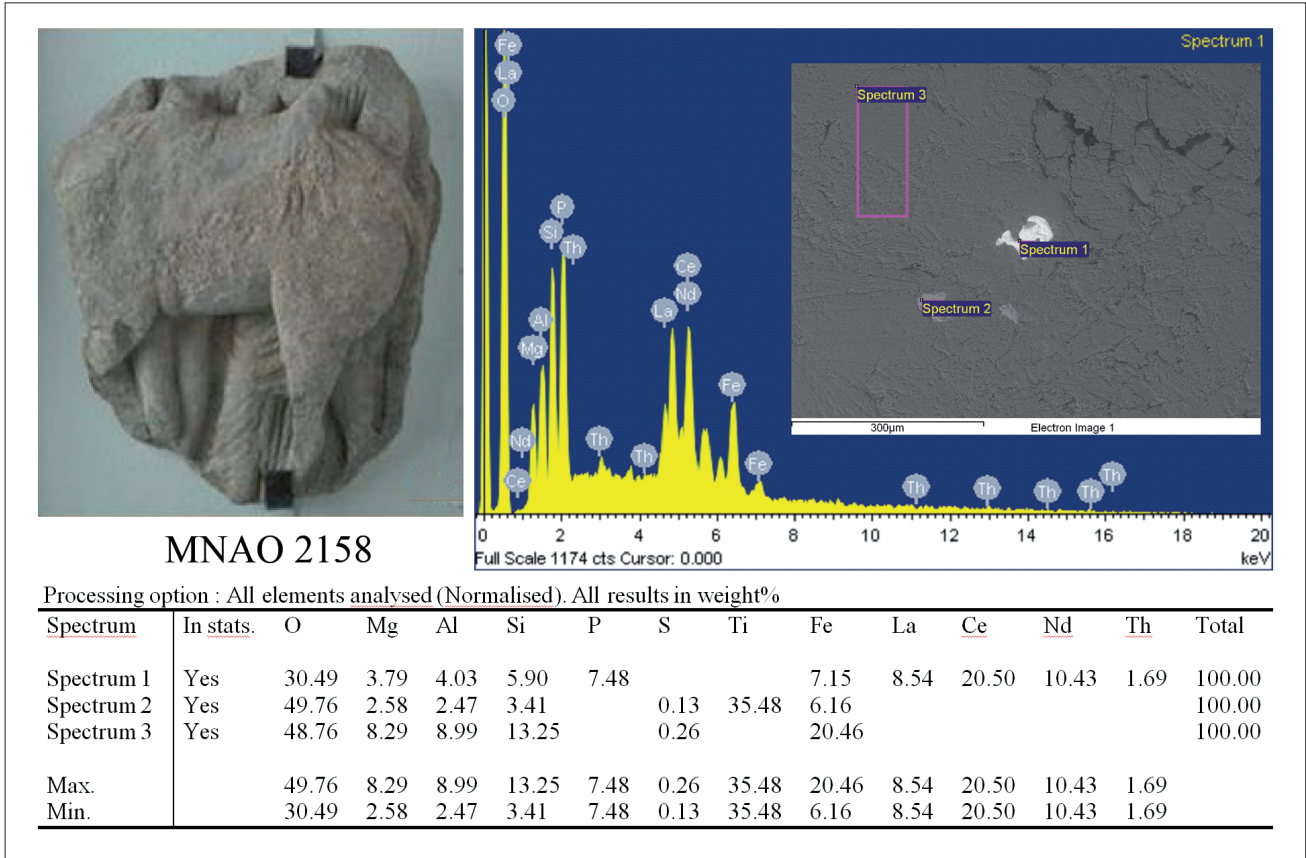


Fig. 4. Spectrum and occurrence of Monazite-(Ce), (SEM sample M2158)

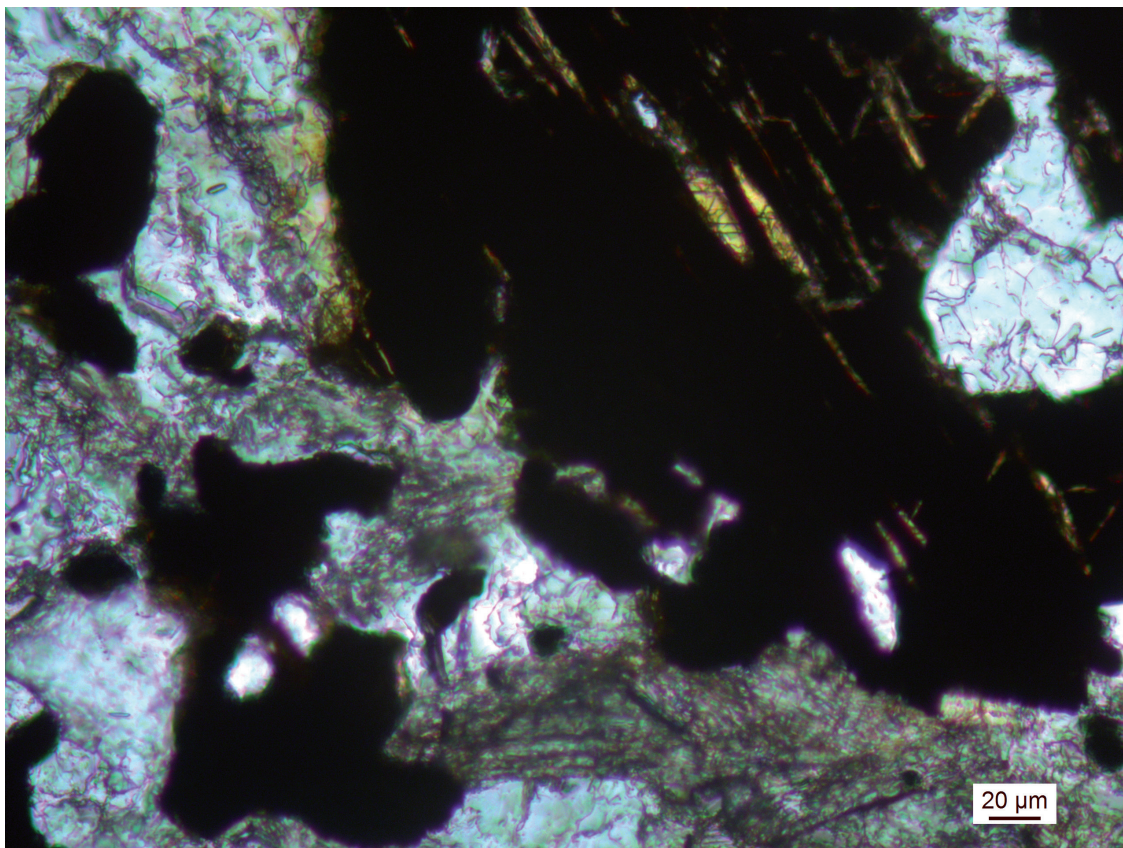


Fig. 5. M1148 - Magnetite partially rimmed by rutile, altered ilmenite-leucoxene, titanite and small zircons (crossed polars)

Nevertheless, due to their textural properties and the effects of dangerous washing during excavations, the traces of the colours on green-schist have less resistance to weathering than those on marble (i.e. 'fresco' techniques).

Many red grains sampled from the schists are assigned to ochres, whereas white grains refer to the so-called calcium carbonate or calcite (see MAO1169bind_ whi, Fig. 6).

Sometimes the coloured grains are accompanied by silicates (e.g. talc) or serpentinitised rocks (chlorites or amphiboles), which are characterised by a complex internal structure²¹.

A singular composition has been observed in an artefact coming from Panr, where 'biacca' was used (Fig. 6, sample MAO4423).

Preliminary investigations on 'stuccos' (Fig. 7) show that their colours are probably similar to the ones on stones, such as the red ochre, with comparable quantities of chemical elements like Mg, Al, Si, and Fe-Ti.

Interestingly, sample M1293 is characterised by small particles of gold leaf folded in various shapes (Fig. 8). The same sample exhibits a fine crystallization of azurite on compact and banded malachite (Fig. 9). The alloy is characterised by Au-Ag, whereas SEM analysis of small opaque areas show high values in Fe-Ti, Al, Si, alkali and alkaline elements.

Workability, alteration and conservation problems

The green rocks of the Swat have workability and conservation problems partially known for various kinds of lithotypes. The conservation problems cannot be reviewed only by studying the final shapes of their products. In fact, the alteration comes from far away and often depends on their previous story, until the processing and the conservation in the final destination's environment²². However, in general the mineralogical and textural component is not a particularly difficult factor for the sculpture, even for lithotypes with an abundance of magnetite, sometimes altered and with limonitic residues. Actually, the soapstone itself, for its softness can be as easily carved as wood. For the micaschists, with a bigger grain than the phyllites, the freedom of handling becomes more crucial with the loss of material in the spalling; the phenomena of detachment (i.e. sample 4152) should be stabilised to avoid the loss of readability of the artifacts in the future.

Regarding the conservation problems, of a more specific mineralogical kind, the rocks of the Swat, notoriously refractory like other green rocks, have proved to be usually resistant enough to chemical alteration. The

practical note of soaking the findings in acid solutions (widely practiced in non-scientific contexts) in order to remove veils and carbonate concretions, has still some very crucial aspects. In fact, when the original rock (even if rich in minerals resistant to the acid attacks, like talc) contains mineralogical phases made of different percentages of apatite, brucite, chrysotile, monazite and obviously calcite and dolomite, it will have a low mechanical resistance to weathering, because it has proved to be sensitive to carbonic acid.

Conclusions

According to the inquiries made during this research on some of the Gandhara artifacts of the MNAO, only some lithotypes have more or less traces of mineral chloritoid, which is very common in the materials of the Gandhara arts according to some studies²³. Moreover, no quarries of the chloritoid-bearing phyllites often used for the Gandhara statues have not been documented. In fact, the majority of the statues have been sculpted in phyllites; others in green schists and only a few in talc schist (see *soapstone*). The phyllites of the statues studied²⁴, and other researches²⁵ have similar mineralogical and rheological aspects, but the chemical composition of the chloritoid widely varies²⁶. According to surveys, we believe that one of the best areas to control the phyllites used for the statues of the Swat is the middle valley of the Jologram, especially on the south bank where fine and graded phyllites of chloritoid come to the surface.

Petro-mineralogical insights from this study help to classify phyllites, at least some of these, as serpentinites, schistose serpentinites, and talcschists. Further basic inquiries have to be completed in the next step

21 HOWIE 1982, 1155-1178.

22 MARIOTTINI, VIGLIANO 2013, 219-233.

23 KEMPE 1982, 25-28. The author confirms the presence of schists rich in Al with a paragenesis in chloritoid-paragonite-muscovite-quartz, compatible with the formations mentioned above, but not yet discovered on the field as sure proofs of ancient extractions. The question of the chloritoid is crucial, because the green schists with such amount of phyllosilicate are common in metamorphic environments of orogenic overthrust but often in regions out of the Swat, far beyond the Khyber Pass, in the middle of the Afghan territory. According to other scholars (CAMBON, LECLARIE 1999) the materials used in Gandhara art, are very homogeneous and "the only exceptions are related to Swat, with chloritite as a case apart..".

24 See also KEMPE 1986, 79-87.

25 NEWMAN 1984, 288; NEWMAN 1992, 163-174; REEDY 1992, 241-287; REEDY 1997, 267-283.

26 NEWMAN 1988, 120-131.

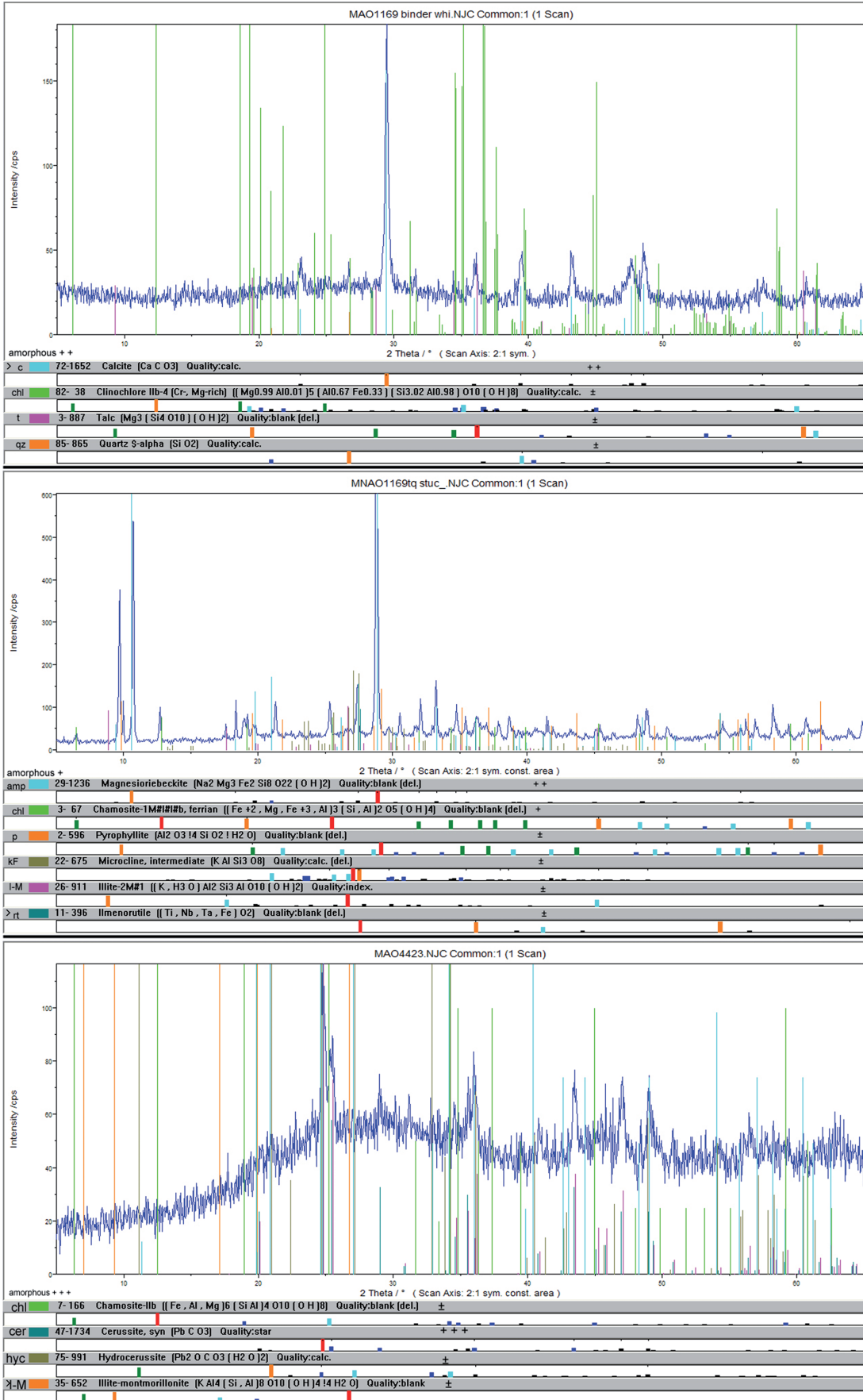


Fig. 6. XRD patterns of the stone (M1169 central) and its residual white binder (M1169 above). Pattern on the bottom refers to sample M4423 from Panr: the white powder reveals a basic lead carbonate

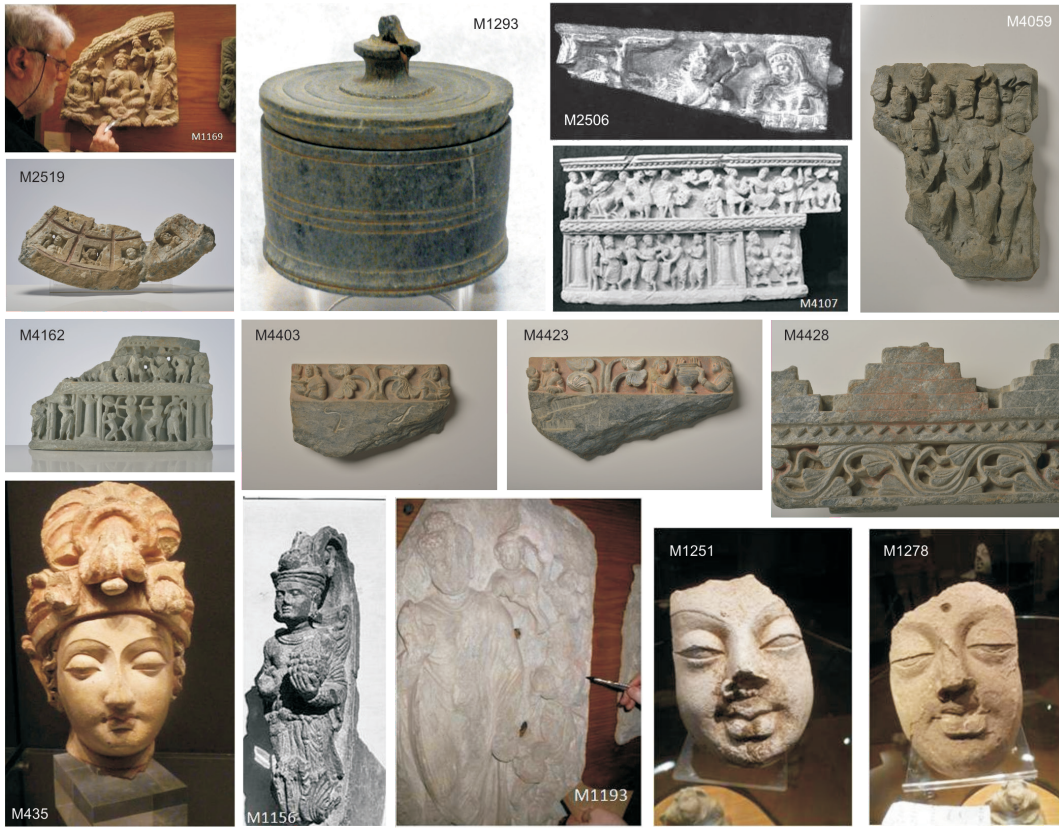


Fig. 7. Examples of artefacts with traces of pigment or preparation layer collected in MNAO: stone (1169, 1293, 2506, 2519, 4059, 4107, 4162, 4403, 4423, 4428) and 'stucco' (435, 1156, 1193, 1251, 1278)

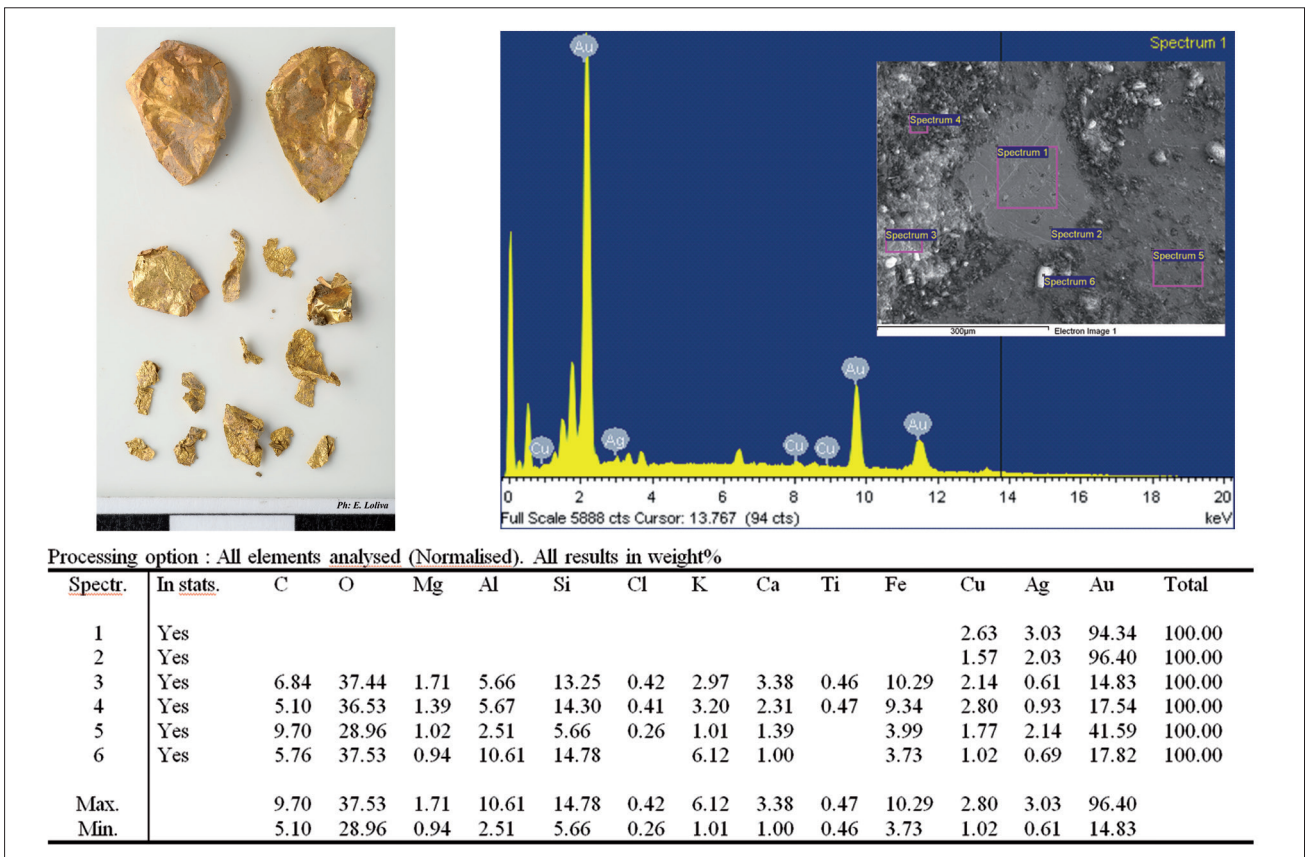


Fig. 8. Reliquary M1293: "gold leaf" folded in various shapes (e.g. heart) and SEM-EDS analysis

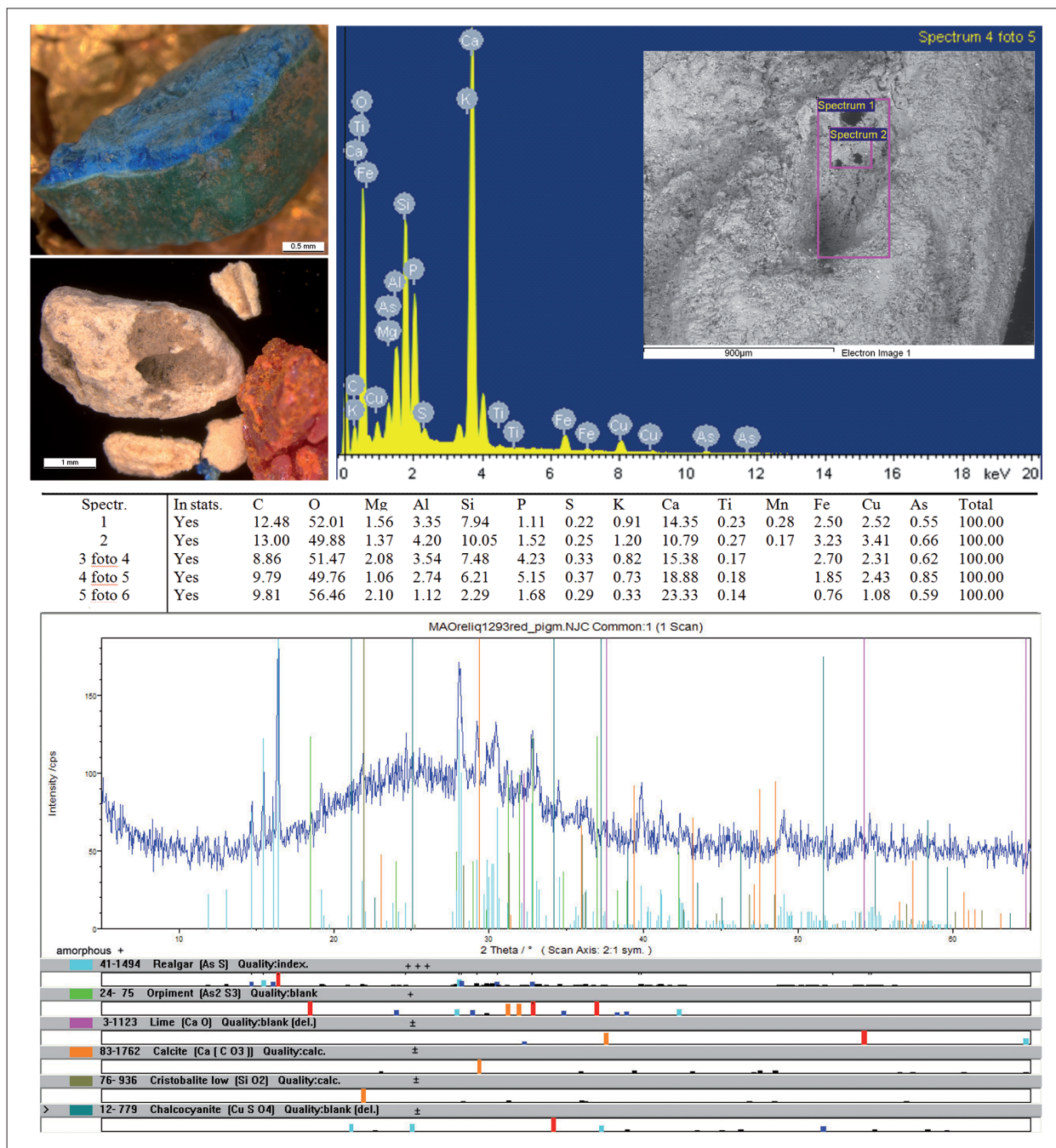


Fig. 9. Grains in reliquary M1293: azurite XX on banded malachite; XRD and SEM spectra of the calcined powder (bones and well crystallized realgar partially altered in orpiment)

of the research by using powder diffraction (XRD) and geochemical analysis on rock samples coming from the Swat. This should help to define chemical correspondence between reliquary and rock and, then, to assign a probable origin of the extraction sites used for the making of the Gandhara statues. It will be fundamental to be able in the near future to collect an exhaustive amount of emerging samples *in situ* and of the possible quarries in the North Western Pakistan area and in Afghanistan.

ACKNOWLEDGEMENTS

The Authors would like to thank the colleague Hawas Khan (Dassu Gems) of the Karakoram University Gilgit-Baltistan for certain bibliographic references and C. Faccenna of the Geological Department of Science - University Roma Tre (Rome) for the support in geological context; the Director of the National Museum of Oriental Art in Rome and his team, in particular many thanks to Laura Giuliano for the patient collaboration in the sampling of the findings.

REFERENCES

- CAMBON P., LECLAIRE A. 1999: "Étude pétrographique des collections gréco-bouddhique du muse Guimet", *Arts asiatiques* 54, 135-147.
- COURTOIS L. 1962: "Examen minéralogique de quelques roches de monuments gréco-bouddhiques", *Arts asiatiques* 9, 1-2, 107-113.
- DI FLORIO M. R., FACCENNA C., LORENZONI S., ZANETTIN E. 1993a: "Lithological analysis of materials used in the buildings of the sacred area of Panr I (Swat Valley, Northern Pakistan) and their origins", Appendix D, in D. FACCENNA, A. N. KHAN, I. NADIEM (eds.): *Panr I (Swat, Pakistan, Ismeo Reports and Memoirs, XXVI, Roma*.
- DI FLORIO M. R., FACCENNA C., LORENZONI S., ZANETTIN E. 1993b: "Evidence of ancient quarrying in Lower Swat, N.W.F.P., Pakistan. A geo-archaeological study", *Science and Technology for Cultural Heritage* 2, 63-74.
- DI FLORIO M. R., FACCENNA C., LORENZONI S., ZANETTIN E. 1995: "Lithological analysis of materials used in the buildings of the sacred area of Saidu Sharif (Swat Valley, Northern Pakistan) and their origins", Appendix D, in D. FACCENNA, Saidu Sharif I (Swat, Pakistan). *ISIAO Reports and Memoirs*, 2 vol., Roma.
- DI PIETRO J. A., AHMAD I., HUSSAIN A. 2008: "Cenozoic kinematic history of the Kohistan fault in the Pakistan Himalaya", *Geological Society of America Bulletin* 120, 1428-1440.
- FACCENNA D. 1974: "Excavation of the Italian Archaeological Mission (IsMEO) in Pakistan: some problems of Gandharan art and architecture", in B. G. GAFUROV *et al.* (eds.): *Proceedings of the International Conference on the History, Archaeology and Culture of Central Asia in the Kushan Period*, I, Moscow, 126-176.
- FACCENNA C., LORENZONI S., OLIVIERI L. M., LORENZONI Z. 1993: "Geo-Archaeology of the Swat Valley (NWFP, Pakistan) in the Charbagh-Barikot Stretch. Preliminary Note", *East and West* 43, 1-4, 257-270.
- GAETANI M., BURG J. P., ZANCHI A., JAN M. Q. 2004: *A geological transect from the Indian plate to the east Hindu Kush, Pakistan. Field-trip Guide Book-PR01. International Geological Congress Florence, Italy. Italian Agency for Environmental Protection & Technical Services, Rome*.
- HOWIE R. A. 1982: "Hornblendic amphiboles from basic and intermediate rocks of Swat-Ko-histan, north-west Pakistan", *American Mineralogy* 67, 1155-1178.
- KAZMI A. H., JAN M. Q. 1997: *Geology and Tectonics of Pakistan, Karachi*.
- KEMPE D. R. C. 1982: "Nature and source of the Gandhara sculptural schist", *Journal of Archaeological Science* 9, 25-28.
- KEMPE D. R. C. 1986: "Gandhara sculptural schist: proposed source", *Journal of Archaeological Science* 13, 79-87.
- KHAN H. 2004: "Exploration and extraction of placer gold and silver in the terraces of Bagrot Valley, Gilgit, Northern Pakistan", *Geol. Bull. Univ. Peshawar* 37, 27-40.
- KHAN S. D., WALKER D. J., HALL S. A., BURKE K. C., SHAH M. T., STOCKLI L. 2009: "Did the Kohistan-Ladakh island arc collide first with India?", *Geological Society of America Bulletin* 121, 3-4, 366-384.
- MARIOTTINI M. 1998: "La provenienza dei marmi cristallini usati in antico: un problema aperto", in P. PENSABENE (ed.): *Marmi antichi II - Cave e tecnica di lavorazione provenienze e distribuzione, Studi miscellanei* 31, Roma, 23-35.
- MARIOTTINI M., VIGLIANO G. 2013: "Il degrado dei materiali lapidei dell'arte egizia", in D. CAVEZZALI (ed.): *La conservazione dell'arte egiziana, Roma*, 219-233.
- MARIOTTINI M. 2014: *Osservazioni geopetrografiche sulle sculture gandhariche (Swat, Pakistan) del Museo Nazionale d'Arte Orientale di Roma, unpublished typescript, Misc A 2014.3, ISCR Library, Rome*.
- MOLNAR P., TAPPONNIER P. 1977: "The collision between India and Eurasia", *Scientific Amer.* 235, 30-41.
- NEWMAN R. 1984: *The stone sculpture of India, Cambridge Massachusetts*.
- NEWMAN R. 1988: "The materials of Hoysala temples and sculptures: a petrographic characterization". *Archaeometry* 30, 1, 120-131.
- NEWMAN R. 1992: "Applications of petrography and electron microprobe analysis to the study of indian stone sculpture", *Archaeometry* 34, 2, 163-174.
- OLIVIERI L. M. 2006: "Per Saxa. Il contributo della missione italiana allo studio geo-archeologico e dei manufatti rupestri nello Swat", in P. CALLIERI (ed.): *Architetti, Capomastri, Artigiani l'organizzazione dei cantieri e della produzione artistica nell'Asia ellenistica. Studi Offerti a Domenico Faccenna nel suo Ottantesimo compleanno. Serie Orientale C, Roma*, 137-155.
- OLIVIERI L. M., VIDALE M. 2004: "Beyond Gogdara I. New Evidence of Rock Carvings and Rock Artefacts from the Kandak Valley and Adjacent Areas (Swat, Pakistan)", *East and West* 54, 1-4, 121-180.

- PETTERSON M. G. 2010: "A review of the geology and tectonics of the Kohistan Island arc, north Pakistan", Geological Society, London, Special Publications 338, 287-327.
- REEDY C. L. 1992: "The materials and technology of Gandharan stone sculptures", in E. ERRINGTON, J. CRIBB (eds.): *Crossroads of Asia: transformation in image and symbol. Ancient India and Iran Trust*, Cambridge, 241-287.
- REEDY C. L. 1997: "Technical studies of Gandharan art", in *Gandharan Art*, in R. ALLCHIN, B. ALLCHIN, N. KREITMAN, E. ERRINGTON (eds.): *Context: East-West Exchanges at the Crossroads of Asia*, Cambridge and New Delhi: Ancient India and Iran trust and Regency Publications, 267-283.
- SNEE L. W., FOORD E. E., HILL B., CARTER S. J. 1989: "Regional chemical differences among emeralds and host rocks of Pakistan and Afghanistan: implications for origin of emerald", in A. H. KAZMI, L. W. SNEE (eds.): *Emeralds of Pakistan. Geological Survey of Pakistan*, Quetta, 93-123.
- SPRY A. 1969: *Metamorphic Textures*, Oxford.
- STERLING GLEASON M. A. 1960: *Ultraviolet guide to minerals*, D. Van Nostrand Co. Inc., Toronto, New York, London.
- TAHIRKHELI R. A. K. 1982: "Geology of the Himalaya, Karakoram and Hindukush in Pakistan", *Geol. Bulletin, Univ. of Peshawar (special issue)* 15, 1-51.
- VIDALE M., KENOYER J. M. 1992: "La civiltà della Valle dell'Indo", *Archeo Dossier* anno VII, n. 9, Novara, 92-95.