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The geological heritage of the historical collections of the University of Messina

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ABSTRACT
The geoheritage housed in the historical collections of the University of Messina dates back to the 1880s. These historical collections comprise a thousand specimens of minerals, gemstones, ores, rocks, and macro- to microfossils. Most of them are provided of scientific, didactic, and cultural values and consequently have to be preserved and enhanced for future generations. Their restoration and cataloging are necessary activities to make this geoscientific naturalist heritage accessible to scientists, students, tourists, and citizens worldwide. The present research reports the description of the geological heritage of the main collections housed at the University of Messina, and the results of the activities and methods carried out for the characterization of geological materials of uncertain classification or composition. The optical observations at the stereomicroscope and by Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS), in tandem with μ-Raman analyses on geomaterials allowed to ascertain the authenticity of suspect specimens, pointing out that such methodologies provide a useful and fast approach to properly discriminate between real and fake geomaterials.

Section: RESEARCH PAPER

Keywords: geoheritage; museum; minerals; gemstones; fossils; geoconservation; historical collections

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1. INTRODUCTION

The university's historical collections represent evidence of prestigious scientific research carried out in the past. In Europe, the "golden age" of university museums goes back to the historical period between 1800 and 1930, when the first museum collections began to be linked to research and didactic activities, connecting social to cognitive forms [1]. University collections, preserving specimens of significant research, may attract students, researchers, and users, linking the science to the territory. Additionally, the Covid pandemic has dramatically modified and improved the way of fruition and has challenged museums to find new ways of communication and engagement.

The geoscientific cultural heritage of the university is of great value for future generations due to its historical and scientific value. However, several problems may affect the geoconservation of historical, and cultural heritage due to the loss of original scientific information. For example, the inventory registers and paper databases of university historical exhibitions may have been destroyed, damaged, or lost after natural (earthquakes, volcanic eruptions, floods) or anthropogenic disasters (armed conflicts). On the other hand, the geological and paleontological materials of the cultural heritage, hosted in private or public collections, may be objects of fraud regarding the authenticity (genuine or fake samples) or provenance of the specimens due to illicit activities.

In all these circumstances, non-invasive and non-destructive analyses and observations are required for characterizing the materials or ascertaining the truthfulness of the declarations attesting to authenticity or provenance.

The historical geological collections of the Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences (MIFT) at the University of Messina (Figure 1) date back to the 1880s and host thousands of specimens of minerals, gemstones, and fossils of which most information was unfortunately lost during moving and armed conflicts. Consequently, appropriate classifications, restorations, and conservation are needed to preserve natural materials that are lacking original labels and information.

The present research aims at presenting the geological heritage of the historical collections of the University of Messina and reports on a case study of activities and methods carried out to characterize of geological materials of uncertain classification.

2. MATERIALS AND METHODS

The geoscientific heritage belonging to the “Historical mineralogical collection”, “Mine mineral collection”, “Geminate mineral collection”, “Siliceous mineral collection”, “Mineral and gem didactic collection”, and “Fossil collection” of Messina University is housed in the permanent expositions of minerals, gemstones, and fossils made available to interested scholars, tourists, and researchers (Figure 1).

Figure 1. The mineral and gemstone hall.

Minerals, gemstones [2], [3], [4], [5], [6], [7], and fossils, whose authenticity was uncertain, were analyzed using non-invasive and non-destructive methods for their characterizations to classify, restore, and valorise the studied geoscientific heritage.

Optical observations were carried out in stereo microscopy using a stereomicroscope (Stereo Discovery V20, Zeiss) equipped with a camera and workstation for image analysis. The main features analyzed were color, lustre, cleavage, fracture, and inclusions. In addition, such observations were carried out with analyses for molecular physical-chemical characterization by μ-Raman spectroscopy. μ-Raman spectroscopy represents a standard tool for quickly identifying the mineralogical composition and authenticity of gemstones, precious and semiprecious stones, and fossils. The use of portable Raman instrumentation for discriminating between authentic and simulant gems or materials was already successfully tested [7]. μ-Raman data were acquired by a portable “BTR111MiniRam™” (BW&TEK Inc.) spectrometer by using a 785 nm excitation wavelength and a thermoelectric cooled charge-coupled device (CCD) detector. The system was equipped with a BAC151B Raman microscope. A 40x objective was used to focus the laser spot on the mineral surface, with a working distance of 3.98 mm and a laser beam spot size of 50 μm. The maximum power at the samples was ~ 90 mW. The spectral range from 60 to 3150 cm^{-1} was analyzed, with an acquisition time of 40 s and a resolution of 8 cm^{-1}.

The collection of fossils can be used as a reference in case of seizures by the Authorities to classify specimens and determine their authenticity. The authenticity can be verified by a macroscopic examination of the preservation state, the eventual embedding rock and infilling sediments, and the skeletal composition. This can be confirmed at a naked-eye examination in many cases, relying on the experience of the palaeontologists and comparing the specimen to similar fossils [8]. In case of uncertainty, analyses under the stereomicroscope or Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS) may help to observe the typical structure of shells and skeletons, where the biominerals and their texture/structure may be revealed. Microscopic analyses on fakes of fossils made up of resins or covered by paints cannot reproduce the genuine textures/structures but only characterize the external aspect and composition.

The verification of fossil authenticity is the first step in the investigations, usually conducted by the Carabinieri’s Nucleus for the Protection of Cultural Heritage. Italian fossils are subjected to the laws for the protection of the cultural heritage and cannot be collected without permission by the competent Superintendence of the Cultural Heritage. Italian fossils are intended for State ownership and cannot be preserved in private houses. Some licenses can be granted in the case of ubiquitous fossils when their large abundance and wide occurrence are known in the area. Foreign fossils are subjected to the laws of the provenance state. Consequently, the authenticity of fossils illegally kept and marketed, accompanied by an indication of their geographic provenance, is essential in launching a penalty process. The property of a fake fossil is not a crime, but the non-authored production and trading are. The sale of fakes, dealt as authentic fossils, is a fraud while selling authored reproductions is allowed. The use of fossils reproduction is every day in museums and exhibitions to show specimens particularly rare and preserved in safety boxes, such as hominin remains. The new advances in the geoconservation of the geological heritage consist of 3-D models of macrofossils, such as vertebrates, giant

Figure 2. Black minerals of rutile (chemical formula: TiO_2) with the original handwritten label from the “Historical mineralogical collection”. Provenance: Australia.

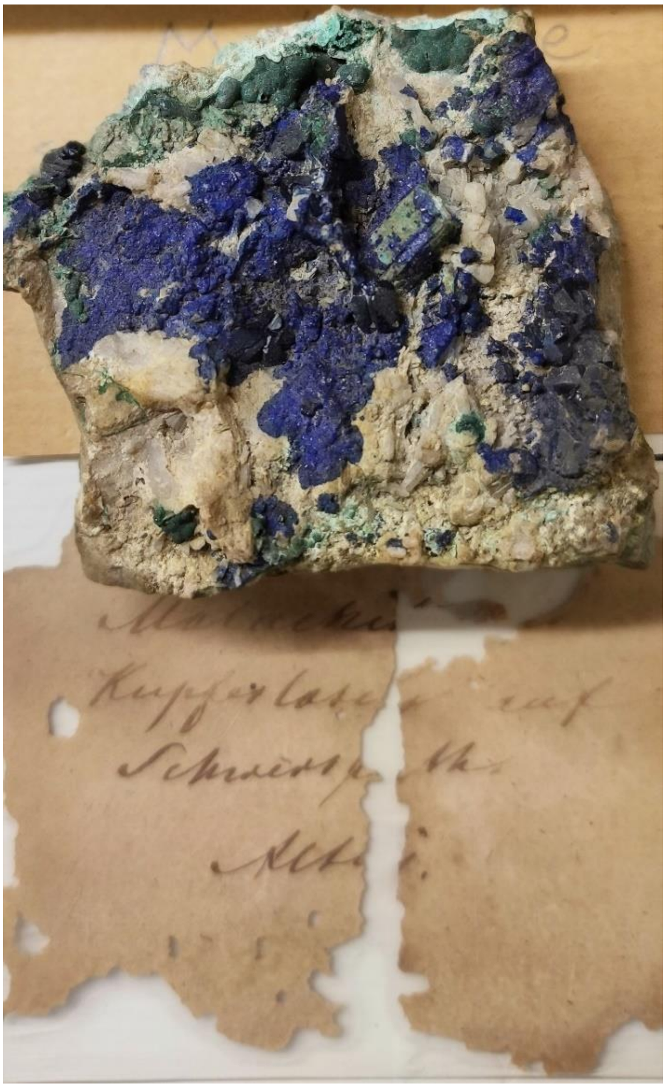

Figure 3. Green malachite ($Cu_2(CO_3)(OH)_2$) with blue azurite (chemical formula: $Cu_3(CO_3)_2(OH)_2$ (sample size: 6.5 x 4 cm) with the original handwritten label from Aradas “Historical mineralogical collection”. Provenance: unknown

ammonites, or dinosaur imprints [9], using laser and blue light structural scanners. These techniques are very useful because they consist of non-destructive methods that guarantee high standards of accuracy, speed, and low costs [10], [11].

3. THE HISTORICAL MINERALOGICAL COLLECTION

Giuseppe Seguenza (1833-1889) was responsible of the oldest collection of minerals, rocks, and fossils [12]. His son, Luigi Seguenza (1873-1908), continued the father’s activities, collecting 446 rocks from the Messina province. One hundred fifty-seven are the specimens of minerals of Andrea Aradas (1810-1882), bought from Aradas’s heirs by Francesco Saverio Starrabba (1886-1954) [10]-[13] (Figure 2 and Figure 3).

The Aradas collection is composed of prestigious samples from the Sicilian sulphur mines, zeolites from the “Cyclops Island” (Acicastello, Catania, Italy) [10], and other localities.

Giuseppe Raimondo Pio Cesaro (1849-1939) introduced in the collection calcite samples dating back to the 20s of the nineteenth century, accompanied by original crystallographic iconographies. The original labels of part of these specimens were re-elaborated by Luigi Sequenza before 1908 and introduced in the historical collection [10].

Francesco Rodolico (1905-1988) enriched the mineral collection with seventy-eight mineralogical samples since the last twenty years of the nineteenth century [14]. Most specimens were derived from scientific research between the University of Messina and university museums from other countries. F. Krantz in Bonn (1809-1872) (Figure 4), L. Sæmann in Paris (1821-1866), and F. Pisani (1831–1920) (Figure 5) in Rue de Furstenberg in Paris were the main responsible of the trade companies selling the mineralogical specimens to the Messina collectors [10].

4. THE MINE MINERAL COLLECTION

An essential aspect of the Sicilian socio-economic history was represented by the mining exploitation, attested in Sicily since the Middle Ages. It occurred up to the middle of the nineteenth century. The “Mine mineral collection” is mainly formed by

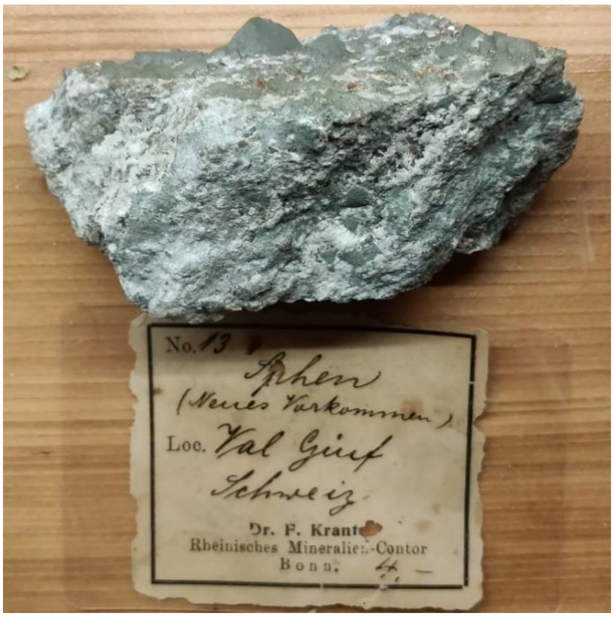

Figure 4. Greenish sphen mineral (chemical formula: $CaTi(SiO_4)O$) from the “Historical mineralogical collection” (sample size: 8 x 5 x 2 cm). Sample purchased by A Krants in Bonn. Provenance: Val Giuf, Switzerland.

Figure 5. Hyaline calcite sample (chemical formula: $CaCO_3$) with the original handwritten label from the "Historical mineralogical collection". Sample purchased by F. Pisani. Provenance: France.

upper Miocene evaporitic minerals and rocks (Messinian age) exploited in central and western Sicily and Paleozoic metamorphic poly-metalliferous mineralization extracted from the mines of the Peloritani Mountains (Messina) [10], today abandoned.

A total of forty sulphur crystals and sixty minerals of celestine, gypsum, and carbonates derive from the Messinian Gessoso-Solfifera Formation present in the mines of Enna, Palermo, Agrigento (Figure 6 to Figure 8), Caltanissetta, and Messina [10].

More than one hundred samples of mineralized rocks derive from the Fiumedinisi and Alì (Figure 9) mines in the Peloritani Mountains. These mines are rich in Pb, Zn, Fe, As, Sb, Cu, Ag, and W poly-metalliferous ore-bearing deposits, characterizing the Variscan basements and occurring in lens and dykes [10], [15], [16], [17], [18], [19].

Figure 6. Messinian yellow sulphur crystals (chemical formula: S_8) (sample size: 30 x 10.5 x 13 cm) on grey limestones from the "Mine mineral collection" (A. Aradas). Provenance: San Giovannello, Casteltermini, Agrigento (Sicily).

Figure 7. Messinian orange sulfur crystals (chemical formula: S_8) (sample size: up to 15 cm) from the "Mine mineral collection". Provenance: Talamone, Casteltermini Mine, Cozzo Disi (Agrigento).

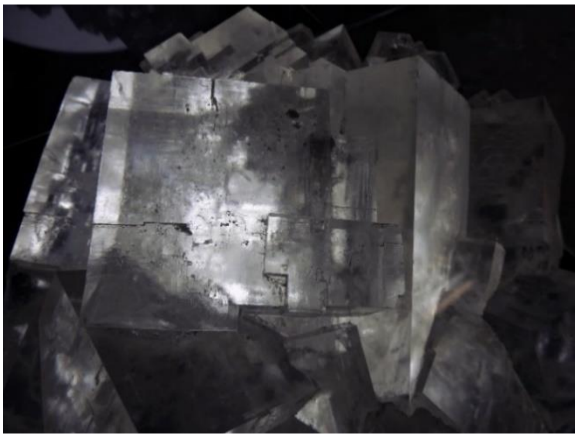

Figure 8. Messinian hyaline halite crystals (chemical formula: NaCl) (sample size: up to 30 cm) from the "Mine mineral collection". Provenance: Agrigento.

Figure 9. Mineralized rock with hyaline fluorite crystals (chemical formula: CaF_2) from the "Mine mineral collection". The mineralization is hosted in the metamorphic basement (phyllites) of the Mandanici Unit. Provenance: Tripi (or Recupero) mine, Alì stream, Alì Terme, Messina.

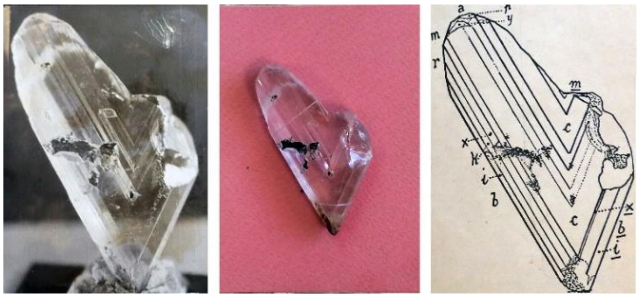

Figure 10. Geminate crystal of cerussite (chemical formula: $PbCO_3$) with iconographies from the "Geminate crystal collection". Provenance: Namibia, Africa.

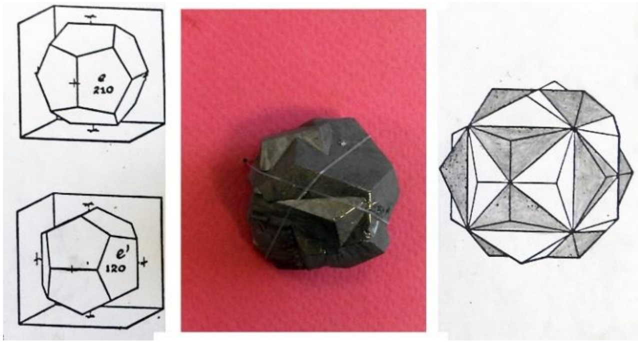

Figure 11. Geminate crystal of pyrite (chemical formula: FeS_2) with iconographies from Geminate Crystal collection. Provenance: Italy.

5. THE GEMINATE CRYSTAL COLLECTION

The "Geminate crystal collection" is composed of forty crystals specimens characterized by rare geminates of cerussite (Figure 10), albite, gypsum, pyrite (Figure 11), and staurolite. These samples were collected by an Austrian collector at the beginning of 1900 and donated to the University of Messina by the direct heirs. During the seventies, the collection was rearranged with descriptions and iconographies for didactic purposes [20].

6. THE SILICEOUS MINERAL COLLECTION

About fifty specimens of siliceous specimens belong to the collection. Most consist of agate, chalcedony, and jasper (Figure 12).

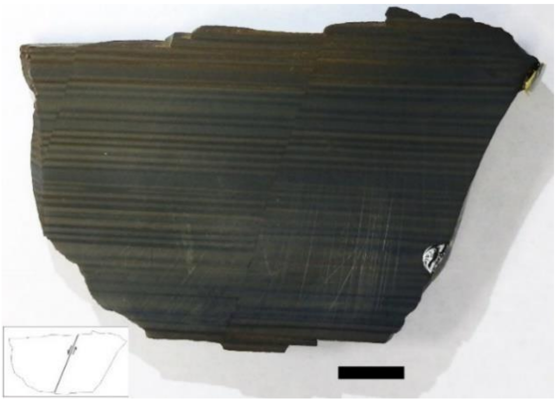

Figure 12. Jasper (chemical formula: SiO_2) of the "Siliceous mineral collection" showing a laminated sedimentary structure with gray and yellow layers, affected by a fault with mm displacement. The scale bar is 1 cm. Provenance: unknown.

7. THE MINERAL AND GEM DIDACTIC COLLECTION

Two hundred and nine are the specimens of the "Mineral and gem didactic collection". The most significant samples consist of sapphire, topaz, emerald, beryl, tourmaline (Figure 13 to Figure 15) [21], garnet, corundum, opal, amber (Figure 16) [21], and quartz (agate and chalcedony) whose provenance derives from all over the world. The oldest specimens date back to the 30s, whereas the most recent samples date to the 80s of the last century. Samples were initially exposed in showcases, but in the 80s, they were arranged into fourteen glass cabinets for didactic purposes. In addition, the didactic collection was used in teaching laboratory activities to show the different characteristics of natural gemstones and simulants, such as the cuts, shapes, colours, and pleochroism [10].

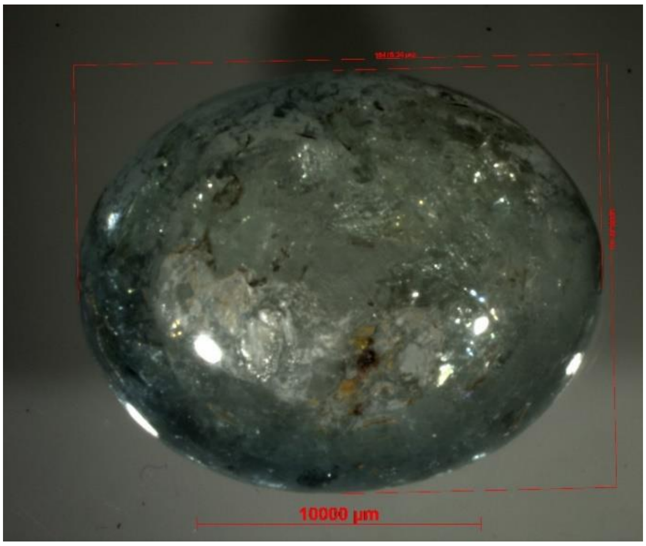

Figure 13. Green tourmaline gemstone with cabochon cut (chemical formula: (Na^+,K^+,Ca^{2+}) $(Li^+,Mg^{2+},Fe^{2+},Al^{3+},Ti^{4+},Mn^{2+})_{3-}$ $(Al^{3+},Cr^{3+},Fe^{3+},V^{3+})_6$ $(BO_3)_3[Si_6O_{18}]$ $(OH)_4$) (sample 119) of the "Mineral and gem didactic collection". Provenance: granitic pegmatites of ore deposits, Northeastern Brazil.

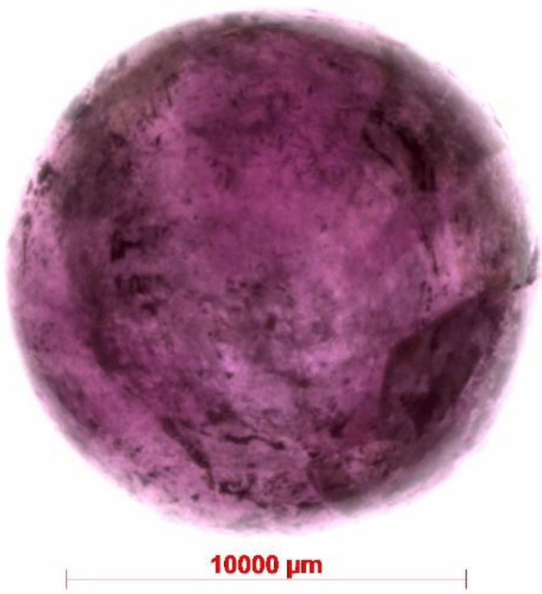

Figure 14. Pink tourmaline gemstone (sample 144) of the "Mineral and gem didactic collection". The sample derives from granitic pegmatites. Provenance: Pala district, San Diego County, California [21].

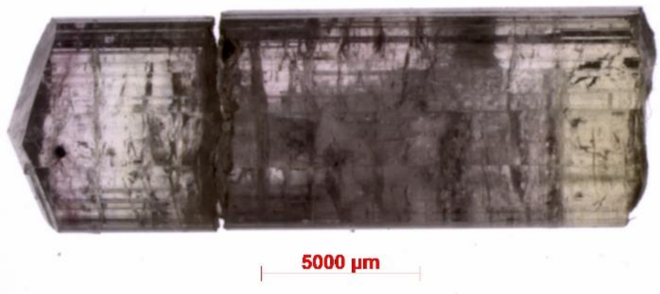

Figure 15. Bi-colored tourmaline crystal (sample 131) of the “Mineral and gem didactic collection”. It is possible to appreciate the pinkish and greenish banding, arranged orthogonal to the c-axis and parallel to cleavage and inclusions (the fracture developed parallel to the main cleavage). Provenance: Chile.

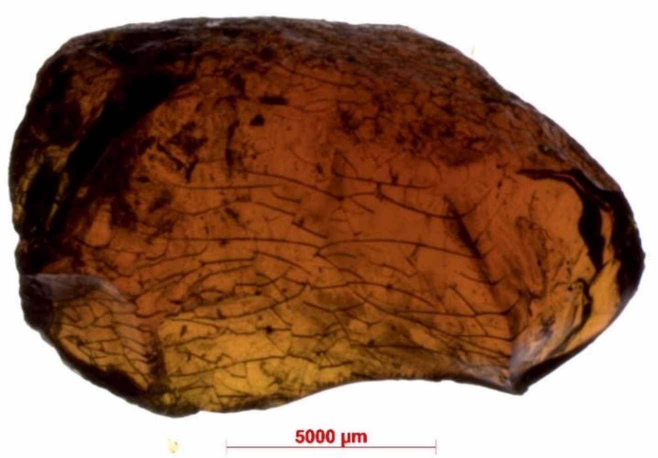

Figure 16. Amber specimen (fossilized plant resin) (sample 10) of the “Mineral and gem didactic collection”. Provenance: Simeto River (Catania).

7.1. Case study

The case study here presented regards a specimen of simulant lapis lazuli (sample 199B) compared with a specimen of natural lapis lazuli (sample 198B), both belonging to the “Mineral and gem didactic collection”.

Lapis lazuli is an ornamental stone. Lapis lazuli rock is a type of contact lazurite-dominated metamorphic rock used to produce gemstones, pigments for painting, sculpting and decorative materials since the past for its special blue color. Lapis lazuli originates as a consequence of magmatic intrusions and hydrothermal metamorphism of carbonate protoliths.

The paragenesis of lapis lazuli rocks is generally characterized by varying quantities of lazurite (blue; $\geq$ 30%; chemical formula: $Na_7Ca(Al_6Si_6O_{24})(SO_4)(S_3){\cdot}H_2O$), wollastonite (white), calcite (white to gray), specks of pyrite (“golden” yellow), and minor quantities of other minerals (augite, enstatite, diopside, other sodalite group members, olivine (forsterite), amphiboles (hornblende), and micas (phlogopite, muscovite) [22].

The typical blue color of the lapis lazuli may be due to the presence of S^{3-} sulfur in the crystalline lattice of the lazurite mineral [23]. The darkness or lightness of the blue color of the mineral may depend on the number of lazurite grains per given area of the white wollastonite matrix [22]. The white color of the rock is mainly related to wollastonite and calcite that may represent the second most abundant minerals. The typical gold lustre of the lapis lazuli is due to pyrite.

Calcite and pyrite minerals usually fill the rock fractures or form thin layers/bands or mottling. Calcite and pyrite bandings are typical structures of banded lapis lazuli.

Lapis lazuli gemstones generally are characterized by cabochon cuts and bead shapes. For being considered of high quality, gemstones must be rich in lazurite and show the presence of pyrite crystals, responsible for an appreciated metallic lustre of gold color.

The provenance of the specimen of the genuine lapis lazuli (sample 198B) is Ovalle in the Coquimbo Region in Chile. The rock was extracted from the Flores de Los Andes mine, where the Río Tascadero marine fossiliferous limestones, Lower Cretaceous in age, formed the host carbonate rock. Two contact metamorphic events affected these sedimentary carbonates during the Oligocene-Miocene. The first event was due to the intrusion of monzogranites (Late Oligocene), whereas the second one was associated with the sulfur-metasomatism depending on the intrusion of dacites and rhyodacties (late-middle Miocene to late Miocene). The superposition of these two geologic events made the Chilean lapis lazuli deposits unique. Hydrothermal alteration introduced sulfur in the rock, allowing the genesis of lazurite and pyrite mineralization. The Chilean lapis lazuli rocks form lenses up to 2 m long and 0.1 m thick hosted by wollastonite marble (deriving from metamorphism of Cretaceous limestones), and are composed of blue lazurite in association with wollastonite, calcite, haüyne, diopside, pyrite, and minor quantities of other minerals [22].

Stereomicroscopic observations

The two specimens were observed at the mesoscale and under stereomicroscope.

Sample 198B

The investigated reference material was sample 198B. It appeared as a gemstone with a typical cabochon cut, mostly blue colored (Figure 17).

Most of the gemstone was composed of a pale blue color mineral (lazurite, determined by Raman), showing thin white mineral relics, characterized mainly by pyrite in the inner part

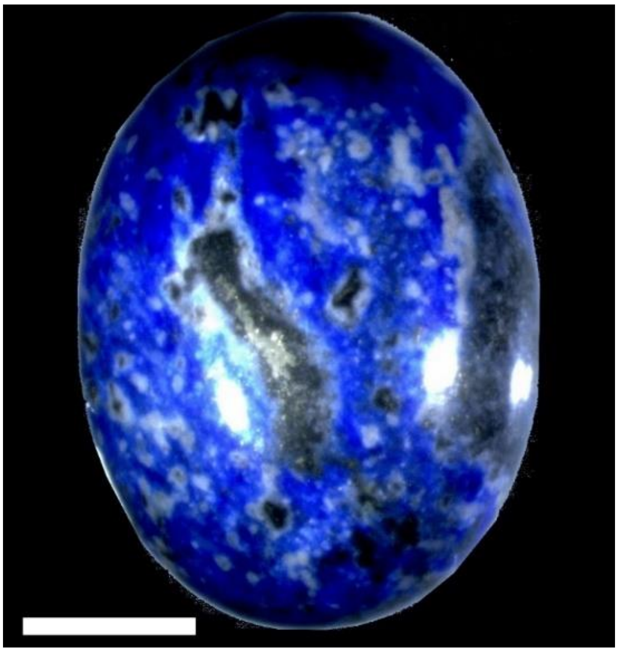

Figure 17. Lapis lazuli gemstone (sample 198B). The scale bar is 500 µm. Provenance: Ovalle, Flores de Los Andes mine, Chile.

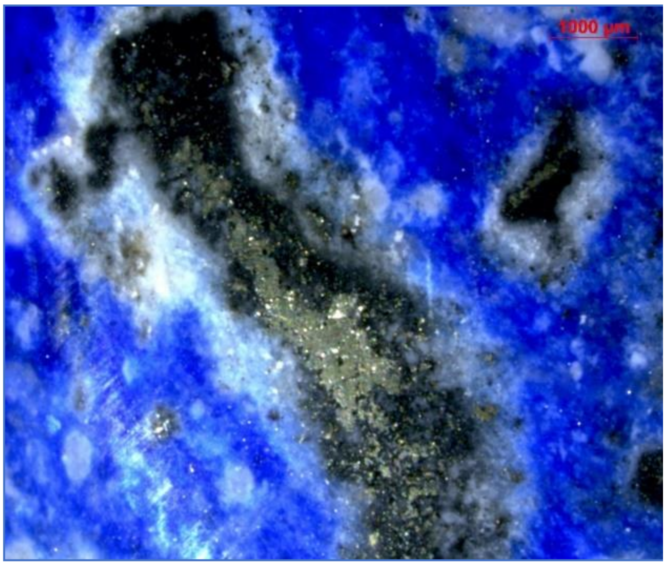

Figure 18. Detail of the central zone of the lapis lazuli gemstone (sample 198B, Figure 15), showing the structure with pyrite (metallic lustre) mineral aggregates and the percentage of the blue mineral grains in the white matrix.

(Figure 18). The typical cleavage and gold-colored metal lustre of pyrite or framboid crystals were easily observed (Figure 18). In addition, some isolated minerals (possible micas) with gold-colored metallic lustre and lamellar structure were also observed.

Sample 199B

The investigated simulant material was sample 199B (provenance: Iran). It appeared as a gemstone with an octagonal shape and pale bluish, orangish-yellowish, and whitish, in color (Figure 19).

The gemstone appeared microcrystalline and was cut by two fracture systems of different ages (Figure 19). Both the cut and color of the specimen revealed atypical for being a lapis lazuli rock.

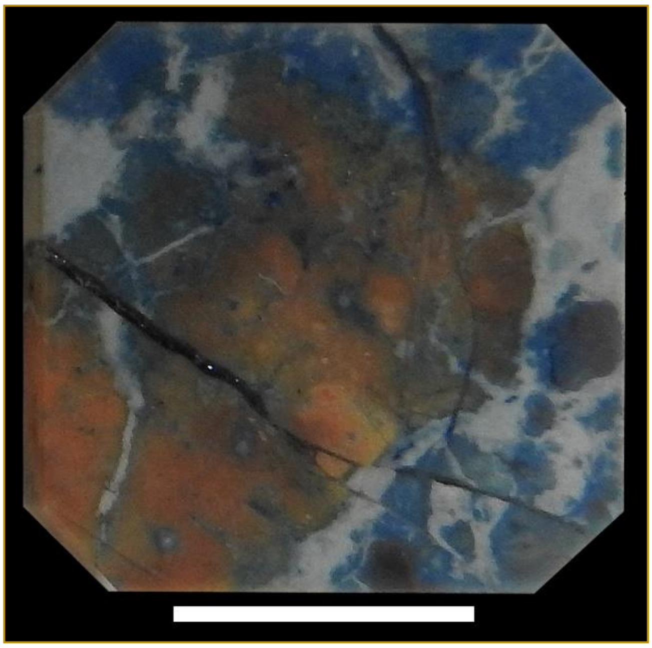

Figure 19. Simulant of lapis lazuli gemstone (sample 199B) showing varicolored microcrystalline texture, cut by two fractures systems of different ages. The scale bar is 1000 µm. Provenance: Iran.

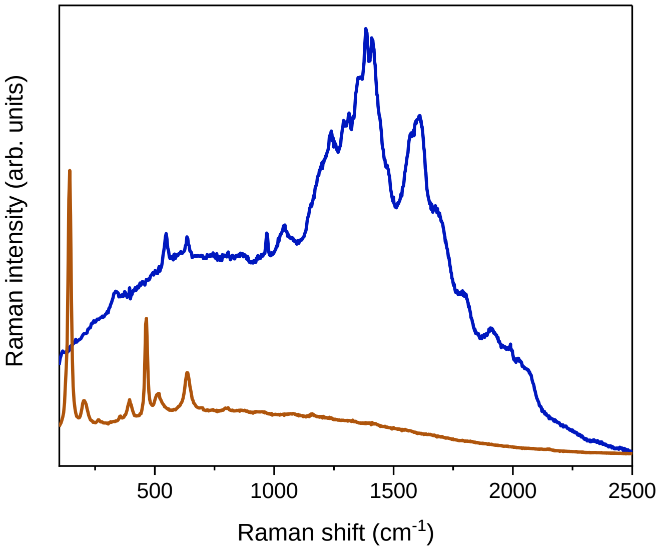

Figure 20. Experimental µ-Raman spectra of authentic (blue line, sample 198B) and simulant (brown line, sample 199B) lapis lazuli gemstones.

µ-Raman spectroscopy

The µ-Raman spectra of the authentic lapis lazuli gemstone (blue line, sample 198B) [23] and the simulant sample of lapis lazuli (brown line, sample 199B) were reported in the range between 100 and 2500 cm^{-1} (Figure 20).

The analysed pale blue mineral authentic lapis lazuli sample showed a spectral profile typical of lazurite with peaks at ~ 338 cm^{-1} (S^{4-} anions), 545 cm^{-1} (S^{3-} chromophore), 634 cm^{-1} (SO_4^{2-} anions), and 972 cm^{-1} (SO_4^{2-} anions) (Figure 20) [23]-[24]. In addition, broad luminescence bands appeared in the high-frequency range (1000-2000 cm^{-1}), ascribable to transition elements contained in the crystalline structure of accessory phases (Figure 20).

The pale blue mineral simulant lapis lazuli sample revealed the presence of quartz identified in the peak at ~ 465 cm^{-1} (Figure 20). Moreover, the contributions centred at ~ 144, 205, 394, 518 and 638 cm^{-1} were assigned to anatase (titanium dioxide, TiO_2) (Figure 20).

8. THE FOSSIL COLLECTION

The fossils housed in the laboratory of palaeontology consist of more than 1800 specimens, mainly belonging to Invertebrates (Figure 21). The collection results from about 80 years of acquisitions and recoveries by university researchers. In this time, the fossil collection had been entrusted to palaeontology professors and moved several times during laboratory work. Moreover, the collections had never been reported to the competent Superintendence, as required by the Protection of the Cultural Heritage laws.

In 2013, one of the Author (A. C. M.) received the responsibility of the Laboratory of Palaeontology of the Department MIFT, including the Palaeontological collections. Unfortunately, the original register was not deposited and got lost. An old database has been recovered by one of the Authors (A. C. M.), who participated in its filing during the 90s of the last century. The inventory has been revised and updated (Figure 21). The taxonomic assessment has been completed when possible. Unfortunately, the provenance of some specimens is yet unknown. Macro Foraminifera are included. On October 8th, 2013, the complete inventory was transmitted to the

Superintendence of Cultural and Environmental Heritage of Messina. In the same period, two graduation theses have been addressed to realize a photographic catalog of the most significant specimens with didactic purposes.

Recently, the micro palaeontological collection, curated by Donata Violanti in the 80s of the last century, has been recovered in the deposits of the Department, accompanied by a chartaceous register stored in a small drawer. The revision of the inventory by two of the Authors (R. M., R. S.) and the digital database are in progress and, when completed, will be transmitted to the Superintendence.

The palaeontological collections are mainly addressed to palaeontology students and include fossils representative of taxonomy, biochronology, palaeoecology, and paleobiogeography. Some specimens have also been used to illustrate different kinds of taphonomic processes and fossilization in two cabinets included in the faculty museum. Boxes with sediments and fossils are also available, to complete the students' direct experience on fossils. The macrofossil collection is supported by a collection of fossiliferous sedimentary rocks. It can also be used as a reference for the taxonomic assessment of new finds and for ascertaining possible palaeontological frauds.

Due to its didactic use, the collection of macrofossils is hosted in a large drawer. A project exhibition inside the laboratory is in progress. Four cabinets will be set up to show fossils following taxonomical criteria. Few specimens represent vertebrates but they are highly representative. Part of the lateral scale cover of the fish Lepidotes sp. (Figure 22) and a partial rostrum of an Ichthyosaurus (Figure 23) are preserved.

Lepidotes species were spread during Mesozoic and characterized by thick rhomboid scales, which were well observable in the sample (Figure 22). Ichthyosaurs were Reptiles adapted to aquatic environments, widespread from Early Jurassic to Late Triassic.

The historical value of some local fossils will be enhanced. Some specimens have a historical and scientific background linked to the research carried out in the Strait of Messina area by Giuseppe Seguenza in the XIX century. Studying the Plio-Pleistocene outcrops of Messina and Reggio Calabria, G. Seguenza collected an impressive number of specimens and published papers. He significantly contributed to the Plio-Pleistocene stratigraphy. Unfortunately, the rich collection of the eminent scientist went lost during the 1908 earthquake in

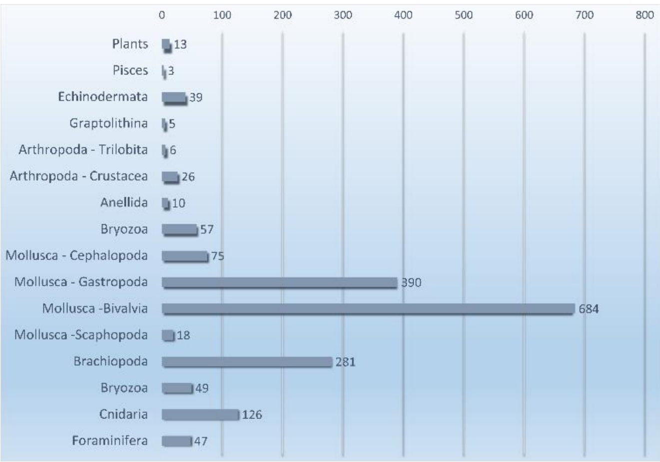

Figure 21. Macro fossil collection of MIFT: number of specimens for each taxonomical group.

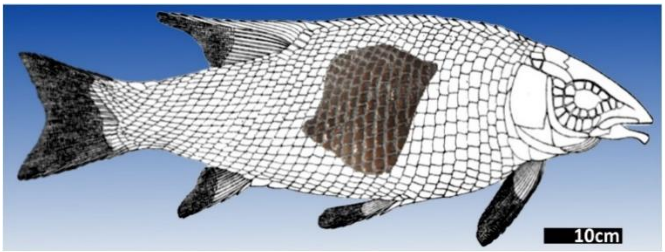

Figure 22. Photograph of the specimen of *Lepidotes* sp. (P001-MIFT: brown color lateral scale cover shown in the central part of the figure) illustrated on the reconstruction of the whole fish (*Lepidotes* drawn under license wiki commons).

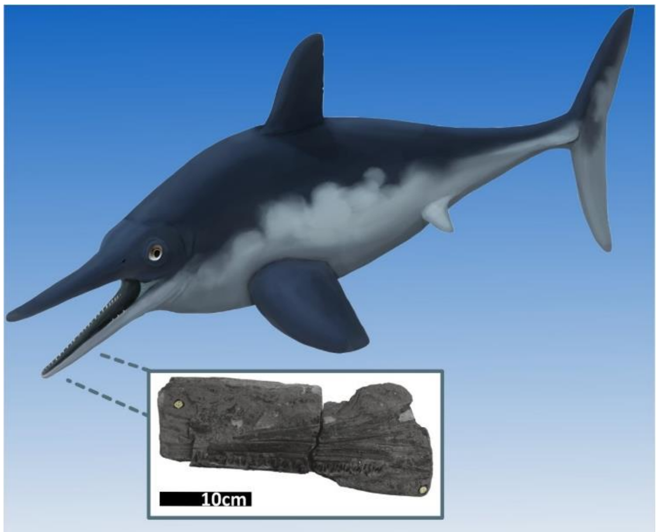

Figure 23. Specimen of *Ichthyosaurus rostrum* (MIFT) compared to living restoration (license wiki commons).

Messina but he and his son Luigi, also a palaeontologist, donated and exchanged some collections with several museums.

The microfossil collection of Giuseppe Seguenza is composed of 28 samples of foraminifera, Pliocene to Recent in age, collected from sediments of the Messina province (Rometta, Scoppo, Masfa outcrops) (Figure 24). The foraminifera have been studied and reorganized and were mainly used to study these outcrops [25]. The specimens were related by Seguenza to the Zanclean (Figure 24), the stage that he instituted as the basis of Pliocene. The name of the stage was inspired by Zancle, the ancient name of Messina.

9. DISCUSSION AND CONCLUSIONS

The geological historical collections of the University of Messina host an important geoscientific cultural heritage that deserves to be preserved and valorised. In Italy, the obligation to guarantee the safety and conservation of the cultural heritage belonging to the universities was ruled by law only in 2004 (Article 30 of the "Urbani Code"; Legislative Decree 42/2004). These actions are crucial for ensuring scientific and historical documentation, education, and public outreach for future generations.

Moreover, most specimens of the collections derive from abandoned mines of Sicily and other areas of the world.

Consequently, it is today essential to the role and mission provided by geological museums [26] of being "archives of memory". Other programs for re-evaluating the collections may regard the organization of naturalistic itineraries for

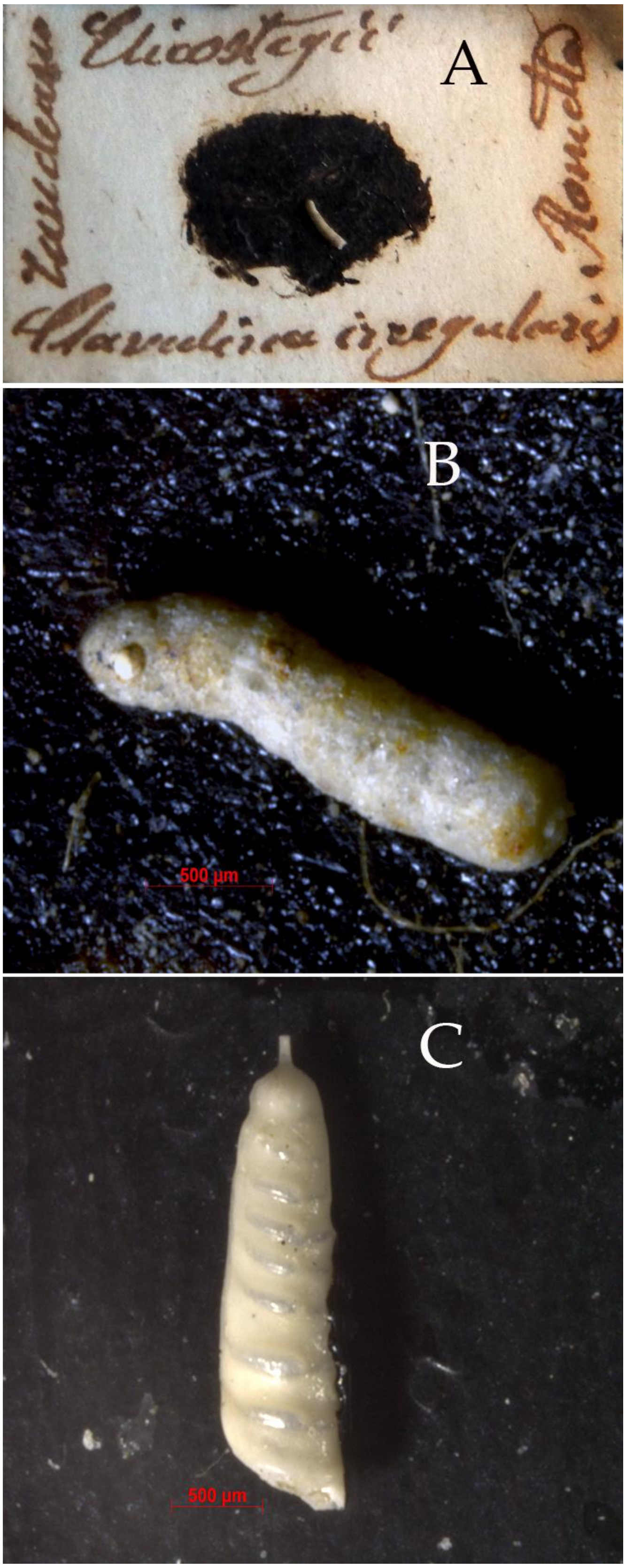

Figure 24. Specimens of Foraminifera from the G. Seguenza collection. A-B) *Martinottiella communis* (d'Orbigny) 1826 (specimen 222-02) (Age: Zanclean, Provenance: Rometta, Messina) with the original handwritten label by Seguenza. C) *Vaginulina legumen* Linneo (specimen 222-17) (Age: Zanclean; Provenance: Scoppo and Masfa, Messina).

undergraduate and graduate students and tourists in the sites of provenance of the samples. The improvement of geological museums and geological heritage [26]-[30] present in geosites and geodiversity sites are strategic tools for promoting sustainable geo-conservation and geo-education [31].

The characterization, using optical observations under a stereomicroscope (and SEM-EDS) and µ-Raman spectroscopic analyses, of natural and simulant lapis lazuli samples of the "Mineral and gem didactic collection", showed as this case study allowed to classify: i) the gemstone of the specimen 199 B, as a natural jasper, a rock used very commonly as lapis lazuli simulant; ii) the gemstone of the specimen 198B, as a lapis lazuli mainly composed of pale blue lazurite, referable to third-quality materials, compatible with the Chilean lapis lazuli rocks, being composed of pale blue lazurite, with appreciable amounts of gray and white minerals and aggregates of pyrite. Further SEM-EDS and Raman analyses are in progress to ascertain the provenance of the lapis lazuli gemstones. The analyses carried out on the fossils of the collection ascertained that no specimens suspected to be fake were present. The acquisition of 3D data for some vertebrate specimens of significant scientific value is in progress.

The analyses carried out in the present work demonstrated that the optical observations under microscope with the µ-Raman spectroscopy may provide a useful, fast, and economic approach to properly discriminate between genuine and fake materials. Moreover, the same approach is classically used in forensic sciences regarding criminal cases of frauds [32], conflict minerals [6], [33], and illegal activities [6], [34], [35].

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