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FROM CLAYS TO POTTERY: ROLE OF GEOMATERIALS IN THE SOCIAL–TECHNOLOGICAL DEVELOPMENT OF THE MESSINA TERRITORY (SICILY, ITALY) AND ARCHAEOLOGICAL–HISTORICAL INFORMATION ON THE MAIN KILNS

Giuseppe Sabatino [a], Melania Franzone [a *],
Maria Clara Martinelli [b], Maria Teresa Rondinella [c], Francesco Italiano [d],
Maria Teresa Caccamo [a], Francesca Mezzatesta [a], Salvatore Magazù [a],
Alessandro Tripodo [a] and Marcella Di Bella [d e]

Abstract. This contribution is intended to answer the question of why in teaching approaches it is important to speak about territory? The answer to the question is driven by the consideration that the territory, including the established human activities, encompasses the history, the events and the culture of the people who populated it. On this regard, it should be noted that the relationship between natural elements and human activities that refer to a given territory has a dynamic character since both influence each other and help to write the history of that place. In this framework, the proposed method is used as an interdisciplinary approach to the theme of clay minerals. These latter are hydrous aluminium phyllosilicates, with variable amounts of iron, magnesium, alkali metals, alkaline earths. They are the main constituents of soils, and have been used by humans since ancient times in agriculture and manufacturing. For this reason, clays played a basic role for the human civilization process since its earliest periods. Clays are recognized amongst the most important rock products, both as raw material and in the form of pottery, bricks, tiles, terra-cotta and many other tools for daily use. This is particular evident in Sicily, where, since ancient times, the availability of local clay sources favoured the diffusion of clay-artefacts and related workshops found over the territory. This paper makes reference to a lecture addressed to university students and includes: i) the description of the main mineralogical features and properties of clay minerals; ii) a brief discussion on the role played by clays in terms of clay-artefacts production in the historical and cultural evolution of the Messina territory; iii) a description of local clay outcrops; iiii) a presentation of the main kilns over the Messina territory, and in particular of unpublished archaeological information on the S. Pier Niceto kilns. The proposed approach aims to increase the interest of students towards the significant aspects that affected the social-economic growth of the Messina's territory and on the importance that geo-materials had in the technological evolution of its civilization process.

1. Introduction

It is well known that the *European Landscape Convention* recognized to each landscape an identity reference value for the population that relates to it. As far as the education point of view is concerned, it should be stressed that the identity process reaches a crucial point during youth. As a matter of fact, nowadays, youngs are led, by modern society models, to have a distracted or disinterested look at the territory in which they live. Although in many cases young people manifest towards the place where they live a kind of rooting, this is mainly due to the fact that they were born or have spent most of their lives there. Others have a "functional" relationship with territory, appreciating it mainly on the basis of the quantity and quality of the services it offers; in any case, most of them, being used to living in a given place, feel that they know enough about it and therefore tend to take it for granted. It has also been found that the link with a given place is often predominantly unconscious in nature and its strength does not emerge until attention is brought to it. In this framework, the present work aims to bring out an emotional link with the Messina's territory through an interdisciplinary approach to the theme of clay minerals.

The term clay (A.S. cloeg; Welsh clai; Dutch kley) although used in a scientific sense to include a variety of argillaceous earths (Fr. argile = clay) used in the manufacture of daily use objects (e.g. bricks, tiles, pottery) and ceramic products (Gr. keramos = potter's earth) generally, is really a word of popular origin and use (Searle 1912; Ion *et al.* 2016). Consequently, it is necessary to consider, when dealing with geological or other problems of a scientific nature, that this term has been included into scientific terminology and that its use in this context not infrequently leads to confusion (Searle 1912). The world "clay" has ambivalent definitions (Bergaya 2000). On one hand it is used to define any soil particle smaller than 2 μm, but on the other hand it includes a large group of microcrystalline secondary minerals based on hydrous aluminum or magnesium silicates characterized by sheet like structures (Manahan 2000; Sen 2017). For a geologist, clay minerals are fine particles (< 2 μm in size), which are also the major constituents of rocks, sediments and soils. For an engineer, ceramicist or mineralogist, clay minerals belong to the family of phyllosilicate (or sheet silicate) of minerals, which are characterized by peculiar properties of plasticity, shrinkage, and hardening upon drying or firing. The types and characteristics of clay minerals depends on their origin of occurrences (Sen 2017).

Clay and clay minerals have been used since the early beginning of the civilization, and nowadays they are very important for industrial purposes and productions. Yet the origin of the substances we know as 'clays', the processes behind their formation and most of the causes of their features, are so important to make their use so extended in arts and sciences. The artefacts belonging to the ceramic heritage are mostly based on all clay types used by humans over the times, as the clays sources were easily available and people were interested to produce ceramics and pottery necessary for daily use.

Clays are composed of hydrated aluminum silicates, with the addition of a variable amounts of other elements as magnesium, iron, calcium, and potassium (Biot 1956; Campanella and Mitchell 1969). Clay minerals are granular and plastic, and when mixed with water they become hard, if combusted. The production of ceramics was first implemented in the Neolithic period. Greeks and Romans developed lime mortar cements, with a remarkable resistance, and some of these archaeological sites stand testimony to this day (Maniatis

2009). The Industrial Revolution of the eighteenth and nineteenth centuries registered significant improvements in the ceramic industry, while the twentieth century contributed to the scientific understanding of these materials (Ion *et al.* 2016).

In this context, Sicily is worldwide famous for its historical tradition of ceramics, also due to the availability of clay outcrops over the territory (Fig. 1 A), in fact archaeologists have discovered pottery dating back to 2400 BC. The abundance of prehistoric settlers from all over the Mediterranean area brought different styles and aesthetics that can still be found in the artwork today. The Greeks brought with them their distinct vases, amphorae (the iconic ancient Greek jar with two handles and a narrow neck) and urns (Fig. 1 B). The Romans introduced terra sigillata, or intricately detailed red pottery. However, the most notable art and design contributions came from the Arabic culture. Nowadays, Sicily still hosts a thriving ceramics industry, centered in four towns: Caltagirone, Santo Stefano di Camastra, Burgio and Sciacca. Each of them marked by its own distinct art style.

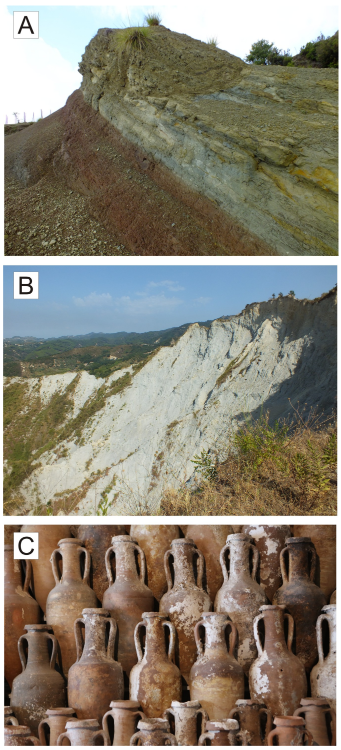

FIGURE 1. A) Clay outcrop at piano Inadà, in the Messina province (latitude 38° 7'47.28"N; longitude 15°24'54.37"E Photo by M. Franzone); B) Clays outcrop at 350 mt a.s.l., between "Serralizzi" and "Lupo" hills, in the Messina province (latitude 38°12'56.48"N; longitude 15°28'28.01"E Photo by M. Franzone); C) Amphores of the "Roghi" wreck dated to 196-173 BC discovered at Capo Graziano, Filicudi Island, actually kept to the Museo Luigi Bernabò Brea, Lipari Island.

This paper contents are addressed to university students with the main aim of increasing their curiosity and interest on the fundamental role that geomaterials gained for the technological development of our society. To achieve this goal we focused the attention on the importance assumed by clay minerals as natural resource in the socio-economic growth of the Messina territory. The topic was treated starting from a summary on the main mineralogical and physico-chemical characteristics of clay minerals, keeping on with a brief discussion on the clay-artefacts production in Sicily, and concluding with the historical/archaeological description of pottery-workshops/kilns of the Messina province.

2. Clay definition and mineralogical features

Clays are sedimentary clastic rocks, endowed with plasticity, which are formed by natural disintegration of pre-existing rocks or mother rocks. They consist mostly of phyllosilicates (produced by the alteration of other silicate minerals) and have a texture parallel to stratification. Other common components of the clays are quartz and mica, however present only in the coarsest fraction. The clay minerals are essentially concentrated in the finer fractions of sediments and soils. They are usually but not necessarily ultrafine-grained, normally considered to be less than 2 micrometres in size on standard particle size classifications. Crystals of clay minerals show colours, which generally depend on the concentration of the additional oxides and their contents (Fig. 2).

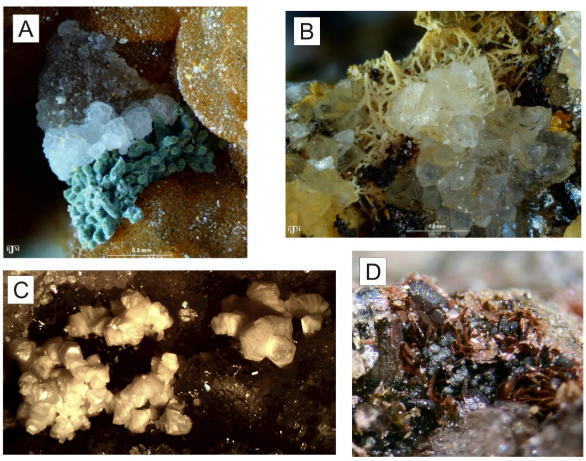

FIGURE 2. A) Montmorillonite (green) strands with dolomite (white) and calcite (clear) on a vugh lining of yellow stained phillipsite, from Otago Region, New Zealand (by Rod Martin; https://www.mindat.org); B) Calcite and manganese oxides on "worms" of montmorillonite from Otago Re--gion, New Zealand (by Rod Martin; https://www.mindat.org); C) White, hexagonal plates in clusters of Kaolinite from Arizona, USA (by Dale Dame and Rolf Luetcke; https://www.mindat.org); D) Red-brown illite with black siderite from KwaZulu-Natal, South Africa (by Giorgio Bortolozzi; https://www.mindat.org).

From a chemical point of view, phyllosilicates are hydrated silicates, mainly consisting of silicon, aluminum, magnesium and iron. Their structure is based on the basic unit $[SiO_4]^{-4}$ characterized by typical form of tetrahedron, with a silicon atom in the center and 4 oxygen atoms at vertices (Fig. 3) (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999). In the phyllosilicates each tetrahedron is connected to three other tetrahedra through the vertices (oxygenals) of a base. Thus planar extensions (sheets) of tetrahedra is formed. The repetitive unit is $[Si_2O_5]^{-2}$ or multiple of it (Bueti n.d.).

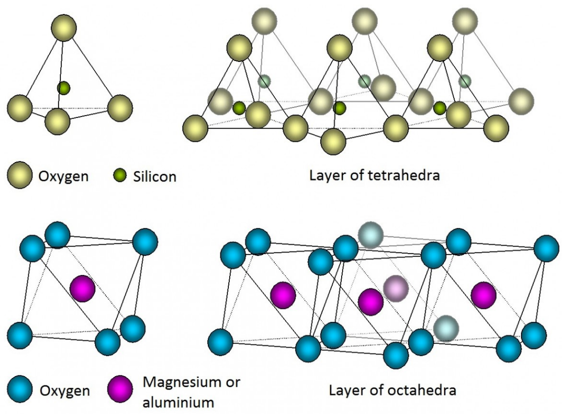

FIGURE 3. Clay structural units: tetrahedra and octahedra (after Jordan, 2014; https://blogs.egu.eu/divisions/sss/2014/09/05/lightening-the-clay-i/).

2.1. Structure and composition of phyllosilicate minerals. In Fig. 3 it is shown how the tetrahedra $[SiO_4]^{-4}$, joined together by the vertices of a base, form hexagonal rings with planar arrangement and present the fourth vertex (oxygen) stretched perpendicular to the basal plane. This structural element is called tetrahedral sheet (T).

The free valences of the apical oxygenals of the tetrahedral sheet are saturated by the right superposition of an octahedral sheet (O), which constitutes the second basic element of the phyllosilicate structure. This sheet is formed by the planar repetition of octahedra formed by a central ion (generally Al or Mg) and by six vertically hydroxyl groups (OH^-). The octahedrons are joined together by an edge and rest on the same plane with one of their triangular faces. On this plane, the faces of the three octahedrons share an OH^- hydroxyl and place the other six at the top of a hexagon.

The connection between the octahedral sheet and the tetrahedral sheet occurs through the apical oxygenals of the latter (Fig. 3). The connecting oxygenals, which in plan are arranged at the vertices of a hexagon, replace the six hydroxyls, also arranged at the vertices of a hexagon, corresponding to two vertices of each of the support bases of three octahedrons. The third vertex of each of these triangular bases of support remains a hydroxyl, common to three octahedrons, located in the center of the hexagon identified by the six oxygenals. A plan is then formed, in common between tetrahedra and octahedrons, with mixed composition O^{2-} + OH^{-} (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).

The octahedral sheet can be of two types, depending on the value of the coordinating ion which is located in the center of each octahedron. If a divalent ion is present (generally Mg, sometimes Fe^{2+}) the octahedral sheet is defined as a burnt type. In this case, each of the three octahedrons with a triangular face associated with the plane of the apical oxygenals of the tetrahedral sheet has all the saturated charges. In this way, three octahedrons are associated with each set of hexagonal ring-shaped tetrahedrons, each with the center occupied by the coordinating ion and its configuration takes the name of triottahedral (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999).

When, on the other hand, the center of the octahedrons is occupied by a trivalent ion (generally Al, sometimes Fe^{3+}), the octahedral sheet is defined as a gibbsitic type. In this way, three octahedrons are associated with each set of hexagonal ring-shaped tetrahedra, two of which have a coordinating ion in the center and one empty. This configuration is defined as an octahedral to emphasize the occupation of only two out of three octahedrons by the trivalent ion.

As mentioned, the main structural motif of the phyllosilicates is given by the superposition, in different ways, of the tetrahedral sheets (or layers) (T) and the octahedral sheets (O). The unit that is formed is indicated by the term packet. They can distinguish the following basic stratiform structures:

– *Two-layer fillosilicates*: the fundamental layer is given by the superposition of a tetrahedral and an octahedral sheet. This package is indicated by the T-O symbol. To this family of phyllosilicates, with dioptahedral structure, belong: kaolinite [$Al_2Si_2O_5$ $(OH)_4$] (Fig. 4 A) (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).
– *Three layer phyllosilicates*: the fundamental layer consists of an octahedral sheet between two tetrahedral sheets. This package is indicated by the symbol T-O-T. Three groups of phyllosilicates with T-O-T structure can be distinguished according to the substitutions and the type of compensation of the fillers: micas, smectites, vermiculiti (Fig. 4 B) (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999).
– *Mixed layer fillosilicates*: two or more packages with structures referable to those described overlap according to repetition periods that can be regular or irregular (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999). Among the most common terms are present illite. Illite can be compared with a muscovite, from which it differs by the presence of water molecules in the interlayer position and by a lower structural order. Illite, typically, has only Al in the octahedral position; therefore it is dioctahedral. In general, the entry of a modest content of water molecules into the interlayer spaces does not determine a variation in thickness. The entry of water molecules into the interlayer

is generally favoured by the loss of K and the consequent weakening of the bond that holds the T-O-T packets together (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).

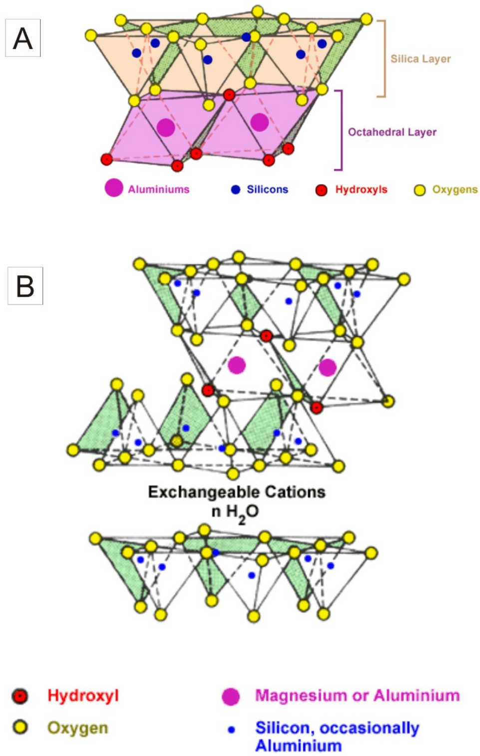

FIGURE 4. A) Structure of kaolinite; B) structure of montmorillonite (after https://www.ihrdc.com/els/ipims-demo/t26/offline_IPIMS_-s23560/resources/data/G4105.htm).

2.2. The physicochemical properties of clay minerals.

2.2.1. *Texture.* The clay minerals are the main components of the clays, they have extremely small dimensions (a few thousands of a millimeter). They are transported in suspension in the waters and, given their size, sedimentation is favoured by the phenomenon of flocculation. Based on the particle size classification, clays are characterized by particles smaller than 2 micrometers (2 μm) in diameter. They differ, depending on the environment of deposition in:

- primary (residual) clays: such as kaolin. They consist of even relatively large and angular particles, have a non-uniform particle size and, inside them, may contain residues of mother rock; these factors make the material little plastic compared to secondary clays;

- secondary (sedimentary) clays: having undergone a strong transport process, they are made up of smaller, more uniform and more rounded particles than those of the primary clays. They are tending towards white, yellowish or greenish. A dark gray or blackish colour can be given by the presence of carbonaceous substances of organic origin. A bluish or dark green is attributed to the prevalent presence of iron compounds with oxidation number +2, while a light yellow to brown red colour is given by the prevalence of iron compounds with oxidation number +3. An intense brown red colour, tending to purplish, generally indicates the presence of manganese compounds combined with those of iron. The black, green or blue clays, after long exposure to atmospheric agents, acquire a yellowish or reddish tint on the surface due to oxidation processes mainly due to oxygen present in the air (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).

2.2.2. *The "electrically reactive sites" of clay minerals.* The crystal-chemical characteristics regulate a large part of the properties possessed by clay minerals. We can distinguish: properties connected to the surface characters of the particles and properties connected to the characters of the interlayer structural sites. In both cases, these are properties that derive from electrostatic charge imbalances, triggered by substitutions of the coordinating ions in the tetrahedral and octahedral sheets and not rebalanced by a correct input of ions in the interlayer positions. This situation generally depends on the fact that the bonds between layer and layer are always very weak and, therefore, subject to easy modifications due to the interaction of clay minerals with the chemical-physical factors of the environment. The surface characteristics of the clay particles depend on the fact that the deviations from the neutrality situations are resolved in the appearance of negative charges on the free surfaces of tetrahedral sheets and positive charges on the free surfaces of octahedral sheets. The characteristics of the interlayer sites are connected to the intensity and / or stability of the bonds that act between layer and layer and to the nature of the ions that can occupy these positions. Depending on the chemical and physical characteristics of the environment that interacts with the clay minerals, the same ions that are in an interlayer position can be hydrated, removed, exchanged with other ions or complexes more permanently housed in the crystalline structure. It is also possible, moreover, that water molecules enter the interlayer positions so abundantly that they determine a significant increase in the interlayer space without substantially disturbing the rest of the structure (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).

2.2.3. *The adsorption.* The characteristics of the electrically reactive sites are the basis of peculiar properties possessed by clay minerals and clays. Among the most typical and of a more specific application interest, the properties connected to the adsorption phenomena which, in relation to particular reactions, are measured as cation exchange capacity, should be mentioned. Adsorption is the effect of the attraction exerted by the charge of clay minerals on ions and / or molecules that are retained on the surface of the particles or in the structural positions of the interlayer. The electrostatic surface characteristics, together with the very small size of the particles, determine a behaviour of the clay minerals similar to that of colloidal substances. Negative charges attract positive ions that form a film, adhering to the particles. This positive ion film determines, in turn, attraction of negative ions or polarized molecules that form a second external film, more weakly linked to the whole. The ability of clay minerals to adsorb and retain water molecules on their external surface determines a fundamental property for the definition of clays, or plasticity. Plasticity depends on the lubricating action that the water molecules exert between the lamellae, allowing the relative movement of each other. The corresponding quantitative parameter is determined by measuring the time that the clay mass takes to regain the original shape after deformation has been exerted on it by means of an oriented pressure of very short duration. When, on the other hand, an oriented pressure is exerted for a long time, the water molecules move away from the affected area, and the partially dehydrated mass retains the shape that has been imposed on it, this factor is linked to another property of the clay called modelling, useful for applications in the ceramic industry, from bricks to fine porcelain. The adsorption and retention of water also has negative aspects, linked to the phenomena connected to the particular instability of the clayey slopes in cases where the soils, soaked in water, are involved in differentiated sliding phenomena that are the basis of the instabilities landslide (Martin 1960, 1962). In recent years, research aimed at the treatment of clay minerals to make their adsorption power more selective has acquired particular development. It is for example the case of smectite, whose interlayer is artificially and permanently expanded through the insertion of appropriate organic molecules. This results in a microporous structure capable of capturing ions and/or compounds with predetermined fundamental characteristics in the available spaces (*Aipea (Association Internationale Puor l'Etude des Argiles), Incontri Scientifici, Istituto di Ricerca Sulle Argille, Metodi di Analisi di materiali argillosi, Tito Scalo, 28-30 settembre* 1999; Bueti n.d.).

3. Clay outcrops in the Messina province

Clay units used in the past as raw materials source to be transformed into "ceramics" have been identified through an integrated study carried out by (Triscari *et al.* 2007). Clay units are widespread in the North-Eastern corner of Sicily with several outcrops on the Tyrrhenian side and with less wider appearances occur on the Eastern Ionian side. On the Ionian coast of Sicily, the colony of Naxos near Taormina in the Messina Province, signs in 734 B.C. the first ever settlement of Greeks, from where they started to complete the colonization of the island founding Messina, Syracuse and the other colonies. The authors realized a map (1:50.000 scale; Fig. 5) of the clay units of the North-Eastern corner of the Messina Province finalized to archaeometric studies. The map is comprehensive of all the clayey units and/or complexes reported in literature and to the newly detected lesser-known outcrops. It reports the clay formations together with representative archaeological finds logs in key locations (Fig. 5). Geographical distributions of outcrops are discussed for past times accessibility. Significant result come from clay units in the surrounding of the Giardini-Naxos area, both important either for the Greek colony of Naxos either for all the impressive brick constructions of the Roman Taormina (Theatre, Naumachie, water duct etc.). The clayey units of Barcellona and Valdina are mostly referred to the Milazzo Greek colony and significant hypothesis arise about the possibility of using these formations for the Aeolian ceramics with volcanic inserts too. In the town of Messina only the clayey portion belong to the "molassic complex" shows to have been a potential source of raw material to be transformed into "ceramic".

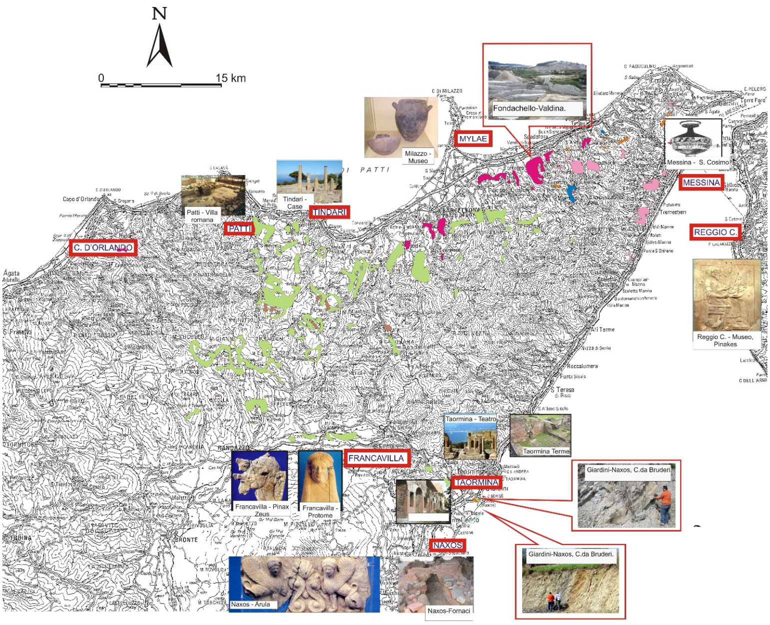

FIGURE 5. Schematic map showing the clay outcrops of the Messina province (by Triscari et al., 2007).

4. When clay become ceramic: the historical tradition of pottery production in Sicily

The art of pottery is one of the oldest human activities, in fact, the discovery of mixing clay with water and cooked seems to have happened in the East between the end of the VI and the beginning of the V millennium B.C. It is believed that the discovery of ceramics occurred thanks to the accidental observation of the clay hardening after the action of the fire. Even in our Sicilian reality we can affirm that of ceramics is the most illustrious and oldest art.

Pottery first appeared in Sicily in the Neolithic period. The geographical position of Sicily has always favoured dominations and has been the object of conquest of the most important civilization process. The Phoenicians, Greeks, Carthaginians, Romans, Byzantines, Arabs, Normans, Swabians, Spaniards and French have landed on the island. Despite the different dominations, Sicilian ceramists have always expressed their Sicilianity in the production of ceramics, thanks to the presence of the Earth (clay), water and fire, which are the same elements present in the culture of Sicily.

The arrival of the Arabs in Sicily gave a strong impulse to the art of ceramics thanks to the introduction of glazing, a technique from the East. The lead glazing of the pottery was a technique that came from Persia, Syria and Egypt and consisted of a mixture of substances sprinkled on the ceramic body, which is then vitrified during cooking.

Currently the most important production centres in Sicily are Santo Stefano di Camastra, Caltagirone and Sciacca. S. Stefano di Camastra, is a town in the Messina province, which was founded at the end of the 17^{th} century by the Duke of Camastra on 6 June 1682. Traces of ancient furnaces and various archival evidences have led to the assumption of past ceramic activity since the Arab time.

5. Kilns in the Messina province: historical-archaeological information

A presentation of the main kilns of the Messina province is reported below. This topic has been dealt from an archaeological and historical point of view. Moreover, unpublished archaeological information on the S. Pier Niceto kilns are also reported.

5.1. San Pier Niceto. During the construction of pipeline for natural gas transportation in Montalbano Elicona-Messina spread (archaeological excavation by Superintendence of cultural heritage of Messina, 2008), two artisan kilns, with vertical development on a round plan were found in Contrada Zi Fronte of San Pier Niceto village. They were partly built with bricks and partly leaning against the surrounding land. A vertical furnace (Di Caprio 1971, 1992; Di Caprio 2007) is a fixed structural plant intended for firing clay artefacts, which always remain separate from the fuel used to cook them. It consists of two distinct chambers, one below, called combustion chamber, and one above, called cooking chamber, communicating each other through a perforated cooking surface. This is a grid surface on which the items to be cooked were stacked, and it is crossed by many small holes that were used to allow the passage of heat, gases and all other combustion products from the chamber below to the cooking chamber. Access to the combustion chamber is anticipated by a *praefurnium*, a corridor that leads to the chamber below through an opening, with the function of conveying the air from the outside so that the combustion can be better fed inside and create the perfect draft.

About the first found structure (Fig. 6), the combustion chamber and the *praefurnium*, the perforated cooking surface and a small part of the cooking chamber (height 1.9 m) are preserved. The perforated surface (diameter 1.90 m) was composed of twenty-five square and rectangular holes of varying sizes; it was supported by eleven pillars; the combustion chamber is partly built with bricks and partly against the surrounding ground; the internal vault was built with bricks, which in the upper part melted together resulting completely blackened, due to having been in direct contact with the flames released by the fuel.

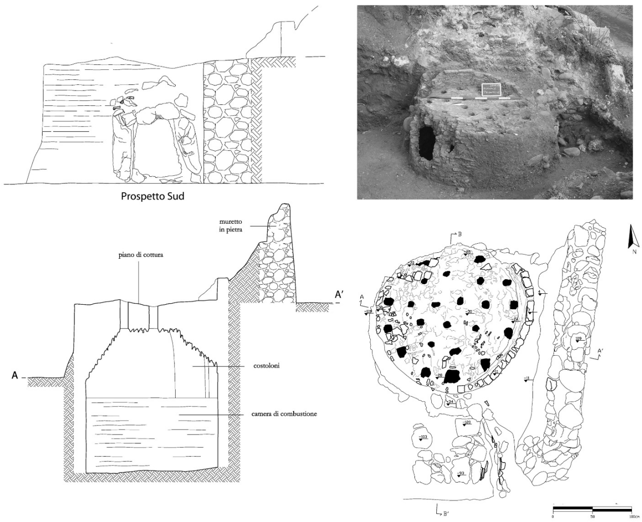

FIGURE 6. Superintendence of cultural heritage of Messina. S. Pier Niceto. Kiln 1 (drawing by M.T. Capone; S. Di Dio Camerino; L. Lopes).

The lower part of the kiln had been consolidated externally using a rather minute mixture of mortar, earth and crushed stone, allowing the heat developed by the fuel that was burned inside to be kept better and longer. The upper level of the furnace had collapsed on itself, encumbering the perforated cooking surface of the bricks that formed the walls of the structure. The upper part had one opening, similar to a chimney, to allow all the gases produced by the fired items to escape. Studies about ancient furnaces suggest that, in general, the ratio between the heights of the two overlapping chambers is 1:2 ca., in which the above cooking chamber has a double height compared to the room below. It is therefore possible to hypothesize that the height of the cooking chamber of the first furnace of San Pier Niceto should be around 3.5 m. This kiln must have a warehouse nearby where to keep the artifacts ready for cooking, of which only a portion of the wall has been preserved.

The second furnace (Fig. 7), similar to the first, preserves the perimeter wall of the cooking chamber, made of small and medium-sized bricks and pebbles; the perforated cooking surface made of brick with forty holes of different shapes (circular, rectangular and square), for the escape of gases. The entrance to the combustion chamber, located to the south, had already collapsed in ancient times.

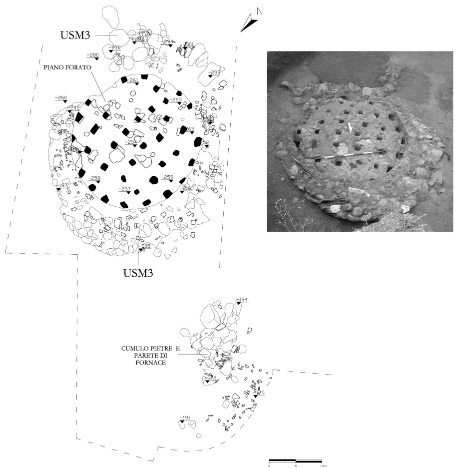

FIGURE 7. Superintendence of cultural heritage of Messina. S. Pier Niceto. Kiln 2 (drawing by M.T. Capone; S. Di Dio Camerino; L. Lopes).

Information on the period in which the furnaces were used is provided by the fragments of the vessels abandoned inside (Fig. 8). Certainly the structural layout is repeated over the centuries without variations (Fiorilla 1991; Arcifa 1996; Di Caprio 2007).

FIGURE 8. Superintendence of cultural heritage of Messina. S. Pier Niceto. 1, 10) Pottery from the first kiln; 2-9, 11) from the second kiln.

During the archaeological dig, few ceramic fragments were found, mostly pertinent to the walls and handles of tableware. Some detailed information can be gathered from the decorative comb-engraved motif composed of a series of parallel lines alternating with wavy lines which is present on some walls found in both furnaces (nos. 1-2). The same motif occurs in a medieval site of the 13^{th} century in Brucato (province of Palermo) (Lesner 1993), on an amphora in use in the 13^{th}-14^{th} century and on a Sicilian production table vases of the 14^{th}-15^{th} century, both inside the cooking chamber in the furnace of Tribunal in Messina (Fiorilla 2001; Sannino 2001). From the second furnace come fragments of a glazed bowl, which has a brown band on the edge of the rim and under it, and a geometric decoration engraved inside the light yellow glazed tank (no. 3). On another fragment of bottom appears a small fish (no. 4), very common decoration in medieval pottery. About Sicily, it is common in "Gela ware" type proto-majolica (13^{th} century), decorated in brown, green and yellow (Fiorilla 1991; Di Caprio 1992). Also from the second structure come fragments of vases produced in the middle 14^{th} century: rim with wall and handle decorated with geometric motifs with dense and minute dots made before cooking (no. 5-6); wall with decoration (Gelichi 1992; Boldrini and Grassi 1997) made with toothed wheel stamps (no. 7); glazed wall with toothed wheel decoration (no. 8). Furthermore, the ceramic fragments covered with vitrified coverings, but not decorated, fall into the class of olive and brown monochrome lead glazed, of Sicilian local production (Fiorilla 2001) in use from the 14^{th}-15^{th} century until a few centuries ago or into the class of white lead-stanniferous glazed, from the most recent dating. The first furnace also returned a brick with the imprint of the paw of a small canine (no. 10) while a terracotta bird, headless and without part of the tail and paws, was found near the second furnace. The plumage is obtained through small incisions made raw along the body (no. 11). Both furnaces were in use during the fourteenth century until the 18^{th}-19^{th} century, specialized in firing bricks, since the quantity of fine ceramic fragments is negligible compared to the tiles and bricks, whole or fragmentary, found near the furnace and in the surrounding area.

5.2. Spadafora - Venetico. At the end of the 19^{th} century, in the provincial road near the Spadafora – Venetico old railway station, a Roman brick and tiles kiln was discovered. The furnace was in bad condition also in ancient times. From the few information we have, the structure must have been very similar to those described. One bronze coin was also found from the bottom of the excavation: a small Mamertine coin with on the O / head of Jupiter and on the R / soldier standing with MAMEPTIN and, isolated, dated around 3^{rd} century B.C. (Salinas 1898).

5.3. Rometta. In January 2012, there was the seizure of the municipal villa by the judicial authority, after a citizen had denounced the presence of artifacts of archaeological interest in the deposits used for fill the flower beds. The scattered fragments were recovered: they came from an excavation for the construction of a private garage located in via Puccini. From a first analysis of the recovered material and from the more isolated diagnostic findings (amphorae and scraps), there are good indications to hypothesize that the site represented the remains of one or more furnaces intended for the production of pottery, attributable to two different historical periods: the early imperial age and the late ancient period. The existence of this artisan plant active since the early imperial age is not surprising, given that the construction site is located along the possible axis of development of via Valeria, probably coinciding in part with the current state road, in an area whose geological context is characterized by excellent quality clay outcrops, still used today for the manufacture of bricks and/or artefacts (Tigano 2012).

5.4. Milazzo. In 2011, during the works for the construction of a building in Cosenza street, two ancient vertical kilns came out, circular in plan but dissimilar in size, embedded in the ground. The best preserved structure is the smallest. Its combustion chamber (diameter 1.25 m) had a central pillar which was to support the perforated cooking surface and was preceded by a rectangular *praefurnium*. The few clay fragments found inside the furnace suggest a dating between the end of the 4^{th} and 3^{rd} centuries B.C. (Tigano 2012).

5.5. Messina. In Cesare Battisti street-block 141, a Roman furnace was found, of which only the lower part of the combustion chamber remains with traces of a central pillar to support the perforated cooking surface and the *praefurnium*. It was anticipated from a small compartment with a temporary storage function for the pottery to be cooked or already cooked. Just this compartment has returned, in addition to common pottery of local production, also about thirty cooked pots, of different sizes but all of the type with brimmed rim, without handles and with the relative lids, used to cook soups to be served with a ladle (Sannino 1999; Tigano 1999).

An investigation in the area of the Garden of Palazzo Piacentini (Tribunal) has revealed traces of a first furnace, too damaged to be investigated, and a second vertical circular furnace still in an excellent state of conservation, about its structure and about the load of material, found still stacked in the cooking chamber. The rest of the oven was partially leaning against the slope. The material of the last load had already been fired but was abandoned inside the chamber, due to a flood. Large deposits of it are found between the medieval and Roman levels. The furnace returns tiles and clay pots, including amphorae and bowls, according to the mixed load technique, *i.e.*, bricks and pottery cooked together (Tigano 2001).

In the Cavour square, during 2005-2006, a sector of the urban system of Zancle was discovered. It was developed between the end of the 6^{th} and 2^{nd} century B.C. In an house (casa 1, second half of 3^{rd} century B.C.), in the room 7, a lime kiln was found. It had been prepared for the construction phases of the house. The furnace consisted of a *praefurnium* and a hypogeic circular chamber (diameter 2.70 cm) paved with bricks and with two square-shaped hearths. The interior of the combustion chamber was filled with white stones and many oyster shells used to produce lime. Another furnace was found inside the courtyard of a peristyle building, under the pavement with bricks. This public building, identified as an agora, remained in use between 3^{rd} century B.C. and 1^{st} century A.D. The kiln has a circular plan (diameter 3.67 m) with a vertical structure consisting of two overlapping chambers. After use, it was filled with bricks, cooking ware fragments and Greek-Italic amphorae (type 469 Lipari). It could have been a mixed production furnace: bricks, amphorae and other pottery cooked together (Lentini *et al.* 2010).

6. Venetico's Hoffmann Furnaces

The Venetico's Hoffman furnaces is an archaeological industrial complex, realized last century following the Friedrich Eduard Hoffmann's prescriptions, which was originally employed for cooking bricks with continuous operation. These furnaces, which consist of four galleries where the tunnels are flanked and closed during operation by doors are placed inside the ex Condor factory, located in Venetico (see Figure 9). A furnace recovery work and reuse for social activities of these furnaces have been recently planned in order to create a highly qualified research center in the field of construction and stone materials.

FIGURE 9. Venetico's Hoffmann Furnaces Photo by M. Franzone.

7. Conclusions

We would like to introduce conclusion of this paper starting from a citation of Pliny the Elder who said:

> *' ... the earth produces so much clay that the pottery-workshops will never have to be without; besides the artefacts made on a potters-wheel, jars invented for our wine, drainage-pipes, tiles and bricks are made of earthenware and accordingly King Numa established as the seventh guild, the guild of the potters'*[1].

This contribution points out, through a specific and paradigmatic case study, the importance of including the Messina's territory in teaching clay minerals. This is due to the circumstance that over the centuries a relevant cultural heritage on clays has settled in this territory in which human, geographical and anthropological factors result linked in an inextricably way. This territory has been interested by a series of transformations of which it is useful to preserve a memory for understanding and maintaining the past, the identity and for grasping new possibilities of transformations.

More specifically, in this contribution it is highlighted how the use of clay in pottery provides a record of past civilizations. As building materials, bricks have been used in construction since earliest time. No other earth material has so wide importance or such

[1](Pliny, NH 5, 1591)

extended uses as do the clays. Known mineralogical and physico-chemical features help to understand why these materials were so important, but also why they are still used in a wide variety of industries in the modern world. The topic proposed in this paper can arise the interest of university students towards this significant aspect that affected the social-economic growth of our territory, and on the importance that in general geomaterials had in the technological evolution of the human civilization process.

We would like to conclude citing a famous phrase which said:

> *"You have to know the past to understand the present"*[2].

This is true as we look at the timeline of history and its effects on the today's world and the world of tomorrow (Sagan 1980).

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[2](Sagan 1980)

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[a] Università degli Studi di Messina
Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra
Viale F. Stagno d'Alcontres 31, 98166 Messina, Italy

[b] Museo Luigi Bernabò Brea
Parco Archeologico delle Isole Eolie
Lipari, Aeolian Islands, Messina, Italy

[c] Archaeologist
Cefalù, Palermo, Italy

[d] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Palermo
Via Ugo La Malfa n° 153, 90146, Palermo, Italy
Sede Operativa di Milazzo
Via dei Mille 46, 98057 Milazzo, Messina, Italy

[e] Stazione zoologica Anton Dohrn di Napoli (SZN)
Villa Comunale, 80121 Napoli, Italy

* To whom correspondence should be addressed | email: mfranzone@unime.it

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