Mineral and Mechanical Characterization of Earthen Building Materials from Argentina

/ GISELA SPENGLER (1) JUAN JIMÉNEZ-MILLÁN (2,*), MARÍA-JOSÉ CAMPOS-SUÑOL (2), MARGARITA DO-CAMPO (3)

INTRODUCTION

The use of sediments for the construction of earthen buildings was a technological development used in every continent, from prehistoric times until the present. Earthen building techniques are varied, and they can be classified in three general types: monolithic systems (rammed earth), brickwork (adobe o mudbrick), mixed systems (wattle and daub) and earthen plasters and mortars. Nevertheless, the recognition of archaeological evidence indicative of these kind of buildings is problematical, because this kind of architecture is vulnerable to destruction by weathering, especially by wind and water erosion.

Rainer (2008) emphasized that, in addition to environmental variables, the type of building material is a key factor affecting their composition and deterioration. The presence of swelling clays, hydrolytic weathering of minerals, mechanical erosion produced by rain drops, meteo-climatic factors, and discontinuities produced by the geological materials are among the major causes that produce the physical and chemical deterioration of the earthen architecture.

The determination of texture, plasticity and mineralogy is important to understand the behaviour of earthen building materials (Spengler et al. 2011). However, detailed mineral and petrographic investigations on Earthen building materials from Andean prehispanic cultures are scarce, and over NW Argentine cultures were never carried out. The aim of this contribution is to fill in part this gap. A petrographic classification of the earthen building materials will certainly contribute to understand their weathering and decay processes, and to define parameters for their determination in archaeological contexts.

MINERAL AND PETROGRAPHIC CHARACTERIZATION

The fill of Vinchina and Guadancol basins corresponds to several sequences of fluvial, lacustrine and aeolian systems (Paleocene-Early Eocene to Pliocene) dominated by sandy-shale and sandy-gravel sediments. The Famatina-Antinaco and Abaunac valleys are surrounded by a series of mountainous ranges belonging to the Famatina Complex comprising crystalline metamorphic basement intruded by diverse Palaeozoic (Ordovician) igneous rocks and containing an Ordovician volcanic record with Ordovician marine sediments interbedded with volcanic rocks.

Detailed petrographic studies emphasize that all the investigated architectural elements consist of a fine-grained groundmass containing lithic and plant fragments.

Lithic fragments chiefly consist of (a) volcanic rocks frequently developing a vesicular texture, (b) banded and foliated metamorphic rocks, (c) feldspar phenocrysts, and (d) very fine-grained quartz-rich sedimentary rocks (mainly sandstone-like). Volcanic fragments are characterized by a highly vesicular texture developed on a high-silica glass matrix with trachytic to rhyolitic composition. Biotite and Ca-amphibole...
phenocrists are frequently observed included in the glassy matrix. Vesicles show subpherical to elongated morphologies and most of them are filled by zeolites.

Metamorphic rocks fragments show a characteristic compositional banding. The compositional banding is the most conspicuous microscopic feature of these fragments defining a foliation probably produced by pressure solution. The banding consists of the alternation of biotite-rich layers and quartz-rich layers several mm thick.

Subuehdral alkali feldspar phenocrysts are frequently found in the groundmass of the earthen elements. A characteristic perthitic texture is developed with wormy and ribboned Na-plagioclase exsolutions. Big fragments of very fine-grained quartz-rich sedimentary rocks can also be frequently observed in the studied materials which are very difficult to distinguish from the surrounding groundmass.

The fine-grained groundmass generally shows an intergranular texture scarcely oriented, and consists of small fragments of minerals included in the bigger lithic fragments. Unfortunately, the fine mineral size strongly limited the microscopic observation of the groundmass in which clay minerals are also widespread.

**PHYSICAL AND MECHANICAL PROPERTIES**

From a granulometric point of view, most of the samples contain less than 30% of clay fraction and a variable proportion of silt and sand. Rammed earth materials are predominantly more richer in sand (around 50% of sand fraction) than in adobe (around 35% of sand fraction). Two groups of mudbricks can be identified: Abaucan Valley mudbricks are richer in sand than those from Vinchina Valley.

Density values of mudbricks (average 1.73 g/cm²) are commonly higher than those of rammed earth (average 1.59 g/cm²). On the other hand, the lowest values of plasticity are found in rammed earth materials (below 9%), while mudbricks usually exceed 10%.

Compressive and flexural strength (CS and FS) were tested, values of CS from adobes are higher (between 14 and 16 kg/cm²) than those of rammed earth (between 10 and 12 kg/cm²). FS values for rammed earth are below 5 kg/cm², while many adobes depict higher values. These test could not be performed for wattle and daub (and earthen plasters) because quantity and coherence of samples were insufficient.

**DISCUSSION AND CONCLUSIONS**

The petrographic study has revealed that volcanic lithic fragments are especially abundant in the archaeological sites from the Abaucan Valley. Volcanic fragments can also be found in the archaeological sites from the Famatina Valley but they are almost absent in earthen materials from the Vinchina and Gudancol Valleys.

The presence of important outcrops of Tertiary and Ordovician volcanic rocks in the mountains surrounding the Abaucan and Famatina Valley indicate the source areas for the Quaternary materials deposited in these valleys, which were used as raw materials for the earthen building materials found in these archaeological sites. Earthen building materials from the Famatina Valley are rich in metamorphic rock fragments, although this kind of fragments can be also found in several samples from the Gudancol Valley. This composition can be related with the outcrops of metamorphic rocks in the surrounding reliefs from Pampean mountains (Famatina-Antinaco Valleys) and Greenville (Gudancol) basements.

Sedimentary rocks are the main component of the lithic fragments observed in the Vinchina-Gudancol Valleys archaeological sites. These archaeological sites were built on Quaternary deposits which source areas are made of sedimentary formations containing fine-grained sandstones rich in quartz and clay minerals.

Grain size is related to the raw materials used but also to the type of building technique. The finest grain sized materials are those made with the sediments from the Vinchina Valley. Concerning the building technique, finer grain size materials were selected to make earthen plaster than in mudbricks and rammed earth.

Other physical and mechanical properties of earthen materials are more controlled by the building technique than by the raw materials. The higher flexural strength of adobes arises from their fiber and clay content. The technological properties of earthen building materials should be mainly controlled by the proportion of clay-versus sand+silt-sized material, but also by the kind and relative proportion of high plasticity clays in raw material, and also to the natural fiber content.

**ACKNOWLEDGEMENTS**

Financial support was provided by the research group RNM-32S of the Junta de Andalucía, and project UBACYT F086 of Universidad de Buenos Aires. This research was conducted by a PhD Scholarship of CONICET and a postgraduate Scholarship of AUJP.

**REFERENCES.**


