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Determining Gypsum Alabaster Provenance in Sculptural Artefacts: an Application Example

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INTRODUCTION

The term alabaster has historically designated both *gypsum alabaster* and *calcite alabaster*. Gypsum alabaster, which is the genuine petrological alabaster, is a compact, white and fine-grained variety of gypsum rocks, which can also display creamish, reddish or brownish colours. Thus, in the present manuscript the term alabaster will apply exclusively to gypsum alabaster.

Although most of the ancient gypsum quarries are currently abandoned or have been converted to gypsum exploitations for industrial purposes (construction industry), their location is well known, in general. However, the provenance of the raw materials of alabaster sculptures or artistic artefacts is often difficult to establish. The mineralogical, textural and compositional characterization, that is mandatory in all the studies, is not distinctive in alabaster rocks given that most of them display similar features. Thus, current macro- and microscopic petrographical studies are not, in general, useful determining tools by themselves.

The use of sulphate isotope compositions ($\delta^{34}S$, $\delta^{18}O$) together with strontium isotope ratios ($^{87}Sr/^{86}Sr$) of alabaster sculptures in order to decipher the geological provenance of their raw materials was tested by Gale et al. (1988), Inglès et al. (2009) and Kloppmann et al. (2011). The objective of the present work is: 1) to present a first geochemical (oxygen-sulphur isotope) database of the main geological units or areas that lodged the historical alabaster quarries in NE Spain, and 2) to promote the use of these isotope analyses routinely in order to obtain information about the sources of alabaster raw materials in art. The work is supported by a previous knowledge of the detailed stratigraphy of the exploited evaporite units. The method was tested in some gothic, renaissance and baroque sculptures, and allowed us to clarify contradictory or unknown origins of the alabaster.

MATERIALS AND METHODS

Two different types of alabaster samples have been selected to conduct the mass spectrometry analyses and to compare the results: a) geological samples from outcrops or quarries (geological standards), and b) sculptural artefacts.

Some of the quarries in NE Spain whose gypsum rocks can be considered as geological standards, were revisited and newly sampled in many cases. Petrographic, stratigraphic, and geochemical data of the geological samples were extracted from published data of our research group on the corresponding gypsum units.

The studied alabaster sculptures were selected from art pieces kept in the MNAC (Museu Nacional d'Art de Catalunya; Barcelona), in the monastery of Santa María de Poblet (Tarragona) and in the basilicas of Manresa and Cervera (Barcelona) (Table 1). Samples of the art pieces were obtained with a microdrill (powdered samples) or with a special hammer, always avoiding contamination from the pedestal, the polychromy and/or other alien substances (restoration waxes, ...).

HISTORICAL QUARRIES AND EXPLOITED EVAPORITE UNITS

Different alabaster units belonging to several geological areas have been exploited in Catalonia, Aragon and Valencia (NE Spain) since the Middle Ages. These evaporite units, which are Tertiary in age, are listed as follows, from older to younger: *a)* marine units from the South Pyrenean foredeep, including the Beuda Gypsum and the Òdena Gypsum; *b)* non-marine units from the Catalan margin of the Ebro Basin, including alabasters from Lilla-Vilaverd, Sarral and Valldeperes areas; *c*) non-marine units from the central part of the Ebro basin, in the Gelsa area (Zaragoza); and, *d)* non-marine unit of Ninyerola in the Coastal Depression of Valencia.

DISCUSSION AND CONCLUSIONS

The bulk isotopic signatures obtained in the geological samples are considered to be representative of the different historical sites where alabaster materials have been extracted since the Middle Ages in NE Spain. The sulphur and oxygen isotope compositions are plotted in Fig. 1. It is widely accepted that the most reliable isotope indicator in gypsum rocks is sulphur, while oxygen is often deeply affected by local controlling factors which modify its original (mother brines) isotope signal.

Two main groups of values are defined: *a)* the composition of the Beuda and Òdena Gypsum units fall in a range of $\delta^{34}S$ between +20 and +24‰, which is characteristic of Tertiary marine sulphates; and, *b)* a larger range of values, from +10 to +17‰, is defined for the Lilla-Vilaverd, Sarral, Valldeperes, Gelsa and Ninyerola alabasters; these latter values are typical of Triassic sulphates and therefore indicate dissolution and chemical recycling processes of Triassic evaporites in non-marine basins. Thus, this method allows

palabras clave: Alabastro de yeso, Procedencia, Petrología, Isótopos estables.

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ART PIECE	Location	Age	Author	Documented provenance	$\delta^{18}O_{vsmow}$ (‰)	$\delta^{34}S_{vcdt}$ (‰)
Mother of God	MNAC (15873*)	XIV	Jaume Cascalls	U/N	+13.5	+21.8
Bust of Christ	MNAC (34879*)	1352	Jaume Cascalls?	U/N	+12.9	+21.6
Annuntiation (altarpiece)	MNAC (9935*)	XIV	Jaume Cascalls	U/N	+14.5	+21.5
Archangel Gabriel	MNAC (9875*)	XIV	Bartomeu de Robió	U/N	+15.4	+15.6
Salvador (medallion)	MNAC (24186*)	1440	Pere Joan	Gelsa?	+16.5	+14.8
Praying cleric 1	MNAC (66168*)	1334 - 1345	Pere Oller	U/N	+13.5	+21.4
Praying cleric 2	MNAC (66169*)	1334 - 1345	Pere Oller	U/N	+13.1	+21.4
Sepulchre (Hug de Cardona)	MNAC (200412*)	1327	Joan de Tournai	Beuda	+12.1	+15.9
Recumbent cleric	MNAC (9923*)	1385	Pere Moragues	U/N	+13.2	+21.4
Altarpiece (funeral ceremony)	MNAC (9933*)	XIV	Unknown	U/N	+12.5	+21.2
Mother of God	MNAC (4359*)	XIV	Unknown	U/N	+12.5	+21.1
Sant Misteri Altarpiece	Basilica of Cervera	XVIII	Jaume Padró	Sarral	+15.7	+15.0
Sant Fruitós figurine (crypt)	Basilica of Manresa	XVIII	Jaume Padró	Beuda	+12.2	+22.1
Royal tombs	Santa Maria de Poblet monastery	XIV	Aloi de Montbrai & J. Cascalls	Beuda	+13.6	+20.8
Major altarpiece	Santa Maria de Poblet monastery	XVI	Damià Forment	Sarral	+15.8	+15.5

Table 1. *Oxygen and sulphur isotopic values of artistic studied pieces. MNAC, Museu Catalunya (*museum stock number). U/ N: Unknown or documentation not found.*

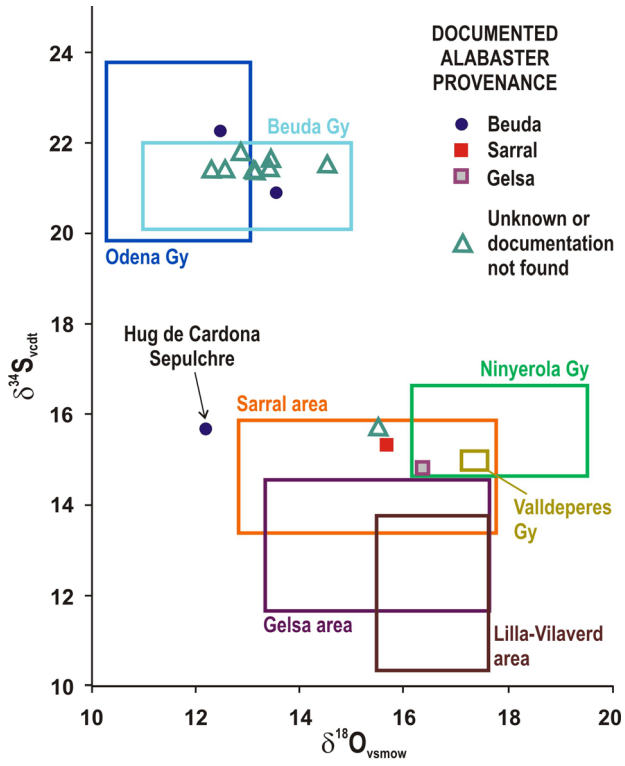

fig 1. *Oxygen and sulphur isotopic compositions of the alabaster units traditionally exploited for ornamental purposes in NE Spain. Circles, squares and triangles: studied artworks.*

us to discriminate between alabaster pieces of Beuda and Sarral provenances, i.e. between marine and non-marine gypsum units of Tertiary age, but it seems to fail to discriminate between pieces of non-marine Tertiary units. Nevertheless, some differences are observed in these non-marine units where a general trend to lower sulphur values is observed: Ninyerola (highest values) - Sarral - Gelsa - Lilla/Vilaverd (lowest values).

When the isotopic signatures of the alabaster pieces are compared with those of the geological raw materials (Fig. 1), there is accordance, in general, with the historical documentation. It seems that most of the unknown provenances are consistent with a Tertiary marine origin. The studied pieces documented from Gelsa and Sarral areas show similar isotope values and therefore the provenance of the alabasters cannot be established with the available data. In this sense, the analyses of more pieces will be necessary to prove the method.

However, the most interesting result corresponds to the Hug de Cardona sepulchre alabaster. Although it has been historically documented as having a Beuda provenance, its isotopic composition is clearly incompatible with this origin, and suggests a Sarral provenance.

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