

**Article : Les cloîtres de l'Abbaye de Gellone : Limestone Sculpture  
from the Abbey at Saint-Guilhem-le-Désert Compositional  
Analysis**



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## *Limestone Sculpture from the Abbey at Saint-Guilhem-le-Désert Compositional Analysis*

Lore L. HOLMES and Garman HARBOTTLE\*

with the cooperation of Annie BLANC\*\*

The Benedictine Abbey of Gellone at Saint-Guilhem-le-Désert lies in a small valley at the mouth of the *cirque du Bout-du-Monde*<sup>2</sup>, in a forbidding and desolate landscape of high cliffs and deep gorges drained by the Herault River, approximately 30 kilometers northwest of Montpellier<sup>3</sup>. Stone for the erection of the Abbey and for the sculptures and architectural decoration that once ornamented its buildings very probably came from the limestone formations of the surrounding region (Fig. 1).

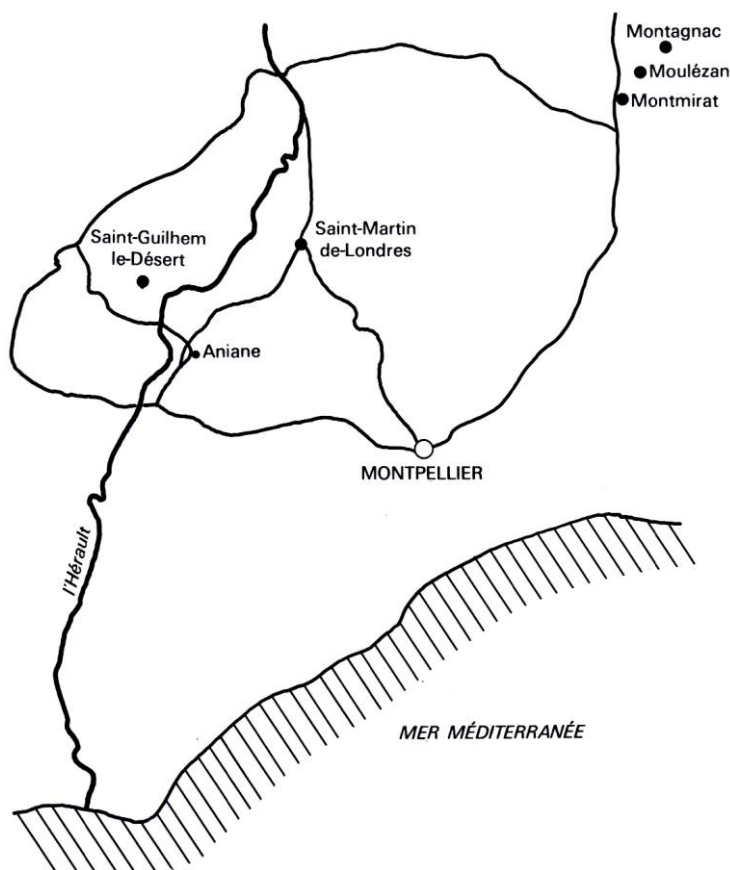


Fig. 1. - Stone sources in the region surrounding Saint-Guilhem-le-Désert. Quarries near Saint-Martin-de-Londres and in the Bois des Lens massif provided stone for sculptural decoration at the Abbey of Gellone.

Recently the composition of limestone from quarries known to the medieval craftsmen of that region and from sculptures that once embellished the Abbey has been determined by neutron activation analysis<sup>4</sup>. This paper demonstrates that statistical treatment of the resulting compositional data permits us to distinguish among stone sources and to associate the sculpture with the source of its raw material. The identification of stone sources is important to art and architectural historians because it sheds light on the economics, transportation and other procurement problems of medieval builders in the region.

Neutron activation analysis quantifies the concentrations of approximately twenty compositional variables present in each stone sample. These variables, which constitute the compositional profile of the stone, include eleven or twelve that are especially useful in distinguishing among limestones from different geological formations and different sculptures<sup>5</sup>.

Regional sources of limestone probably known to medieval artisans and possibly used for much of the sculptural decoration at the Abbey produced one of three different types of stone<sup>6</sup>:

- Hard, fine-textured yellow Eocene limestone that was probably extracted from ancient quarries south of Saint-Martin-de-Londres, approximately 20 kilometers northeast of Saint-Guilhem.

- Softer, yellowish-white Eocene limestone that may have come from ancient quarries surrounding Aniane, about seven kilometers south of Saint-Guilhem near the banks of the Herault River.

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**Table 1. - Composition of stoize from regional quarries (mean values).**

	Na <sub>2</sub> O*	K <sub>2</sub> O*	Rb <sub>2</sub> O	Cs <sub>2</sub> O	SrO	BaO*	Cr <sub>2</sub> O <sub>3</sub> *	MnO*	Fe <sub>2</sub> O <sub>3</sub> *	CoO	Sc <sub>2</sub> O <sub>3</sub> *	La <sub>2</sub> O <sub>3</sub> *	CeO <sub>2</sub>	Eu <sub>2</sub> O <sub>3</sub> *
	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	PPM	PPB
St-Martin-de-Londres	530.	840.	6.8	0.54	1570.	86.	5.9	241.	0.369	0.69	0.78	1.57	3.49	55.
Aniane	47.	DL	2.20	0.089	31.	16.8	1.49	500.	0.69	1.18	0.107	0.217	0.50	12.6
Bois des Lens	22.2	30.	2.20	DL	198.	5.1	7.9	34.	0.011	0.221	0.157	0.82	0.84	38.5
	Sm <sub>2</sub> O <sub>3</sub>	Yb <sub>2</sub> O <sub>3</sub> *	ThO <sub>2</sub> *	Lu <sub>2</sub> O <sub>3</sub>	As <sub>2</sub> O <sub>3</sub>	HfO <sub>2</sub>	ZrO <sub>2</sub>	UO <sub>3</sub> *	CaO	Number of samples				
	PPM	PPB	PPM	PPB	PPM	PPB	PPM	PPM	%					
St-Martin-de-Londres	0.42	142.	0.46	27.4	1.36	209.	19.4	1.98	52.	9				
Aniane	0.124	17.6	0.092	3.7	6.1	19.8	8.7	0.86	56.	5				
Bois des Lens	0.224	162.	0.058	28.2	0.17	20.2	6.1	0.64	57.	12				

DL : concentration below detection limit.  
 PPM : micrograms/gram of sample  
 PPB : nanograms/gram of sample  
 \* : compositional variables used in niultivariate statistical analysis.

- White oolitic Cretaceous limestone similar to that from some of the dozen ancient quarries in the Bois des Lens massif, approximately 50 kilometers northeast of Saint-Guilhem and 20 kilometers west of Nîmes, some of which have been exploited since Gallo-Roman times.

Stone from these three quarrying areas was found to be distinguished by sharp differences in the concentrations of the variables determined by neutron activation analysis (Table 1). These compositional distinctions are clarified by multivariate statistical procedures which involve the mathematical combination of the concentrations of many variables to calculate « canonical discriminant functions » in multidimensional space. When such calculations are carried out using concentration data for available quarry samples, three discrete, well-marked groups emerge. The results of these calculations and the groups thus formed are illustrated (more simply but less reliably) by plotting the concentrations of just two compositional variables, the oxides of chromium and iron (Fig. 2).

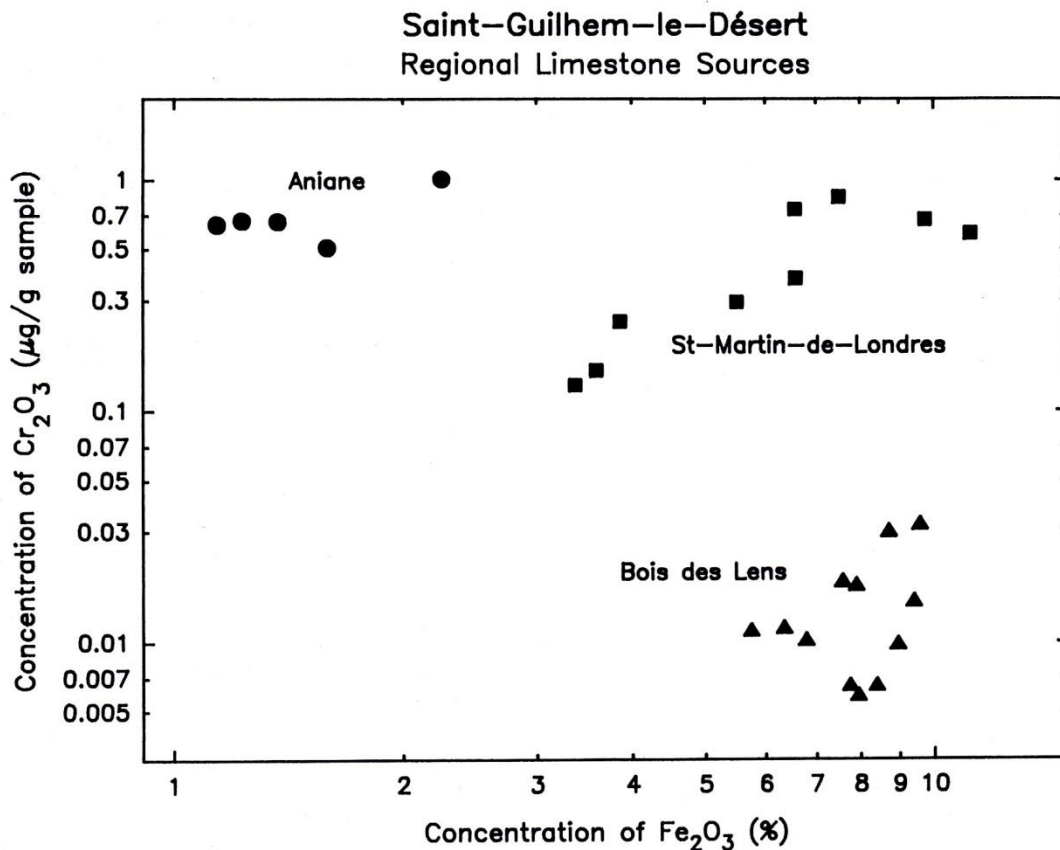


Fig. 2. - Chromium oxide-iron (III) oxide correlation diagram showing that stone from three geographically and geologically different limestone sources in the Saint-Guilhem region can be distinguished by compositional differences.

Compositional analysis plot only differentiates effectively among stone sources, but it also makes possible the association of sculpture and architectural fragments that may once have ornamented the Abbey with these particular sources. Such fragments are now displayed in the Abbey's refectory, in the Musée de la Société Archéologique at Montpellier, and in the Cloisters Museum of The Metropolitan Museum of Art, New York 1 (Table 2).

**Table 2. - Sculpture from the Abbey of Gellone.**

BNL ID	Sample no.	Description of Object	BNL ID	Sample no.	Description of Object
<i>Stone from Bois de Lens massif</i>					
U1012	SGD 111	Chancel : slab/flagstone	U1028	SGD 33	Keystone with pointed faceted decoration
U1034	SGD 101	Pilaster with rosettes	U1029	SGD 34	Keystone with pointed faceted decoration
U1037	SGD 123	Fragment with lion	U1030	SGD 68	Pilaster column with undulating decoration
<i>Stone from Saint-Martin-de-Londres</i>			<i>Stone from Saint-Martin-de-Londres</i>		
U991	MTP 01	Old Men of the Apocalypse : right block	U1031	SGD 69	Pilaster from undulating column
U992	MTP 02	Old Men of the Apocalypse : center block	U1033	SGD 85	Christ as pilgrim
U993	MTP 03	Old Men of the Apocalypse : left block	U1035	SGD 112	Ecoincon with devil's head
U994	MTP 04	Tablet of pillar : 5 figures carved in relief (apostles)	U1038	SGD 130	Gothic coat-of-arms : Guillaume des Deux Vierges
U995	MTP 05	Angle of pillar	U1039	SGD 133	Angel
U996	MTP 06	Slab of pillar with 3 persons	U1040	SGD 134	Cloister fountain : fragment
U997	MTP 07	Statuette with book and censer	U1041	SGD 136	Keystone with acanthus leaves
U998	MTP 08	Epitaph of Guillaume de Roquefeuille	U1042	SGD 137	Keystone with acanthus leaves
U999	MTP 09	Capital (broken, held together by two copper dowels).	U1043	SGD 138	Keystone with acanthus leaves
U1003	SGD 03	Tomb : Prior Guy de Vissec	U1044	SGD 187	Romanesque cloister, upper gallery : frieze with acanthus leaves
U1007	SGD 08	Cloister gallery : small decorated column beneath capital	U1004	SGD 04	Capital (bought recently)
U1010	SGD 76	Tombstone : Bernard de Bonneval	U1005	SGD 05	Capital (bought recently)
U1014	SGD 139	Keystone with acanthus leaves	<i>Stone source uncertain :</i>		
U1015	SGD 121	Inscription (?)	<i>White limestone</i>		
U1016	SGD 131	Coat-of-arms : des Mostuéjous	U1001	SGD 01	Christ in Majesty
U1017	SGD 07	Cloister gallery : capital with leaves	U1002	SGD 02	Chancel : stone slab between slabs 12 and 19
U1018	SGD 19	Flagstone decorated with scroll pattern	U1008	SGD 09	Chancel : tablet/slab fixed in East wall near entrance
U1019	SGD 25	Romanesque Abacus with leaves	U1009	SGD 12	Chancel : flagstone/slab ?
U1020	SGD 31	Keystone decorated with beading	U1013	SGD 132	XIV-century tombstone
U1021	SGD 135	Keystone with acanthus leaves	<i>Yellow limestone</i>		
U1022	SGD 161	Sommier with pig	U1006	SGD 06	Tomb : Guilhem de Mostuéjous
U1023	SGD 160	Spring stone with monkey	U1011	SGD 78	Arch stone
U1024	SGD 79	Spandrel	U1032	SGD 84	Two Apostles holding palms
U1025	SGD 80	Capital	U1036	SGD 122	Fragment with horns of stag
U1026	SGD 30	Keystone with pointed faceted decoration	U1000	SGD 10	Fragment with cock
U1027	SGD 32	Keystone with pointed faceted decoration			

MTP : Musée de la Société archéologique à Montpellier - SGD : Abbey of Gellone, Saint-Guilhem-le-Désert

Although wear, aging and weathering of the stone impose uncertainties, skillful examination and comparison of the surfaces of sculpture and quarry specimens by Mme Blanc, geologist and expert on medieval stone sources, suggests that :

- Most sculpture now at the Abbey or in the museum at Montpellier was fashioned of yellowish limestone similar to that found in the ancient quarries near Saint-Martin-de-Londres. Some artifacts also resemble a somewhat softer yellowish stone from old sources near Aniane.

- White limestone sculpture resembling in color and types of inclusions stone from the Bois des Lens area was probably produced from one of the four quarrying locations in that formation from which specimens were available.

To test these hypotheses, 44 samples from sculpture stored at the Abbey and ten samples from carvings displayed at the museum at Montpellier were analyzed by neutron activation. The compositional data were compared with those for quarry samples by means of several multivariate statistical techniques. The results are summarized in Figure 3, which shows the samples to be divided into three discrete compositional groups : stone from Saint-Martin-de-Londres, Aniane and the Bois des Lens massif.

The Saint-Martin group comprises nine quarry samples and stone from 41 architectural fragments (all identified by square symbols), such as capitals, pillars, keystones and slabs. The compositional investigation therefore confirms the quarries near Saint-Martin to have been a major source of stone for artisans constructing the Abbey and identifies those fragments having this quarry source.

Although visual examination suggests that the yellowish stone from the Aniane area might have been used to carve some fragments, Figure 3 clearly shows that the Aniane group (identified by circles) consists solely of five quarry specimens. None of the sculpture samples supplied for this project have a compositional profile consistent with an origin in the ancient Aniane quarry. Evidently the quarry at Aniane was not a source of stone for these sculptures.

Twelve quarry specimens from the Bois des Lens massif came from four separate sites in the département of Gard : carrière Matthieu (near Moulézan-Montagnac), carrière Rocamat, carrière des Pielles (near Montmirat), and carrière Haute de Matalas. Samples from three sculptural fragments, identified as white oolitic limestone, are consistent with an origin in these ancient stone sources.

Although compositional analysis permits the association of 44 sculpture samples with stone sources in the Saint-Guilhem région, Figure 3 includes ten samples (identified by the symbol X) which lie close to but outside the Saint-Martin and Bois des Lens compositional groups. They come from sculptures visually similar to the yellow Saint-Martin stone (eight specimens) or the white oolitic stone of the Bois des Lens region (three specimens), but for all these samples the calculated probabilities of membership in their respective groups are extremely low. Comparison of their compositional profiles with all others in the Brookhaven Limestone Database (approximately 1 400 analyses including stone from 47 quarries) shows that these samples resemble Saint-Martin and Bois des Lens stone more closely than stone from any other French source. A likely explanation for the lack of correspondence of these ten samples with quarry material from the Saint-Guilhem region lies in the inadequate characterization of stone sources. In the Bois des Lens massif, especially, more quarrying sites need to be investigated. That differences exist among quarrying locations in one stone formation is shown by samples from Haute de Matalas in the Bois des Lens massif; these differ from other Bois des Lens specimens in having higher concentrations of most compositional variables. Identification of these ten samples must therefore await the future extension of the Limestone Database.

Not only can compositional analysis help to identify sources of raw material, but it also makes possible an estimate of the period during which those sources were active and provides additional information about the sculptures themselves. Included in the Saint-Martin group is stone from an epitaph dedicated to Guillaume de Roquefeuil (who died in 1248) (Fig. 4), and from the coats-of-arms of the abbot Guillaume des Deux-Vierges (1248-1287) and of the Moustuéjous family (dated to the XIV century), as well as samples from the tombs of the abbot Bernard de Bonneval (died 1318) and prior Guy de Vissec (died 1324) (Fig. 6). These fragments, dated by medieval records relating to the lives of the prelates<sup>8</sup>, and XII-century pieces dated according to stylistic criteria, such as a relief of Christ as Pilgrim (Fig. 5), make it highly probable that masons used stone from the quarries near Saint-Martin from at least the twelfth to the fourteenth centuries.

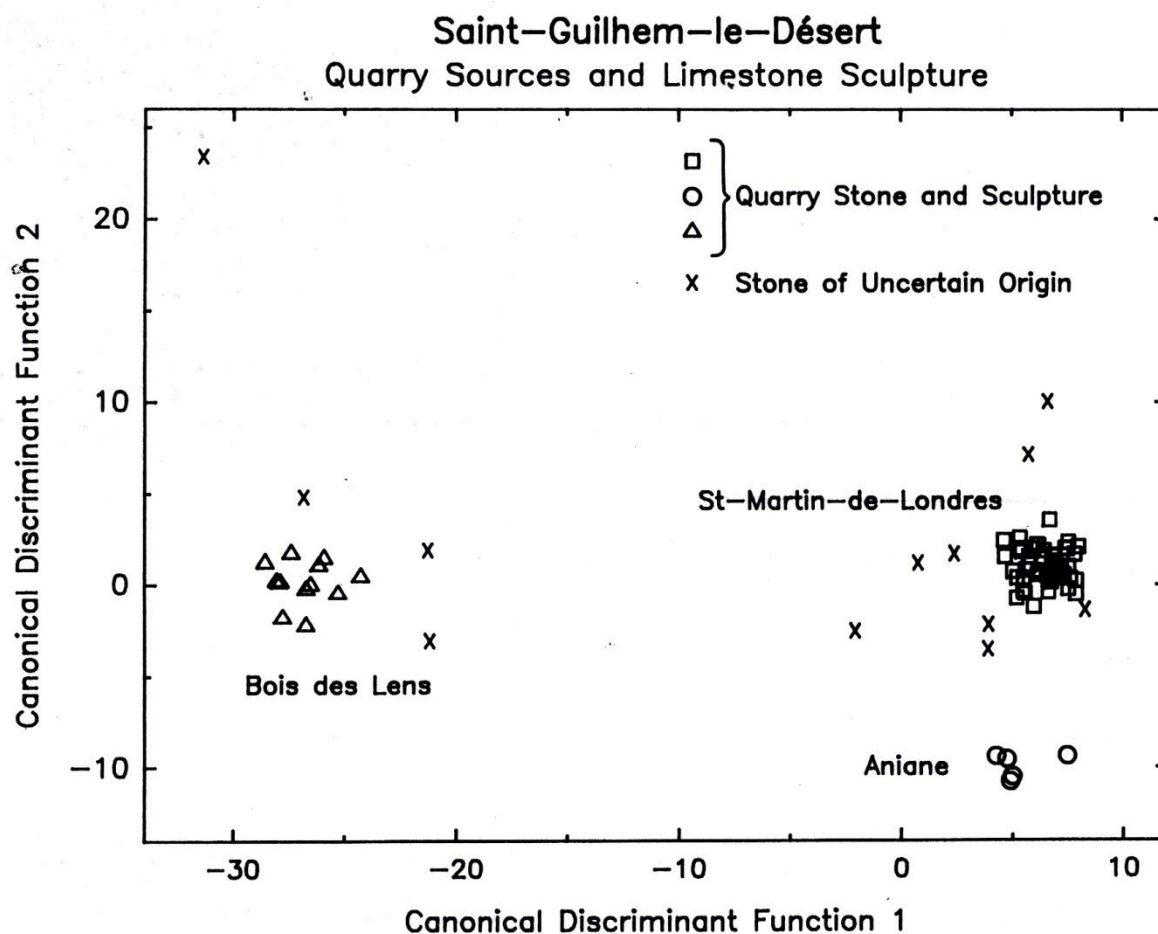


Fig. 3.- Canonical functions in Discriminant space showing that the composition of sculpture from Saint-Guilhem is consistent with an origin in quarries in the Bois des Lens region ( $\Delta$ ) and near Saint-Martin ( $\square$ ).



Fig. 4. - Epitaph for Guillaume de Roquefeuil. In collection of Abbey of Gellone from Saint-Guilhem-le-Désert et sa région, photo D. Kuentz).



Fig. 5. - Relief showing Christ as Pilgrim. In collection of Abbey of Gellone from Saint-Guilhem-le-Désert et sa région, photo D. Kuentz).

Compositional data testify to the authenticity of two small capitals purchased recently for the Abbey's collection. Samples of their stone have a statistically significant probability of belonging to the Saint-Martin group. Analytical data also provides clues to painted decoration eroded by time and wear. Specifically, the gamma spectrum of stone from the relief bearing the Moustuéjols coat-of-arm includes a mercury peak, implying that a mercury pigment such as cinnabar was once applied to its surface.

The results of this research show that analysis of stone from sculpture thought to have embellished the Abbey of Gellone validates art-historical and petrographic judgements about the sources of their stone and about the authenticity of fragments that have lost their histories.



Fig. 6. - Coat-of-arms of Guillaume des Deux-Vierges. In collection of Abbey of Gellone from Saint-Guilhem-le-Désert et sa région, photo D. Kuentz).

*Appendice - Méthode analytique*

Les analyses chimiques élémentaires permettent de caractériser les carrières de calcaire aussi bien que les sculptures elles-mêmes. La comparaison entre échantillons et sources d'une part, et échantillons entre eux, d'autre part, permet de résoudre des problèmes de provenance, d'authentification, et de variabilité au sein d'une carrière.

La composition du calcaire est déterminée par activation neutronique. Cette technique a été utilisée pour analyser des vestiges archéologiques et a été décrite en détail par Bishop, Harbottle and Sayre<sup>9</sup> et par Fillières<sup>10</sup> (Fig. 7).

Avant l'irradiation neutronique, les échantillons doivent subir une préparation. Les impuretés de surface sont éliminées en creusant une légère dépression avec un foret de tungstène-carbide. On prélève alors un échantillon de poudre de calcaire (au moins 1 g), que l'on mélange bien afin d'en assurer l'homogénéité. Les échantillons sont séchés au four à 1 000 C pendant une journée. Puis, environ 100 mg sont pesés avec une grande précision et scellés dans une ampoule de quartz très pur. Des standards dont la composition est connue sont inclus avec chaque groupe de calcaires à analyser. La comparaison entre les résultats donnés par les standards et les inconnus permet de déterminer les concentrations en éléments de chacun des échantillons analysés.

L'activation neutronique comporte deux étapes utilisant l'un puis l'autre des réacteurs de Brookhaven National Labora-

tory. Premièrement, le groupe d'ampoules est irradié par un flux de neutrons thermiques ( $1.1 \times 10^{13}$  neutrons/cm<sup>2</sup>/sec pendant 20 minutes) pour produire les isotopes radioactifs de périodes courtes : manganèse, sodium et potassium. Deuxièmement, il est encore irradié par un flux de neutrons thermiques ( $7,5 \times 10^{13}$  neutrons/cm<sup>2</sup>/sec pendant 16 heures) pour produire les isotopes de périodes longues soit 16 éléments. Un comptage suivant chaque irradiation permet de doser les éléments de périodes courtes puis longues, le premier quelques heures après l'irradiation, le second huit à neuf jours plus tard.

Les spectres des éléments présents dans le calcaire et dans les standards sont dépouillés par un détecteur de rayons gamma au germanium-lithium associé à un bloc-mémoire. Les données sont enregistrées sur disquettes afin d'être traitées informatiquement. Les résultats sont obtenus avec une précision de 5 % à 10 %, suivant les éléments.

Le profil chimique élémentaire de chaque échantillon de calcaire est sa carte d'identité. La comparaison de ces profils permet de regrouper les échantillons « semblables ». Ce degré de similitude est déterminé statistiquement. Il est donc nécessaire d'avoir le plus grand nombre possible d'échantillons tant pour les sources (carrières ou monuments) que pour sculptures à identifier.

Dominique Fillières

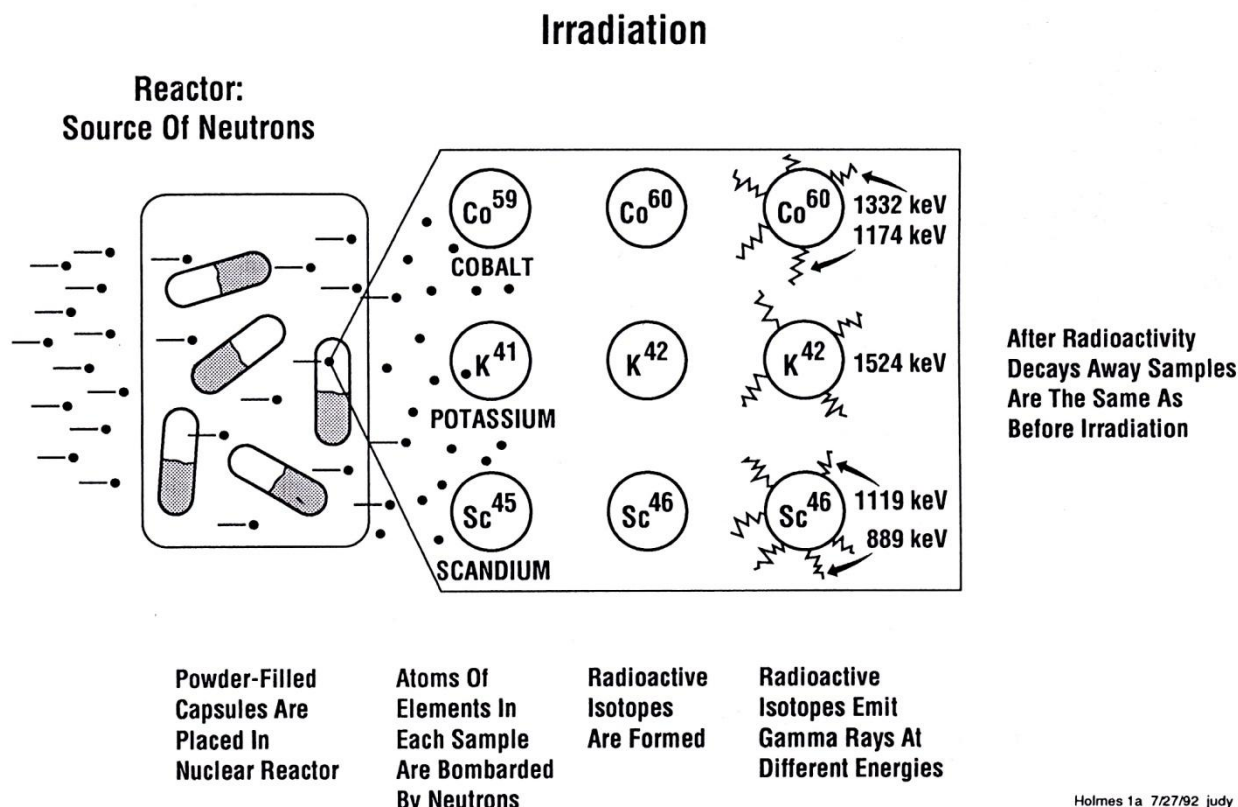


Fig. 7. - Irradiation of samples. Neutrons bombarding encapsulated limestone powder are captured by the nuclei of atoms present in stone to form radioactive isotopes. These radioactive isotopes, which are unstable, achieve stability by emitting gamma rays at uniquely different energies.

### Notes

1. The topic of this paper was first proposed by Jean-Claude Richard, Directeur de recherche au C.N.R.S., at an international meeting attended by art historians and scientists held in Paris, 16 June 1993. The participants included among others : Françoise Baron (conservateur-en-chef, Musée du Louvre) ; Françoise Bercé (directeur, Centre de recherches sur les monuments historiques) ; Jean-Pierre Caillet (professeur université de Paris X) ; Alain Erlande-Brandenburg (directeur, Musée national du Moyen Age) ; Charles Little (curator, Department of Medieval Art, The Metropolitan Museum, New York) ; Anne Prache (professeur, université de Paris IV) ; Neil Stratford (keeper, Department of Medieval and Later Antiquities, The British Museum, London).
2. A deep, steep-walled, semicircular basin formed high on the side of a mountain by the erosive activity of a mountain glacier. The back edge of the glacier, which is formed by the compaction of snow and ice in a mountain valley, plucks sediment from the mountain's lower rock ; the resulting rock material, embedded in the glacier, gouges a concave floor.
3. *Saint-Guilhem et sa région*, pp. 8-9, 17-20.
4. The method is described in the Appendix; see also GESTA XXXIII/1 (1994), 10-18.
5. Concentrations of oxides of the following elements are routinely determined by neutron activation analysis at Brookhaven National Laboratory : sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), strontium (Sr), barium (Ba), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), scandium (Sc), lanthanum (La), cerium (Ce), samarium (Sm), europium (Eu), ytterbium (Yb), lutetium (Lu), thorium (Th), zirconium (Zr), hafnium (Hf), uranium (U), antimony (Sb), tantalum (Ta), and calcium (Ca).
6. A. Blanc, private communication. Samples of quarry material were collected and made available for analysis by Mme Blanc, who also examined their petrographic characteristics.
7. *Saint-Guilhem et sa région*, pp. 111-116. *Saint-Guilhem-le-Désert, la sculpture du cloître de l'abbaye de Gellone*, pp. 7-29.
8. *Saint-Guilhem-le-Désert et sa région*, p. 116.
9. R. L. Bishop, G. Harbottle, and E. V. Sayre. Chemical and Mathematical Procedures Employed in the Maya Fine Orange-Fine Grey Ceramic Project. *Peabody Museum Memoir* 15, N° 2 (Harvard University : Cambridge, Massachusetts), 1980.
10. Dominique Fillières. *Contribution à l'étude de la production et de l'exportation des amphores dites Marseillaises et des céramiques grecques d'Occident du Midi de la France au moyen d'analyses par activation neutronique avec traitement taxinomique des résultats*. Thèse de l'université de Paris I, Panthéon-Sorbonne, 1978.

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- Saint-Guilhem-le-Désert : la sculpture du cloître de l'abbaye de Gellone*. Montpellier, Association des Amis de Saint-Guilhem-le-Désert, 1990.

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**HISTOIRE ANCIENNE ET MÉDIÉVALE :**

*Jacques BRIARD*, Thésaurisations et paléomonnaies du Bronze final méridional et du Launacien ;

*Jean-Louis ANDRIEU, Jean-Luc ESPÉROU, Jean-Pierre MAILHE*, Les aqueducs romain et médiéval de Gabian.

**Les cloîtres de l'abbaye de Gellone**

*Jean-Claude RICHARD*, 1985-1994, incertitudes, hypothèses et recherches en cours ;

*Gabriel VIGNARD et Alii*, Détermination de l'origine des matériaux du cloître de l'abbaye de Gellone ;

*Lore L. HOLMES, Garman HARBOTTLE, Annie BLANC*, Limestone Sculpture from the Abbey at Saint-Guilhem-le-Désert Compositional Analysis.

**HISTOIRE MODERNE ET CONTEMPORAINE :**

*Xavier AZEMA*, Alexandre de Toulouse et de Lautrec, seigneur de Montfa 1632-1698 ;

*Claude BOYER*, Sète, naissance d'un port au XVII<sup>e</sup> siècle Le peuplement de Sète de 1666 à 1715 ;

*Pierre DAVID*, L'autorité de l'abbaye de Saint-Guilhem-le-Désert contestée dans sa seigneurie ;

*Dominique BILOGHI*, Logistique et Ancien Régime les étapes du roi et de la province de Languedoc aux XVIII<sup>e</sup> et XIII<sup>e</sup> siècles ;

*Roland GALTIER, Jean-Claude RICHARD*, L'orgue de Notre-Dame des Tables à Montpellier Jean-Pierre Cavallé et l'orgue Dom Bedos.

**SOCIÉTÉS, TECHNIQUES, ETHNOGRAPHIE :**

*Nadine BOUDOU*, L'exploitation salinière dans l'Hérault le salin de Villeneuve-lès-Maguelone ;

*Jacques BASSET*, Le barrage de la Meuse à Gignac Hérault 1860-1964 Un exemple d'équipement hydraulique en Languedoc ;

*Pierre TRINQUIER*, Sobriquets du Lodévois ;

*Jean-Pierre BESOMBES-VAILHE*, Pieds-Noirs en Biterrois Analyse des pratiques associatives et de l'identité collective des pieds-noirs ;

*André SOUTOU*,

Notes de toponymie I-Montferrand et Roque Farran sur la montagne du Pic Saint-Loup ;

Notes de toponymie II-Le nom de lieu Le Vignogoul, commune de Pignan (Hérault).

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**CHRONIQUES, ACTUALITÉS :**

*Claudie DUHAMEL-AMADO*, La féodalité autour de Béziers-un cas particulier de transition ;

*Jean NOUGARET*, Archéologie médiévale Histoire de l'Art Bibliographie 1992-1994.

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