Analysis of the authorship of the scientific output on Levantine and Schematic post-Paleolithic rock painting in Spain (1907-2010)

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Abstract

The body research comprised of more than two-thousand titles on post-Paleolithic cave art in Spain spanning the one-hundred and three years (1907-2010) is examined in terms of author productivity, collaboration patterns, foreign authorship, and the structural dynamics of scientific collaboration. The study concludes that research in the field of post-Paleolithic cave painting continuous to rely on individual authors and authors not associated with any institutional organ.

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Resumen

Análisis de la autoría en la producción científica sobre pintura rupestre postpaleolítica de los estilos levantino y esquemático en España (1907-2010)
Miguel Ángel Mateo-Saura, Isidoro Gil-Leiva y *Antonio Pulgarín-Guerrero*

A más de un siglo de investigación sobre la pintura rupestre postpaleolítica en España, que ha llevado a una producción científica que supera los 2 000 registros, se lleva a cabo un estudio para evaluar su rendimiento durante el periodo 1907-2010. Se presentan los resultados obtenidos tras el análisis de la productividad de los autores, de la colaboración científica, del papel de la autoría extranjera en la producción científica y de la estructura y dinámica de los grupos de investigación. Se concluye que la investigación sobre la pintura rupestre postpaleolítica en España sigue descansando en el trabajo individual y en autores independientes que carecen de adscripción institucional.

Palabras clave: Bibliometría; Autores; Colaboración Científica; Prehistoria; Pintura Rupestre; Pintura Postpaleolítica; Arte Levantino; Pintura Esquemática.

Introduction

After a period of nearly 25 thousand years of cave paintings in the territory of modern Spain, several other graphic and cultural expressions supervened that may be collectively called post-Paleolithic cave art, which individually are attendant to various social, cultural and economic milieus. The two major post-Paleolithic styles are the Levantine, whose makers are currently the subject of much debate (though many researchers associate these works with the last wave of Mesolithic hunters occurring in the tenth to the fourth centuries BC); and the Schematic style linked to the first groups of Neolithic tool makers inhabiting the Iberian peninsula in the fourth to the third centuries BC.

While Levantine art developed in the pre-coastal range of the Iberian Peninsula parallel to the Mediterranean Sea from Lérida and Huesca in the north moving to the south toward Jaén and Almería, the Schematic art style attained a larger geographic range and can be found throughout the Iberian Peninsula, from the Mediterranean coast to the Atlantic in the lands around Cadiz to the northern reaches of Castilla-León.

While each style is associated with groups with distinct economic and social features (Mateo Saura, 2009), they also exhibit some similarities that have fueled speculation about the affiliations between them (Mateo Saura, 2001). Most of the representations in both styles are painted on the walls of small overhangs (in calcareous terrains formed by the reaction of wind erosion and rain water and that dissolves the soft rock) and receive direct light. Along the Mediterranean coast of the Iberian Peninsula the two styles are often found in the same rocky niche. An analysis of the features of these shallow caves and overhangs, including the typology of the sites, their orientation, altitudes and the position of the painted figures on the walls suggest several parallels between the two styles.

Though more research needs to be done in this area, we also observe similarities in technical details, such as the composition, (Hernanz Gismero and Ruiz López, 2012; Montes Bernández and Cabrera Garrido, 1992; Ripoll Perelló, 1961; Roldán García, 2009, 2012); and in representational treatment, in which the artist exploits simple lines to define easily identifiable forms. The use of lines, of course, is distinctive to each style. While the Levantine style uses narrow lines with well-defined edges, the Schematic style generally uses thicker lines with fuzzier definition. Both styles generally exploit red dyes, though black paint is also common to both. The Levantine artwork found in the Albarracín región in Teruel also uses white paint. The size of the painted motifs range from 5 to 50 cm, though there are some miniature paintings of a few scant millimeters and others larger than one meter in length.

The main differentiating feature between the styles lies in the expressive language each deploys. The Levantine style is naturalistic, allowing the diverse motifs to be recognized. For example, a bowman and a cervix are easily discerned thanks to the rendering of their morphologies. In contrast, the Schematic style employs abstraction, which not only reduces forms to basic linear expression, but also posits coded signs that cannot be readily identified by an uninitiated reader.

In terms of iconography, this degree of abstraction is the major difference between the two styles. Levantine art depicts human and animal figures in narrations of the hunt, human figures involved in warfare and in domestic activities, often featuring women gathering food. There are also large grouping of archers and other human groupings whose meaning escapes us. Some paintings show herds of animals without the presence of hunters. On other occasions a single animal is portrayed in the sheltered space. The Schematic style also exhibits human and animal figures involved in both hunting and herding activities. These figures, however, are accompanied by a variety of symbols that are to be interpreted by their formal similarity to things we vaguely recognize but cannot identify with any certainty.

In this general context and over the course of one-hundred years of research on post-Paleolithic art in Spain, the question of the identity of the creators of this art is perhaps one of the most widely researched and debated. The training of researchers is perhaps something that best reveals this situation. If since the early twentieth century, when archeology was a new discipline, until the middle of the century, research on prehistoric art was in the hands of priests, such as Henri Breuil or Hugo Obermaier; and geologists, such as Eduardo Hernández Pacheco, or persons associated with the fine arts, such as Juan Cabré or Juan Bautista Porcar, since the 1960s archeologists and prehistoric history specialists take center stage just as the Pre-History, Archeology and Ancient History specializations are founded in the Spanish university system. In recent years, researchers have begun to explore prehistoric art as something other than exclusively aesthetic phenomena. In addition to addressing aesthetics, these studies include examinations of technical, ideological and symbolic factors. These technical studies have opened the way for contributions from disciplines such as Physics, Chemistry, Biology and Informatics.

Most research done these days, with few exceptions, is carried out by research teams. This occurs for many and sundry reasons, including controlling costs, widening scope and advantages in securing funding (Rusell, Madera Jaramillo and Ainsworth, 2009; Valenciano *et al.*, 2010; Zulueta, Cabrero and Bordons, 1999). Along this line, Beaver and Rosen (1978) describe a long list of reasons for collaboration, which in addition to those cited include gaining access to certain abilities or technical teams in order to save and optimize time, acquiring experience and multiply training opportunities, while also overcoming intellectual isolation and preparing disciples. Whatever the motivation for working in teams, the practice exerts a positive effect on the productivity of researchers and the visibility of the works they produce.

Scientific collaboration is without a doubt a hallmark of modern science. Price (1963) stated that by the end of the twentieth century individual research would be gone and collaboration the norm, predicting a collaboration rate of 2.5 authors per paper. Even though the rate of collaboration has increased significantly in the experimental fields, the Humanities and social sciences, in general, are still far from attaining Price's rates (Over, 1982). In any case, collaboration is an indicator of the degree of professionalization of a scientific community (Sancho, 1990) and of the economic support the science receives, since such investment usually serves to promote the formation of teams (Agulló Martínez and Aleixandre Benavent 1999).

In the bibliographic analysis of scientific output on post-Paleolithic art of both the Levantine and Schematic styles found in Spain and published between 1907 to 2010, the question of the identity of the creators in conjunction with scientific production itself constitute two sides of the same coin. If the bibliographic indicators provide information regarding the size, growth, development, visibility and structure of the research process (Agulló Martínez, 1998; Bordons and Zulueta, 1999; Maltrás Barba, 2003; Terrada, 1971, 1973), the indicators of production, based on the measurement of scientific output (López Piñero and Terrada, 1992), will reveal concrete features such as the growth of the science and the chronological development of scientific output, and also the productivity of researchers, their degree of collaboration and cooperation among institutions. The structural dynamics of the research groups that produce and consume documents will also be shown (Bordons and Zulueta, 1999; González de Dios, Moya and Mateos, 1997; Sancho, 1990).

A bibliometric analysis of authorship of research on post-Paleolithic art in Spain published between 1907 and 2010 ad the structure of the research groups is the object of this study.

Material and Method

Since there is no single referential data base bringing together all the papers published in the field, we have been forced to consult several sources of information. As such, the following resources have been consulted: the ISBN database for books and monographs; the TESEO database for doctoral theses; the ISOC database of CSIC for scientific articles and lectures read in conferences; the Dialnet database; the Web of Science database; the biblio-

graphic collection of *Corpus* de Pintura Rupestre Levantina del Instituto de Historia del CSIC; the cataloge of the Biblioteca de Humanidades de la Universidad de Murcia; and the catalogue of the Biblioteca del Centro de Arte Rupestre de Moratalla (Murcia). Likewise, wide reading of scientific articles in the field of cave art over these decades and special attention to the bibliographies of the same provided a significant number of references.

Search terms specific to the field of cave art, such as "rock art," "cave art," "Levantine art," "Levantine painting", "Schematic art" and "Schematic painting"[1] were used to query the catalogues and the national and international databases cited. These terms were used to retrieve documents held in Subject, Title, Summary fields. When nothing was retrieved, the Any Field option was used.

Using the extensive bibliography used in the BA degree project by Mateo Saura (1992) and the documents drawn from the queries of the diverse resources mentioned, a data base of 2,186 entries was built using *Microsoft Access.* As of the March 31, 2011 the last records were entered into the data base.[2]

This *ad hoc* data base of 2,186 entries was structured to include fields serving our purpose. With the database set and the records found dumped into the same, the task of homogenization of the data ensued, a process that resulted in the reliable identification of authorship. Bibliographic data bases often contain records of an author who is named in several different ways. The maternal last name is often omitted or the name is abbreviated excessively, e.g., with the second initial appearing in a compound name. This circumstance inserts doubt about whether all of the variants refer to the same person or whether they correspond to as many authors as there are variants.

As such, we have attempted to record all authors with both paternal and maternal surnames. To do so we have gone directly to the ambiguous documents for orientation one way or the other. Some of the indicators used include the coincidence of geographic area or field sites under study, places of work or the eventual association of the author to collaborative research teams. For those cases still resistant to this approach, we have resorted to a criterion used in other work (Abad Pérez, 1987; Miguel Dasit, 2003) and we entered such names variants as distinct authors. Likewise, the abbreviations

1 The actual Spanish terms used in the search are as follow: "arte rupestre", "pintura rupestre", "arte levantino", "pintura levantina", "arte esquemático" o "pintura esquemática".

2 The data base can be consulted at: http://webs.um.es/isgil/

"and others," "*et alii*", or "*et al.*" have been eliminated and the surnames and complete names of all credited authors recorded.

For the study of scientific output of authors, the simplest, most often used indicator is obtained by counting the number of credited authors. This approach has proven that most scientific output is driven by a small number of very productive authors, working with many authors who only occasionally contribute. One might argue that greater output is not necessarily correlated to greater importance; however, the correlation between output and scientific relevance has been proven. The first researcher to understand this and express it mathematically was Lotka (1926). His study examined the distribution and frequency of papers published by 8,216 authors, showing that for each paper published by an author the number of authors declined in a regular way. Our work, performed on the basis of the methodology proposed by Pao (1985) and Nicholls (1986), has verified "Lotka's Law."

We have also calculated the productivity index proposed by Price (1963) on the basis of the logarithm decimal of the number of publications by authors. This allows us to define productivity groups of low, medium and elite authors, using the productivity index of an author whose position in the distribution of authors corresponds to the square root of the total number of authors. We have also calculated the "transitory index" (closely associated with the productivity index), defined as the number of authors who publish only one paper (Price and Gürsey, 1976). This index allows us to weigh the degree of maturity of the scientific field and its consolidation as an area of study.

Scientific collaboration, which can occur in areas as varied as co-authorships, informal communication of ideas and projects in meetings and congresses or exchange of correspondence, is often very hard to measure. Perhaps this is why the question of collaboration is examined from the standpoint of co-authorship. The indicator that provides us the information is the credit/work index, or collaboration index in the terminology of Lawani (1986). Likewise, the analysis of collaboration on the basis of authorship provides us with other indicators, such as participation of foreign authors in research on post-Paleolithic cave art in Spain. It also tells us about Spanish authors who publish abroad. Both of these measures are fairly reliable indicators of the degree of internationalization of the field of study.

The establishment of research teams is a direct consequence of scientific collaboration. This is commonly associated with what Price (1963) called invisible colleges, understood as scientific groups researching a single object but working in different, often faraway, places, who engage in exchange of information other than through conventional printed media. Most bibliometric studies of networks are based on citations of the publications thereby revealing the relationship structure among scientists. In our case, however, the general lack of references to citations and the concomitant absence from citation indexes in question (because Spanish journals are not indexed in international data bases) invalidates this approach. As such, we approach collaboration groups from the angle of co-authorship.

To delimit these groups and include the collaborating authors, we began with the methodology used in Bordons *et al.* (1995), and Zulueta, Cabrero and Bordons (1999), which acknowledges the most productive researchers as the lead author. This author must have published at least one paper per year over the period under study. For an author to be assigned to a group, he must have signed at least 60% of his production with the lead author. The occasional authors (1-2 published papers) are not assigned to a group. The group must be made up of at least three authors; and the groups established on the basis of co-authorship (rather than institutional affiliation) may include authors from other institutions. Because of the exclusive features of our data, we have had to perform a specific adaptation to some of these general criteria. If a researcher going years without publishing is taken as an exclusion factor, several of the most productive authors would be excluded. If we were to exclude the occasional authors, who represent more than 75% (Mateo Saura, 2013) and those whose output does not reach the 60% co-authorship with lead author threshold, we would paint only a partial and very unrealistic picture of scientific collaboration in the field of cave art in Spain.

To learn the degree of cohesion of the groups, we calculated the density on the basis of the relationship between the number of links established by each group and the number of possible links between members of the same (Otte and Rousseau, 2002; Valderrama *et al.*, 2007; Valenciano *et al.*, 2010). Finally, Pajek software was used to generate the graphs showing these networks (Batagelj and Mrvar, 2007).

Results and discussion

The documental typology of the 2,186 works on Levantine and Schematic style cave art published between 1907 and 2010 in Spain and abroad constitute the basis of our study. This typology breaks down as follows: 1,208 papers (55.26%), 421 lectures delivered in congresses; (19.25%), 248 chapters in collected works (11.34%), 218 monographs (9.97%), 52 notes (2.37%), 23 PhD dissertations (1.05%) and 16 undergrad degree final projects (0.73%). This variety of typology exerts an impact on diverse aspects of the authorship itself, especially with regard to the parameters of collaboration. Some document types are signed by a single author, such as dissertations and undergraduate degree final projects. Other types of works tend also to be signed by a single author, such as monographs and book chapters; but co-authorship is the preferred route in papers read at congresses and journal publications. In all events, as shown in the section on collaboration, the discipline under study exhibits a clear penchant for individual authorship across all document typologies.

Author output study

The 2,186 documents analyzed were produced by 846 authors. Of these 484 have published a single work, and account for 57.21% of the author sample. Another group of 130 (15.36%) authors has published two works and 63 (7.44%) authors have published three works, while 29 (3.42%) share credit in four articles, and 19 researches (2.24%) share credit in up to five works. This trend continues until we reach a subset of highly productive authors, "super-productive" in the words of Martínez Fernández (1996). This group is comprised of twelve authors (1.41%) who have published ≥40, of which there are two authors having signed 92 and 93 works, respectively, and one, Antonio Beltrán Martínez, with 179 publications (*Table 1*).

Table 1. Distribution of works by author

Works	Authors	% authors
1	484	57.21
2	130	15.36
3	63	7.45
4	29	3.43
5	19	2.24
6-10	57	6.74
11-15	23	2.72

16-20	12	1.42
21-25	9	1.06
26-30	6	0.70
31-35	1	0.11
36-40	3	0.35
≥41	10	1.18
Total	846	100

In accord with the productivity index obtained as a reference in our distribution of authors, which is 1.32 corresponding to Jesús Vicente Picazo Millán, an author who occupies 29th place (√346) in said distribution, we can define a first group of lesser producers, those who publish only one work and whose productivity index is equal to 0. This group is comprised of 484 authors (57.21%), who account for 14.45% of the total output. A second group, the medium producers (from 2 to 20 works) consist of 333 authors (39.36%), who account for 47.95% of the works. The last group of super-producers (≥21 publications), whose productivity index is equal to or greater than 1.32, consists of 29 authors (3.42%), who account for 37.60% of the publications.

These data also show that the highest productivity index of 2.25 is held by a single author (Antonio Beltrán Martínez) who has published 179 works. Moreover the transitory index determined by the number authors having published only once (Price and Gürsey, 1976) is 57.21%, which is quite interesting because this is a very reliable indicator of the degree of consolidation of the scientific activity in the field (Shubert and Glänzel, 1991). In this case, the transitory index may be considered quite high, though other fields exhibit transitory values even above 80% (Álvarez Solar, López-González and Cueto-Espinar, 1998).

With regard to Lotka's Law, once the slope of the authorship distribution and the constant are obtained (-1.79 and 0.5271, respectively, and the critical value is set (0.056), with a significance level benchmark of =0.01, and maximum difference of 0.047, we can safely assert that our sample matches a Lotka type distribution.

Within the subset of high producers there is a subset of 12 super producers (≥40 publications). These twelve authors account for 1.41% of the authors while producing 37.20% of the output (813 documents) (*Table 2*). The institutional affiliation of these super producers is also a point of interest, as only four of the 12 are associated with academic institutions. Antonio Bel-

trán Martínez works in the Universidad de Zaragoza; Mauro Severo Hernández Pérez in the Universidad de Alicante; Martí Mas Cornellá in UNED; and Eduardo Ripoll Perelló has worked at different times in the universities of Barcelona, Oviedo, Bellaterra and the UNED of Madrid. A fifth author, Vicente Baldellou, is the director of the Provincial Museum of Huesca. Of the remaining seven, five are teachers of secondary education, while Ramón Viñas Vallverdú and Alexandre Grimal Navarro are not associated with any university or cultural organism. Most of Ramón Viñas Vallverdú's output was achieved before 2005 without any affiliation to an official institution, and only since then on the basis of his membership in the Instituto Catalán de Paleoecología Humana y Evolución Social, while Alexandre Grimal is a painter without any institutional affiliation.

Table 2. Super-producers group (P.I. Productivity Index)

Nº	Author	Publications	%	P.I.	Research period	Institutional affiliation
1	Beltrán Martínez, Antonio	179	8.18	2.25	1954-2006	Universidad de Zaragoza
2	Mateo Saura, Miguel Ángel	93	4.25	1.97	1991-2010	Secondary school teacher
3	Alonso Tejada, Ana	92	4.20	1.96	1977-2010	Author without institutional affiliation
4	Viñas Vallverdú, Ramón	65	2.97	1.81	1971-2010	Instituto Catalán de Paleoecología Humana y Evolución Social (2005-2015)
5	Grimal Navarro, Alejandro	64	2.92	1.80	1985-2010	Painter
6	Baldellou Martínez, Vicente	60	2.74	1.77	1979-2010	Director del Museo Provincial de Huesca
7	Hernández Pérez, Mauro Severo	48	2.19	1.68	1982-2009	Universidad de Alicante
8	Mas Cornellá, Martí	47	2.15	1.67	1985-2009	Universidad Nacional de Educación a Distancia
9	Gómez-Barrera, Juan Antonio	44	2.01	1.64	1979-2010	Secondary school teacher
10	Ripoll Perelló, Eduardo	41	1.87	1.61	1951-1997	Universidad de Barcelona (1953-1968); Universidad Autónoma de Barcelona (1968); Universidad de Oviedo (1969); Universidad de Bellaterra (1970); Universidad Nacional de Educación a Distancia (1981-1988); Emérito de la Universidad Nacional de Educación a Distancia (1988-2006)

11	López Payer, Manuel Gabriel	40	1.87	1.60	1973-2009	Secondary school teacher
12	Soria Lerma, Miguel	40	1.82	1.60	1978-2009	Secondary school teacher

At another step in the output scale we have those authors with 10 to 39 works published. These authors exhibit a considerable variety of institutional affiliations. Among these 61 authors, publishing 835 works and accounting for 38.19% of the sample output, there are 27 (44.26%) university professors or authors associated with universities in some way at the time of publication. Another 23 (37.71%) are associated with cultural agencies, mostly as municipal museum directors, or hold posts within the general cultural directorates or similar agencies. The last group is comprised of 11 authors (18%) who work outside of university and official institutions, many of which are secondary or elementary school teachers.

Foreign authors

The participation of foreign authors in the research of post-Paleolithic cave art in Spain and the appearance of Spanish authors in foreign publications constitute the most reliable indicators for assessing the degree of internationalization of the field. In this regard, 72 foreign researchers have publications in the sample, which represents only 8.51% of the authorship. They are authors or co-authors of 193 works or 8.82% of the total output (*Figure 1*).

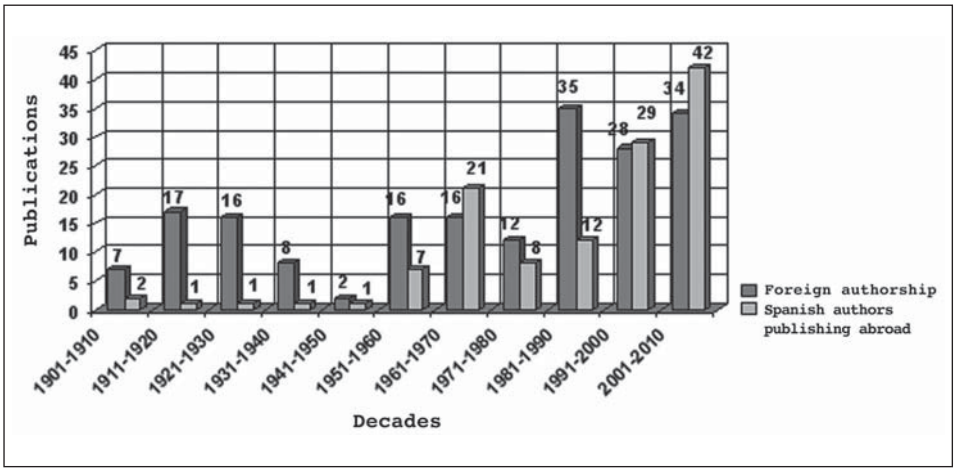

Figure 1. Distribution of production of foreign authors and Spanish authors publishing abroad

The work of foreign researchers is quite marked during the early years, when authors such as Henri Breuil and Hugo Obermaier monopolized the field. In fact over the first four decades of the study period, they published 43 works, which accounted for 82.69% of the output up to that time. These researchers were joined by other foreign researchers such as Paul Wernert, Herbert Kühn, Emil Cartailhac, Miles Burkitt, Henri Begoüen and George H. Luquet, who published largely in co-authorship with Henri Breuil. This is not surprising, since research on cave art in Spain at that time was largely in the hands of foreign institutions such as Instituto de Paleontología Humana de París. Spanish institutions such as the Comisión de Investigaciones Paleontológicas y Prehistóricas, often incorporated foreign researchers, including those already mentioned. The few Spanish authors, associated with fields as disparate as Natural Sciences or Fine Art played for the most part a complementary role, and it should be remembered that the field of prehistory and archeology hardly existed at all in those years in Spain.

Over the period of 1931 to 1950, the participation of foreigners in cave art research in Spain declined considerably. From 1941 to 1950 foreign participation was reduced to the status of testimonial, a period in which only two foreigners published work in the field. This may well be due to the general isolation of the country at that time. From the early 1980s forward the incidence of foreign authors began to rebound. In the last three decades of the study period, 97 foreign authors appear. The data for the last thirty years, however, could suggest a changing trend in foreign authorship of studies on post-Paleolithic cave art in Spain; though this extreme should be corroborated in a later study. In all events, the reticence of many Spanish journals to accept manuscripts in languages other than Spanish constitutes a serious obstacle to publication of submissions by foreign authors (Osca Lluch and Mateo Marquina, 2003).

Spanish authorship in foreign publications

The 82 Spanish authors who have published outside of Spain (9.69%) account for 125 works, which constitutes 60.97% of the output published abroad and only 5.71% of the total output (*Figure 1*).

The number of Spanish authors published in foreign publications is scant over the first fifty years of the study period. In fact, the few works we found are co-authorships with foreign lead authors who dominated the scene at the time, especially Henri Breuil and Hugo Obermaier. At the beginning of the

1950s we find a greater number of authors, including authors signing work individually. This trend hit a peak, in the ten year span of 1961-1970, in fact tripling the number of published works in the previous decade. The last twenty years has seen a greater number of Spanish authors published in foreign publications, though they still account for very low percentages of the total output. While the growth of foreign authors publishing in Spain in this field might suggest a shifting trend, we cannot assert the same with regard to Spanish authors publishing abroad. Only another study with a broader time span that the last twenty years would verify what appears to be a line of growth or, as warranted, show the opposite.

Analysis of scientific collaboration

The 2,186 documents bear 3,374 signatures, which comes to a collaboration index 1.54 of signatures to published work. The 1,462 documents signed by a single author comprise the largest group, accounting for 66.88% of the total output; while the other 724 (33.11%) works were collaborations. A large group comprised of 468 works signed by two authors represents 21.40% of total output and 64.64% of the collaboration subset. Works with three authors came to 147, 6.7% of total output and 20.30% of the collaboration subset; while those signed by four authors came to 67, which is 3.06% of total output and 9.25% of the collaboration subset. The 42 documents signed by five or more authors account for a mere 1.92% of the total output and 5.80% of the collaboration subset. Of this latter subset, there was one article with as many as eleven credited authors (*Table 3*).

Table 3. Distribution of signatures/works in the output set

Number of signing authors	Number of publications	% over collaboration	% over total output	Total number of signatures
11	1	0.14	0.04	11
10	1	0.14	0.04	10
9	3	0.41	0.14	27
8	3	0.41	0.14	24
7	9	1.24	0.41	63
6	5	0.69	0.23	30
5	20	2.76	0.92	100
4	67	9.25	3.06	268
3	147	20.30	6.72	441
2	468	64.64	21.40	938

1	1.462	-	66.88	1.462
Total collaboration	724		33.11	-
Totals	2.186	-	-	3.374

During the period under study, the greatest growth of scientific collaboration occurred in the last three decades, even though during the first three it was not altogether absent. Until 1970, the few collaborative works had at most three authors. In fact, of the 45 co-authored works up to that time, only five were signed by more than two authors. After the decade of the 1970s both the number of collaborative works and the ratio of co-authors to works increased significantly. Nonetheless, works signed by two authors remained the most common modality of collaboration, and holds for the entire period under study. In the ten years from 1991 to 2000, the percentage of multiple authorship rose to 40%, and in the next decade it rose to 41.45% (*Table 4*).

Table 4. Evolution of co-authorship over time

Decade/signatures (credits)	1	2	3	4	5	6	7	8	9	10	11
1900-1910	9	3	1	-	-	-	-	-	-	-	-
1911-1920	29	10	1	-	-	-	-	-	-	-	-
1921-1930	30	6	2	-	-	-	-	-	-	-	-
1931-1940	15	1	1	-	-	-	-	-	-	-	-
1941-1950	39	-	-	-	-	-	-	-	-	-	-
1951-1960	61	8	-	-	-	-	-	-	-	-	-
1961-1970	107	12	-	-	-	-	-	-	-	-	-
1971-1980	151	35	6	2	1	-	1	-	-	-	-
1981-1990	316	97	32	11	2	1	3	1	-	-	-
1991-2000	329	138	46	27	7	2	-	-	1	-	-
2001-2010	373	158	58	27	10	2	5	2	2	1	1
Without date	3	-	-	-	-	-	-	-	-	-	-
Total	1.462	468	147	67	20	5	9	3	3	1	1

The collaboration index of 33.11% obtained is slightly higher than that exhibited in the bibliometric study of Levantine rock art, in which collaborative work came to 23.07% (Cruz Berrocal *et al.*, 1999), which is also consonant with indices exhibited in other archeological areas. Analysis of works published in the pre-History journal *Trabajos de Prehistoria* to 1993 indicate a co-authorship rate of 28.52% (Rodríguez Alcalde *et al.*, 1993), while co-

authorship in the study of prehistory by Spanish and Portuguese historiographers came to 32.30% (García Marín *et al.*, 1997). In contrast, the percentage of co-authorship in the field of ancient ceramics is quite high at 78.32% (García Heras, 1997). This figure falls considerably to 59.01% when we look at collaborative works involving only archeologists. It is when we include specialists from experimental sciences that the collaboration rate shoots up to 75.32%.

The co-authorship index calculated for the *Boletín de la Asociación de Amigos de la Arqueología* came to 18.88%, of which 74.7% were signed by two authors (Rovira Llorens, 1994). In contrast the journal *Revista d'Arqueologia de Ponent* exhibits a collaboration rate of only 34.82%, with 49.57% of these works credited to two authors (Armada, 2009). The *Archivo Español de Arqueología* published 31 co-authored papers between 1985 and 1996, a mere 13.08% of total publications in that period (García del Toro *et al.*, 1999), while coauthored papers up to 1995 in *Cota Zero* came to 25.21% of the published research (Cruells, 1995).

The relatively low level of collaboration in archeology and prehistory journals (Rodríguez Alcalde *et al.*, 1996) is consonant with the low levels of co-authorship exhibited across the social sciences and especially the Humanities (Bordons and Gómez, 1997; Cronin, Shaw and La Barre, 2003), and in all events lower than that exhibited in the fields of experimental science and health (Over, 1982). Several bibliometric works have examined these matters of collaboration in the journals published by Universidad de Extremadura, where rates of 89% in the scientific fields were found versus a rate of 49% in the social sciences and the Humanities[3] (Pulgarín *et al.*, 2003, 2004). Alonso Arroyo, Pulgarín Guerrero and Gil Leiva (2005) obtained similar results in their study of collaboration in the Universidad Politécnica de Valencia, where the collaboration rate in journal publications came to 86.29%.

The low collaboration we found seems to indicate that the study of post-Paleolithic cave art exists at the margins of the general trend of science, and is in many ways a local, individual endeavor and has been since its inception.

3 As the authors of this study acknowledge, the distinct data sources in each case (international sources in scientific-technical fields and national in the fields of social sciences) could exert an effect on the final results.

The collaboration index, understood as the number of credited authors per work (Lawani, 1986), in our study came to 1.54. In the Humanities and Social Sciences the number for authors to works is 1-2, versus the ratio of 2.5-3.5 in experimental and technical fields (Bordons and Gómez, 1997; Sancho, 1990). As such, our collaboration index is below that of 2.6 found in archeological ceramics (García Heras, 1997), but quite near the index of 1.74 found up to 1993 in the journal *Trabajos de Prehistoria* (Rodríguez Alcalde *et al.*, 1993).

Scientific output these days is increasingly a collaborative phenomenon. This collaborative approach exerts a positive impact on overall output, in that the most productive authors are also those who collaborate the most (Agulló Martínez and Aleixandre Benavent, 1999; Miguel Dasit, 2003; Valenciano *et al.*, 2010). In the field of post-Paleolithic cave art, however, this is not the case. The existence 12 super producers (≥ 40 publications), accounting for 37.28% of total output, serves as evidence of the low levels of collaboration in the field. Of the 813 works published by these authors, 384 have been coauthored, which comes to 47.23% of their output. In contrast, the credits/work index is quite low, standing at 1.70, a figure explained by the prevalence of co-authorships of two (265 such papers), coming to 69.01% of co-authorship subset. Even though there are four super-productive authors signing a high percentage of the collaborative output, the other eight still have a credit/work index below 2. On one hand, this is because of the prevalence of works signed by a single author against those published in co-authorship; while on the other the coauthored subset is largely made up to works published by only two authors.

The output of the super producers is quite revealing. The journal article is the most commonly represented in this output subset, accounting for 54.01% of their publications, with 20.54% of output in the form of presentations in congresses. Even though both of these modalities readily lend themselves to co-authorship, our analysis reveals the persistence of individual work. The number of papers signed by the super-producer group of 12 authors is 439, and the number of total authors is 714, which yields a credit/works index of 1.6. Of the 439 papers including super-producer credit, 241 are signed by a single author (54.89%), while only 62 works (14.12%) are signed by three or more (*Table 5*).

Table 5. Distribution of credit/work in papers involving super-producers (≥40)

Author	Number or papers	Number of credits (signatures)	Credit/work index (CWI)	Numbers of credit/works				
				1	2	3	4	5
Beltrán Martínez, Antonio	103	115	1.11	92	10	1	-	-
Mateo Saura, Miguel Ángel	57	82	1.43	38	13	6	-	-
Baldellou Martínez, Vicente	44	79	1.79	29	2	6	7	-
Viñas Vallverdú, Ramón	42	89	2.11	10	19	11	2	-
Alonso Tejada, Ana	37	72	1.94	7	25	5	-	-
Gómez Barrera, Juan Antonio	30	44	1.46	22	5	1	1	1
Grimal Navarro, Alexandre	23	42	1.82	4	19	-	-	-
López Payer, Manuel Gabriel	23	52	2.26	-	17	6	-	-
Soria Lerma, Miguel	23	52	2.26	-	17	6	-	-
Ripoll Perelló, Eduardo	22	23	1.04	21	1	-	-	-
Mas Cornellá, Martí	19	31	1.63	13	3	1	1	1
Hernández Pérez, Mauro Severo	16	33	2.06	5	5	6	-	-
Totals	439	714	-	241	136	49	11	2

An analysis of the production of the 73 most highly productive authors (≥10 publications) does not bring significantly different results. The works bearing a single credit comes to 921, or 49.9% of the subset total output, which is still a substantial proportion. In fact, of these 73 highly productive authors, only seven (9.58%) have worked exclusively in the modality of co-authorship; while another 18 (24.65%) have published less than five works on their own. Another two highly productive authors have done all of their work on their own, while seven others exhibit negligible incidence of co-authorship. At the same time, of the 938 works signed by these highly productive authors, 525 (55.97%) were signed by two authors. As the number authors rises, the number of works diminishes significantly (*Table 6*). The credit/works index (CWI) of the highly productive authors is 1.92, somewhat higher than the 1.54 for the total output.

Table 6. Distribution of credit/work among authors with 10 or more documents

Number of credits	Number of documents	% of co-authorship
2	525	55.97
3	239	25.47
4	104	11.08
5	25	2.66
6	13	1.38
7	10	1.06
8	9	0.95
9	12	1.27
10	0	0
11	1	0.10
Total	938	100

These data appear to contradict the positive effects on output that collaboration exerts in scientific fields (Arora and Pawan, 1995; Agulló Martínez and Aleixandre Benavent, 1999; Beaver and Rosen, 1978, 1979; Pao, 1982). Price (1963), who predicted that by the end of the twentieth century almost all science would be approached collaboratively, coined the term Big Science to define the scientific products of collaboration, distinguishing this modality from what Agulló and Aleixandre (1999) called "artisan" science, which is the "Little Science" of individual inquiry. This indicator suggests the study of post-Paleolithic cave art in Spain has not reached the degree of maturity or professionalization seen in other scientific fields.

The presence of multiple signatures is positively correlated to economic support, in such a way that the scant economic support for research forces researchers to rely on personal initiative (Agulló Martínez and Aleixandre Benavent, 1999). While the field under study has seen an increase in the collaboration rates, attaining percentages 40% in the decade of 1991-2000 and of 41.45% for 2001-2010; these figures do not yet constitute a line of consolidation from which further, steady growth can be expected.

It was only in the years 1999 and 2010 that we see the number of collaborative works surpass those signed by individual authors, the former year coming in at a rate of 50 to 49, and the latter at 18 to 16. In 1997, these modalities were equal at 22 apiece. For all other years in the study period, works signed by single authors outstripped collaborative works by a wide margin. Moreover, the number of works with multiple authors varied widely from year

to year. Between 1991 and 2000, the percentage of scientific collaboration fluctuated from 25% in 1992 and 45.45% in 1994, while in the next decade collaboration increased slightly, coming in at 38.93% in 2006 and 47.05% in 2003. The year 2009 was particularly low in terms of collaboration, reaching a meager rate of 25% of total output for the year. These erratic ups and downs prevent any talk of consolidation of the growth in the modality of collaboration in the field.

International collaboration

Within the subset of the collaborative modality, international collaboration is quite prominent. If the signatures of a foreign authors is taken as a reasonably reliable indicator of the degree of internationalization of the field, our data on the participation of foreign researchers seems to corroborate that the field of post-Paleolithic cave art has not attracted significant interest abroad. Of the 193 works with participating foreign authors, 71 (36.78%) were in collaboration, even though in the general context these works account for only 9.80% of the total collaboration modality subset.

The 71 works published in collaboration include 347 signatures (credits), which yields a credit to work index (CWI) of 1.79, which is somewhat higher than the 1.54 exhibited for collaboration against total output. In terms of signatures, 36 works were signed by two authors (50.70%), while only one (1.40%) was signed by eleven authors.

In the first three decades of the period under study, 14 of the 23 co-authored works (60.86%) included a foreign author. This high proportion can be traced to the preponderance of foreign organizations and individuals in the field of Iberian cave art. In fact, one of the most productive foreign authors and most frequently working in collaboration is Henri Breuil, who signed ten of thirty works in co-authorship with both foreign (Hugo Obermaier, Emil Cartailhac and Mile Burkitt) and Spanish authors (Juan Cabré, Federico de Motos, Pascual Serrano and Juan Bautista Porcar). Between 1931 and 1950 there is a marked decrease in the international co-authorship that parallels a decline in overall output because of the Civil War and subsequent period of isolationism in Spain.

Between 1951 and 1970 international collaboration rebounds slightly, reaching a rate of 35% (7 of 20 works), but then in the decade of 1971 to 1980 it declines again to 2 of 45 works, or 4.44%. Since the early 1980s, co-author-

ship with foreign researchers has seen some modest gains, though the figures come only to 8.63%, i.e., 47 de 544 documents *(Figure 2).*

Of the 71 works coauthored with foreign researchers, 45 (63.38%) are signed by Spanish and foreign authors, while 26 (36.61%) are signed only by foreigners. The highest collaboration index attained by Spanish and foreign researchers has occurred during the last three decades of the study period, touching a rate of 75.50% *(Table 7).*

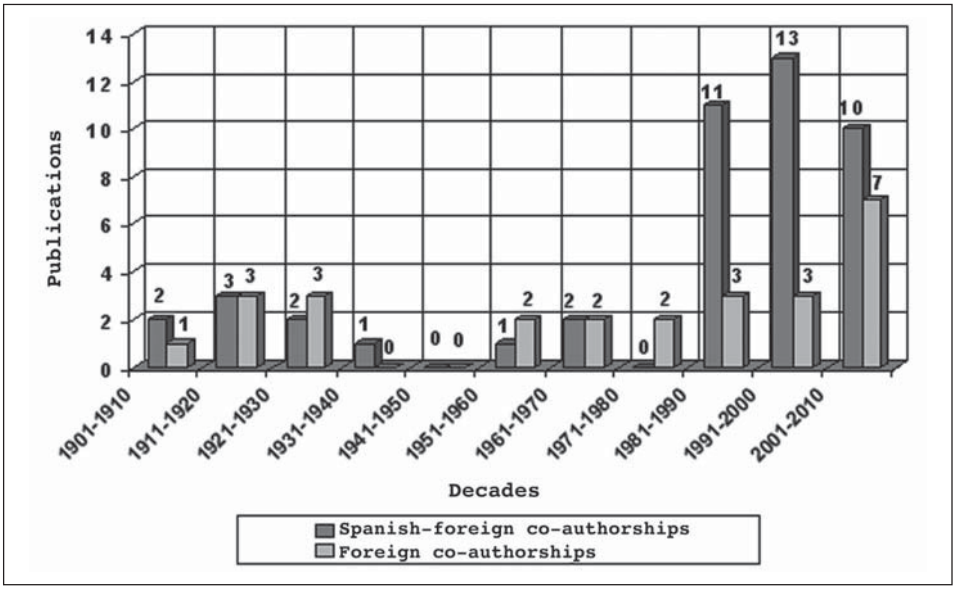

Figure 2. Evolution of co-authorship out involving Spanish and foreign researchers

Table 7. Distribution of international collaboration

Type of co-authorship	Number of works	Number of credits per work										Total credits	CWI
		2	3	4	5	6	7	8	9	10	11		
Spanish-foreign	45	12	12	12	2	2	3	0	1	0	1	171	3,80
Exclusively foreign	26	24	2	0	0	0	0	0	0	0	0	54	2,07

Collaborative groups

Despite some limitation in the approach, the network analysis was performed on the basis of observing the co-authorship network, which can be very useful for identifying collaborative groups (Molina, Muñoz and Doménech, 2002; Russell *et al.*, 2009). These groups may be seen as informal communication networks with some sort of social organization (Pulgarín,

Lagar and Escalona, 2010). In terms of scientific collaboration, these groups may be more or less clearly formed and stable (Carpintero and Peiró, 1981). Moreover, the analysis of collaboration from the standpoint of co-authorship offers the advantage of not knowing about the existence of the group under study. For example, authorship does not reveal institutional affiliation (Zulueta, Cabrero and Bordons, 1999). As such, authorship is a useful tool for making an initial approximation of a definition of any such collaborative groups (Pulgarín, Lagar and Escalona, 2010).

In accord with the criteria discussed in the methodology section, several collaboration groups have been defined, most of which center on a lead, super productive researcher (≥40 publications) (*Table 8*). Of these lead researchers, the following three are most frequently found in collaborative co-authorships: Ana Alonso Tejada, Miguel Soria Lerma and Ramón Viñas Vallverdú. Their collaborative output surpasses their respective sole-author output.

Tabla 8. Grupos de investigación (D., Density; PI, Productivity Index; CWI; credit/WorkIndex

Lead researcher	Number of members	Publications		D	PI	C/WI	No. of credits per work								
		Sole	Co-authorship				1	2	3	4	5	6	7	8	≤9
Viñas Vallverdú, Ramón	40	21	44	0.10	1.62	2.20	21	23	14	5		1		1	
Martínez Valle, Rafael	36	9	29	0.15	1.05	3.02	9	11	7	5	2		1	1	2
Mas Cornellá, Martí	32	36	11	0.20	1.47	2.56	36	3	3	2	1		1		1
Alonso Tejada, Ana	20	19	73	0.17	4.60	1.97	19	61	9	2		1			
Beltrán Martínez, Antonio	18	153	26	0.26	9.94	0.35	153	22	2		1			1	
Baldellou Martínez, Vicente	16	40	20	0.32	3.75	1.83	40	3	7	9			1		
Gómez-Barrera, Juan Antonio	14	35	9	0.30	3.14	1.38	35	5	1	2	1				
Collado Giraldo, Hipólito	11	22	3	0.40	2.18	1.45	22	2	1						
Hernández Pérez, Mauro Severo	11	25	23	0.30	4.36	1.79	25	10	12		1				

Breuil, Henri	10	20	10	0.46	3	1.43	20	7	3					
Mateo Saura, Miguel Ángel	9	53	40	0.36	10.33	1.55	53	28	12					
Soria Lerma, Miguel	9	3	37	0.44	4.77	2.16	3	26	10	1				

Three of the twelve research groups identified begin collaborating in the late 1970s. These groups are headed by Ana Alonso Tejeda, Vicente Baldellou Martínez and Ramón Viñas Vallverdú. Another four groups are launched in the 1980s, led by Juan Antonio Gómez-Barrera, Mauro Severo Hernández Pérez, Martí Mas Cornellá and Miguel Soria Lerma, while three others, led by Hipólito Collado Giraldo, Rafael Martínez Valle, and Miguel Ángel Mateo Saura, get their start in the 1990s. Over the first twenty years of the period under study, we were only able to identify the existence of one research group, that led by Henri Breuil. In the 1950s, Antonio Beltrán Martínez headed another of these work teams. The groups headed by Breuil and Beltrán Martínez were almost always made up of occasional collaborators, of which only one appears as a lead authors of a single work. This manner of collaboration is quite common across all of the research groups identified. The output of these collaborative groups comes to 761 documents, which is 34.81% of the total sample output.

An analysis of the research groups identified and their scientific output reveals that there is no positive correlation between the number of members of a group and the number of works it publishes. The groups with most members do not necessarily publish the most; while the largest group (with 40 members) published 65 works, we have three other groups with less than half these members with nearly twice the number of publications.

The fact that there is no positive correlation between number of members in a group and the number of publication is mediated by the specific weight of output signed only by the lead authors of these groups (*Figure 3*).

In terms of cohesion, the low density exhibited in all of these groups indicates that collaboration among authors diminishes as group size increases in such a way that density is highest when groups have fewer members. In our study, groups with nine members exhibited the highest degree of cohesion.

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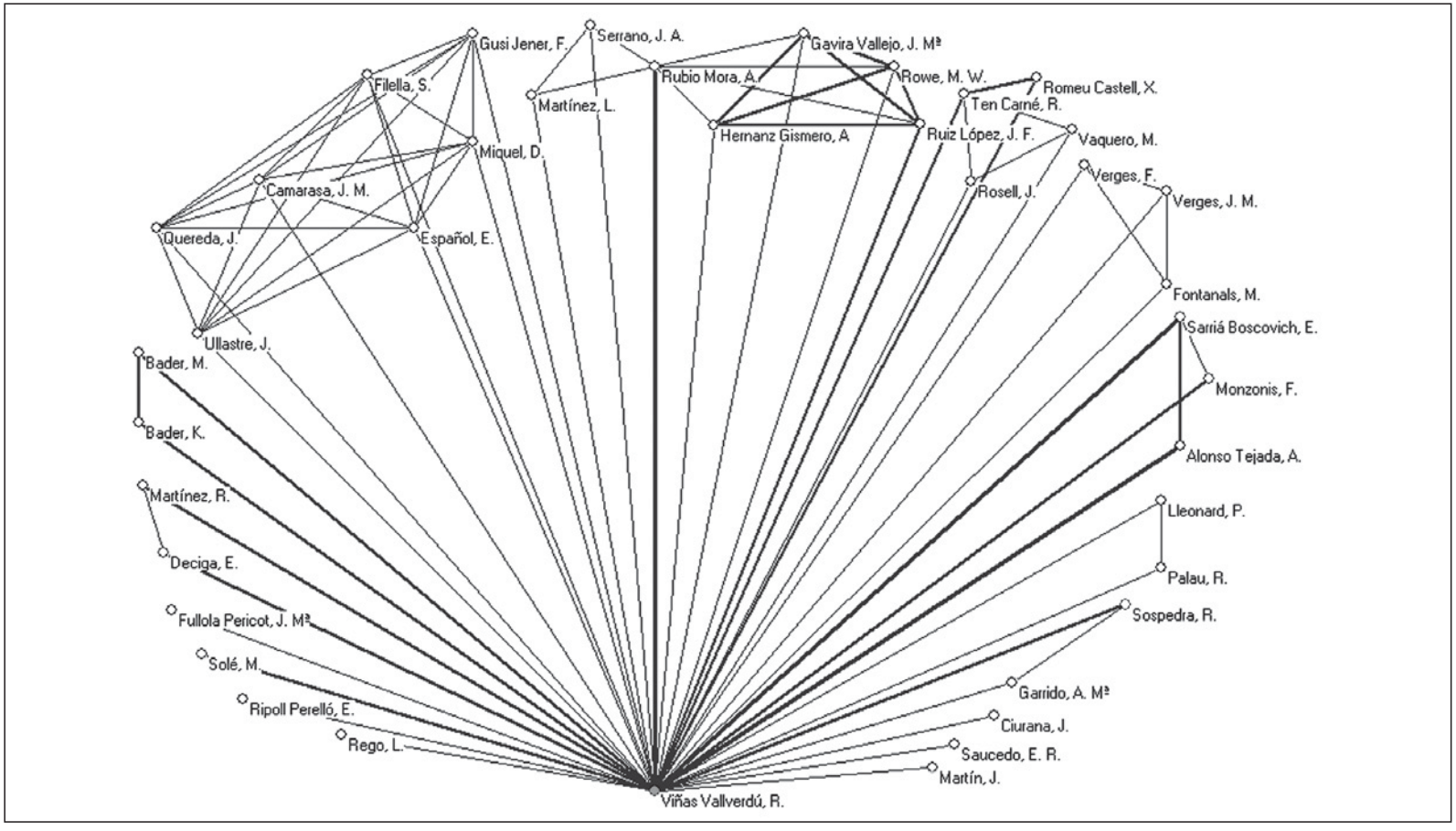

Figure 3. Collaborative group of Ramón Viñas Vallverdú

Conclusions

While the analysis of scientific output in the field of post-Paleolithic cave art in Spain for the period 1907-2010 reveals marked features of localism and meager international reach (Mateo Saura, 2013), the study of authorship may show the way toward its maturation as a science.

In the first place, the traditional tendency for individual work must move toward a collaborative, interdisciplinary approach. As stated by Cruz Berrocal *et al.* (1999) in an earlier work, this personal approach has been a hallmark of research in prehistoric and Levantine art since its very early days. While the prevalence of co-authorship in such fields has begun to grow since the middle of the period under study, reaching as much 42% of output over the last decade studied, fully 64.64% of this collaboration is comprised of works signed by two authors; while 5.80% of these works bear five or more credits.

The research team approach offers several advantages, including cost sharing, broadened access to resources and enhanced visibility. In our view, without interdisciplinary teamwork an exhaustive study and understanding of cave art cannot at this time be achieved. For a long time, the study of cave art was largely circumscribed to descriptive analysis of the iconography, something performed by an individual, usually a specialist in prehistory. Newer outlooks on prehistoric art, however, go beyond questions of iconography and demand the application of techniques from other scientific fields. A true understanding of cave art in all its facets will require the formation of interdisciplinary teams.

In the last several years several interdisciplinary works have in fact been published. Nonetheless, our data for the last two decades of the period under study show that individual authorship still accounts for 60% of output. In this light, the output of the 12 super producers is quite revealing. The output of these authors is 813 works, which is 37.19% of total sample output. Of these works 429 documents (52.77%) are signed by a single author. In view of the data, we cannot categorically safely assert that the field is undergoing a process of consolidation, as most output continues to be achieved by individuals.

In conjunction with this individual bent, we observe that there are, even today, many individuals publishing who are not associated with any academic or administrative institution. Of the 12 super producers identified (≥40 publications), only four are ascribed to a university and one to a museum. Since such institutions provide funding and material support for research, we might well think that these independent researchers are either securing support from external sources or they are approaching the field as aficionados, something which might raise, in the strictest sense, questions about their degree of professionalism. Nonetheless, it is quite clear that the study of cave art in Spain owes an incalculable debt to these inquiring individuals. In this light, researchers specializing in cave art should make every effort to join institutions in charge of the field; and the institutions themselves should reach out to this community of researchers, while encouraging the formation of interdisciplinary research groups to study the nature of cave art more fully.

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