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The Reflection of Karst in the Online Mirror: A Survey Within Scientific Databases, 1960-2005

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THE REFLECTION OF KARST IN THE ONLINE MIRROR: A SURVEY WITHIN SCIENTIFIC DATABASES, 1960–2005

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Abstract The field of cave and karst science is served by a literature that is dispersed across far-flung topical journals, government publications, and club newsletters. As part of an inter-institutional project to globalize karst information (KIP, the Karst Information Portal), the USF Library undertook a structured battery of literature searches to map the domain of karst literature. The study used 4,300 individual searches and four literature databases: GeoRef, BIOSIS, Anthropology Plus, and GPO Access. The searches were based on a list of 632 terms including 321 karst-related keywords culled from three leading encyclopedias and glossaries of cave and karst science. An examination of yearly changes in publication rate indicates that for the last 45 years, the number of cave and karst publications has increased steadily, as has the number of journals in which they appear. In particular, the past ten years cover a period of rapid growth where karst-specific journals achieved peer-review status, and individual journals accepted more cave and karst papers for publication.

INTRODUCTION

Part of what attracts students of geology is the field experience, the idea that the first challenge in studying an outcrop is getting to it. Biology and archaeology share this element of expedition. This challenge is ever-present in karst, even more so than in most other fields. Cave science is not only logistically demanding and physically challenging, but also conceptually intricate and difficult to categorize:

> The idea that there is a science of speleology that includes everything that one might like to know has proved infeasible. Instead of an inwardly focused study on caves, the current generation of cave scientists are finding out that they need to look outward rather than inward. To understand caves, one must also understand the landscape, drainage basins, and rock units in which they occur. One must draw on geochemistry, fluid mechanics, crystallography, and many other disciplines that provide essential understanding of the processes that occur in caves.
>
> - White and White, 1998, p. 40

Karst researchers encounter additional challenges in managing an information environment wherein a large amount of the information pertaining to karst originates outside of the academic world. The National Speleological Society is perhaps the largest source and repository for cave data (in the form of maps, trip reports, etc.) in the United States, even though, according to a 2005 survey, only around 15% of NSS members consider themselves professional scientists. Thus, as karst scientists, we enjoy and depend upon the cooperation and companionship of industry professionals, explorers, and amateur scientists whose standards for data-gathering may meet or exceed those of the scientific institution.

Traditionally, little of the data collected by non-scientist cavers makes it into literature with widespread distribution; the information ends up in consulting reports, expedition summaries, and caving-club newsletters. These publications are termed gray literature by virtue of being unavailable through conventional channels of library acquisition (Bichteler, 1991). Library professionals find guidebooks to be particularly frustrating, branding them "sneaky, fly-by-night, changecoat publications [that are] hard to identify, hard to acquire, hard to catalog and retrieve, and hard to preserve" (Walcott, 1990). These gray literature venues rarely find their way into standard bibliographic indices, and are not only difficult for researchers to track down, but may only exist in personal libraries that can suffer from damage or loss. Academic scientists, however, are more concerned with the fact that much gray literature manages to make its way into print while avoiding the peer-review process (Bichteler, 1991, p. 40).

Despite these concerns, recent data indicates that scientists across several disciplines are citing more gray literature (e.g., Mili, 2000, in economics; Osif, 2000, in the transportation sciences). In one particular study of papers from a fisheries management conference, Lacanilao (1997) found that 92 percent of the total number of citations were to gray literature.

Gray literature publications serve an important role in supporting the sciences (Cordes, 2004; Luzi, 2000). Research appearing as an unreviewed abstract or proceedings paper may yet be innovative and is oftentimes the only work on a particular subject. In the karst community, gray literature publications may document the first observations within a cave, the first identifications of new species, or the locations of important archeological sites.

For 65 years the *Journal of Cave and Karst Studies* has provided one avenue by which karst scientists can place

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their research on permanent record and communicate with non-science cavers in the United States and abroad. *GeoRef*, a leading earth science citation database, classified this journal's predecessor, the *NSS Bulletin*, as a non-peer-reviewed journal. This changed in 1995 with the change in name. Moreover, the *Journal* has been indexed with the Institute for Scientific Information (ISI) since 2003.

One example of a pioneering effort to document gray elements of the karst literature is the bibliography of Northup et al. (1998). Published in 1998, *A Guide to Speleological Literature of the English Language, 1794–1996* documents 3,558 works in print concerning caves as of 1996. As this paper demonstrates, the growth in publication of karst related research has increased substantively during the succeeding decade, a fact that has led in part to the Karst Information Portal (KIP) initiative. As a partnership with karst researchers from many perspectives, the KIP promises to be a dynamic descendent to the type of bibliography represented by Northup et al. (1998), providing access to white and gray information sources in multiple formats, a repository facility, and expert evaluation of key resources.

THE KARST INFORMATION PORTAL

Scientists and information specialists from the National Cave and Karst Institute (NCKRI), the University of New Mexico (UNM), and the University of South Florida (USF), concerned about the fragmented distribution of data and literature about karst resources, have initiated the KIP. The intent of the KIP is to gather content and metadata from disparate masses of karst research into one online searchable portal and to facilitate communication among karst scientists.

With an international focus, designers intend the KIP to serve as a one-stop source for sharing information about karst literature. The KIP will include material that is often hard to locate, such as technical reports, conference proceedings, theses and dissertations, newsletters, maps, databases, and photos of karst resources.

Ascertaining the domain of karst literature is one vital step toward establishing the KIP. For instance, identifying journals that publish karst literature will assist information specialists in acquisitions. Tracking publication trends in karst will help plan for the future needs of the KIP. Understanding where karst research occurs and how the karst literature clusters around fields of study and subject keywords, will provide a metric by which administrators can assess the content of the KIP against the real distribution of karst literature.

EXPLORING KARST THROUGH ONLINE DATABASES

To lay groundwork for the KIP, we undertook a survey of the existing karst literature. This survey, primarily conducted between October, 2005 and January, 2006, consisted of more than 4,300 literature searches across four major scientific databases: *GeoRef*, a leading earth-science database administered by the American Geological Institute (AGI); *BIOSIS Previews*, the medical and life-science database of the *ISI Web of Knowledge* owned by the Thompson Corporation; *Anthropology Plus*, managed by Eureka and combining the Anthropological Literature from Harvard University and the Anthropological Index from the Royal Anthropological Institute in the UK; and *GPO Access*, the primary search engine for publications published by the US Government Printing Office.

Part of the goal of this study is to find out what sort of ontology best captures the relevant literature. Our classification of search terms is therefore somewhat rudimentary. We culled a list of 321 cave- and karst-related terms from the glossaries of the *Encyclopedia of Caves* (Culver and White, 2005), *A Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology* (Field, 1999), and the online *Glossary of Speleological and Caving Terms* (ASF, 2004).

We combined lists of terms from all three glossaries and deleted the duplicates. To supplement the list of 1,875 words that remained, we included a list of 30 names of important caves around the world, 26 fields of study related to caves and karst, 24 geographic settings where caves and karst features are found, all seven continents with 37 sub-regions within these continents, and 187 independent nations, former countries, and alternate spellings of these countries. In all, this refined list included 2,186 terms.

From our refined list, we extracted a short list of 15 primary words likely to capture a large number of the English-language citations relevant to caves and karst studies. These words included the word stems karst, cave, and several linguistic variations thereof (e.g. *cueva*). Major related words were included in this list – spring(s), conduit(s), and bats, for instance.

Next we outlined two groups of modifiers for the words in the original list. The higher-level group consists of locations, scientific disciplines, and settings within which karst might be found. For example, the terms paleontology, marine, and Romania are all higher-level modifiers. The lower-level group includes 321 keywords that would fall within the karst field itself (either physically or bibliographically). These are generally more specific, such as sediment and model. The remaining 1,539 terms were either too specific or too general to capture relevant citations and were eliminated.

One set of searches utilizes the primary terms applied to all four databases in this study. The second set of searches consists of each term from the two lists of modifiers, combined with the term cave or karst and the appropriate wildcard symbols, such as an asterisk (*), to capture all of the derivatives. It is important to note that the results of these searches are not filtered for relevance; they are presented in this paper as returned by the search engine.

Table 1. Search results for the primary search terms.

Search Terms	GeoRef[a] All	GeoRef[a] Peer-Review	GeoRef[a] Journal	GeoRef[a] Conference	GeoRef[a] Books	BIOSIS Previews[b]	Anthropology Plus[c]	GPO Access[d]
bats	251	107	215	41	16	16,062	96	25,253
carbonate aquifer(s)[e]	347	91	278	178	63	31	1	497
carso[f]	3,663	1,402	3,237	802	346	316	0	39,655
cave	24,180	5,199	21,265	6,690	2,595	23,961	8,450	64,988
conduit(s)[g]	2,840	1,131	2,466	1,220	323	6,731	11	26,738
cueva(s)	998	210	768	380	212	178	853	451
grotte	910	89	860	163	45	63	1,813	60
grotto(s)	673	37	632	64	40	75	49	754
karst[h]	27,379	6,570	23,698	10,031	3,407	5,234	269	7,800
limestone aquifer(s)	1,640	390	1,375	684	235	50	0	495
sink	7,893	2,501	6,803	2,870	937	13,625	158	58,659
spring(s)[i]	71,986	29,018	65,504	31,361	4,873	87,528	1,211	349,274
spel(a)eo[j]	10,452	1,748	9,563	3,410	828	696	370	621
stygo	29	10	27	10	1	488	0	158
troglo	84	27	70	21	5	4,853	430	1,291

[a] Search included entire reference.
[b] Topic search.
[c] Keyword search.
[d] General search.
[e] The search string, carbonate aquifer(s), includes the phrase, carbonate aquifer, and the plural form, carbonate aquifers. This construction applies to all search strings with a similar format.
[f] The search string, carso, includes the word, carso and all derivatives that use carso as a prefix. This construction applies to all search strings with a similar format.
[g] The search string, conduit(s) results in many citations that are unrelated to karst studies.
[h] The search string, karst, includes the word, karst, and all derivatives that use karst as a root word and have prefixes or suffixes. This construction applies to all search strings with a similar format.
[i] The search string, springs, results in many citations that are unrelated to karst studies.
[j] The search string, spel(a)eo, includes all terms that contain the root, speleo, or the alternate spelling, spelaeo.

We performed an additional set of searches to net the entire body of citations related to caves or karst within *GeoRef* for each year between 1960 and 2005. We separated these by publication type and extracted a subset of peer-reviewed journal articles. We performed similar general karst searches within the abstract archives of the Geological Society of America.

The Domain of Karst Literature

Primary Terms

The primary search term results are dominated by the term spring, which does not specifically refer to karst springs (Table 1). The search results for spring in *GPO Access* reflects the loose nature of this search engine: a search here returns hits on any document within all U.S. government websites. The results are not restricted to scientific documents; thus the term spring returns almost 350,000 citations, most of which probably refer to the season of rebirth, rather than a point of resurgence (Table 1). Because the results from this search engine appear to have little relevance to the desired body of literature and little advantage over a conventional web-search engine, we eliminated *GPO Access* from all subsequent searches.

Second and third in order of prevalence in the primary search terms are the words karst and cave, the most general of the remaining English-based terms (Table 1). Citations within *Anthropology Plus* refer almost exclusively to caves, with comparatively few references to karst. *BIOSIS Previews* had four times more references to caves than to karst, whereas in *GeoRef* they occur about the same number of times (Table 1).

The relatedness of terms to specific disciplines influences their distribution among the databases. For example, the biology-related terms bats, stygo-, and troglo- returned by far the most results from *BIOSIS Previews*, while geological terms such as carbonate aquifer and limestone aquifer are more prevalent in *GeoRef* (Table 1).

Higher-Order Modifiers

Results for the searches of higher-order modifiers are included in Tables 2 and 3, separated into setting, location, field of study, and subject keywords.

The modifier sea appears as the most frequent geographic setting mentioned in karst-related GeoRef citations (Table 2). This is not surprising; even in studies of mid-continental karst, it is difficult to discuss karst development without invoking sea-level or referring to a base level of some sort. It should be noted that there is likely considerable overlap between sea and the second and third ranking geographic modifiers, marine, and island (Table 2).

With a glance at Table 2, karst appears as a decidedly Eurocentric discipline: Europe is by far the most-cited continent in cave and karst references, with more than three times the number-two continent, Asia. However, although North America comes in at a distant third place as a continent, the United States is the country mentioned the most times overall, with about as many citations as the continent of Europe itself (Table 2). These numbers surely reflect the history of karst (with its European origins), the distribution and impact of journals in different countries, the amount of karst accessible to each region, and other scientific and socio-economic influences, as well as vagaries of the search process. For example:

1) There are about as many references in *BIOSIS Previews* to karst in Norway as there are references to caves in the United States (Table 2). We find that this is because of references to the Norwegian spruce (*Picea abies* (L.) Karst). Only 21 references remain when the species name is excluded from the search.
2) On the other hand, both France and Spain have anomalously large numbers of references to cave in *Anthropology Plus* (Table 2). No doubt these citations reflect a long and distinguished record of cave archeology, particularly as it relates to famous Paleolithic cave art at sites such as Lascaux and Altamira.

The predictable partiality of each database to its own sub-discipline is clearly demonstrated in our search results for the fields of study (Table 2): the geology and geomorphology papers are in primarily in *GeoRef*, the biology and ecology papers are dominant in *BIOSIS Previews*, and archaeology papers comprise the majority of the *Anthropology Plus* results.

Results for the 30 most commonly occurring keywords are presented in Table 3. General rather than specific keywords compose most of this list. Yet, a few more specific terms that refer to specific scientific methods, such as isotope, make the list. The phrase cave system seems to permeate biological literature, whereas phrases such as karst water and karst hydrology occur commonly in geological literature.

Annual Publication Rates in the GeoRef Database

Searches for karst-related GSA abstracts show continued, rapid growth of the field during the past ten years (Fig. 1). Karst-related abstracts now constitute about 2.5% of all GSA abstracts produced each year, more than twice the percentage in 1995. The pattern of peer-reviewed articles not associated with conference proceedings shows a slightly different profile (Fig. 2). Growth of the field during the 1990s yields to a slight downturn after 2003. This may simply be the manifestation of a lag time of data entry in *GeoRef*.

The increase in journal diversity mirrors the increase in number of articles on caves and karst (Fig. 2). Between 1960–2005, karst articles appeared in 437 different peer-reviewed journals. However, as is true of most scientific disciplines, the majority of the karst literature is concentrated in a few core journals (Bradford, 1934). The top 25 journals account for 46% of the karst-related citations. Figure 2 shows this list of 25 journals, ranked by the total number of karst and cave articles from 1960 to 2005.

While karst-specialty journals account for only 8% of the peer-reviewed publications for this time period, it has only been in the last ten years that the *Journal of Cave and Karst Studies*, *Cave and Karst Science*, and *Acta Carsologica* have been included in *GeoRef* as peer-reviewed journals, all three with short but intense histories of publishing karst papers (Fig. 2). *Environmental Geology*, while not exclusively a karst journal, has a similar publication profile. The *Journal of Hydrology* has included several articles concerning karst each year for most years since its inception, making it the top source for karst-related articles from 1960 to 2005.

General science journals such as *Nature* and *Science* have a long history of intermittently including karst articles that are cited by *GeoRef* (Fig. 2). These accumulate large numbers of karst citations through their long life spans. In the major geological sub-discipline journals such as *Chemical Geology* and *GroundWater*, we see a substantial increase in the number of articles over the past ten years (Fig. 2).

CONCLUDING REMARKS

This study represents one in a series of steps to designing an information portal for the karst sciences; a portal that will facilitate worldwide communication on research on karst phenomena. The series of 4,300 literature searches that compose this study identify the scope of cave- and karst-related literature and the changes through time that karst literature experienced. Karst as a science is growing, and the past ten years encompass much of that growth. Our searches reveal several factors that partially explain the increasing volume of peer-reviewed karst literature:

1. The karst-heavy journals achieved peer-review status;
2. The number of journals that publish karst-related articles increased; and
3. The number of cave and karst articles in each journal increased.

With respect to the first point, obtaining peer-review status was a critical step for establishing the credibility of

Table 2. Ranked summary of search results for the top five geographic settings, all continents, and the top 25 countries.

		Search Engine						
		GeoRef[a]		BIOSIS Previews[b]		Anthropology Plus[c]		
Search Area	Rank	Cave[d]	Karst[e]	Cave	Karst	Cave	Karst	Totals
Geographic Setting								
Sea	1	741	1,249	466	191	21	1	2,669
Marine	2	558	874	677	198	10	0	2,317
Island	3	728	624	506	79	66	0	2,003
Plateau	4	566	814	97	95	25	1	1,598
Mountain	5	709	529	157	141	39	3	1,578
Continents								
Europe	1	8,749	10,387	1,203	1,342	435	40	22,156
Asia	2	2,415	3,671	526	183	254	2	7,051
North America	3	2,455	722	887	242	188	2	4,496
Africa	4	1,096	652	537	55	359	0	2,699
Australia	5	951	395	417	64	150	3	1,980
South America	6	530	320	294	62	28	0	1,234
Pacific[f]	7	334	199	189	25	67	1	815
Antarctica	8	0	0	0	0	0	0	0
Countries								
United States[g]	1	12,795	9,336	1,604	265	67	4	24,071
France	2	3,618	1,780	398	205	1,264	17	7,282
Germany[h]	3	2,280	1,251	138	253	138	9	4,069
United Kingdom[i]	4	2,903	497	148	45	0	0	3,593
China	5	1,105	1,961	179	95	126	2	3,468
Spain	6	878	974	358	135	721	5	3,071
Italy	7	1,145	988	423	246	3	8	2,813
Mexico	8	1,016	656	422	70	217	4	2,385
Australia	9	951	395	419	64	245	3	2,077
Norway	10	295	98	48	1,629	3	2	2,075
Canada	11	1,006	600	120	92	14	0	1,832
U.S.S.R.[j]	12	547	1,063	115	72	15	0	1,812
Austria	13	978	508	69	62	55	11	1,683
South Africa	14	726	120	286	11	371	0	1,514
Switzerland	15	672	381	74	51	36	2	1,216
Czechoslovakia[k]	16	506	489	34	106	39	19	1,193
Yugoslavia[l]	17	216	639	168	112	31	15	1,181
Hungary	18	342	460	51	42	50	8	953
Poland	19	346	364	92	112	17	9	940
Slovenia	20	304	359	76	74	13	10	836
Japan	21	435	88	240	26	33	0	822
Israel	22	273	148	98	19	240	1	779
Romania	23	265	278	168	42	7	0	760
Greece	24	168	320	125	21	110	2	746
Brazil	25	193	177	247	42	55	1	715

[a] Search included entire reference.
[b] Topic search.
[c] Keyword search.
[d] The search string, cave, includes the word cave and all derivatives that use cave as a prefix.
[e] The search string, karst, includes the word karst and all derivatives that use karst as the root word and have prefixes or suffixes.
[f] Though not a continent, we included Pacific in this section because it includes a variety of island nations not included within the other continents.
[g] The country search, United States, also includes the search USA, U.S.A., and America.
[h] The country search, Germany, includes the previous states of the Federal Republic of Germany and the German Democratic Republic.
[i] The country search, United Kingdom, also includes the search phrases UK, U.K., Britain, and England.
[j] The country search, U.S.S.R., does not include Soviet Union or Russia which are separate searches.
[k] The country search, Czechoslovakia, does not include Czech Republic or Slovakia which are separate searches.
[l] The country search, Yugoslavia, does not include searches for any of the present countries that comprise the former Yugoslavia.

Table 3. Ranked summary of search results for the top 10 fields of study and the top 30 subject keywords.

Field of Study and Subject Keyword	Rank	Search Engine						
		GeoRef[a]		BIOSIS Previews[b]		Anthropology Plus[c]		
		Cave[d]	Karst[e]	Cave	Karst	Cave	Karst	Totals
Field of Study								
Geomorphology	1	11,554	8,736	22	32	19	3	20,366
Geology	2	12,477	5,408	729	501	91	8	19,214
Ecology	3	487	519	6,373	3,146	44	1	10,570
Biology	4	234	70	6,332	3,855	18	0	10,509
Arch(a)eology[f]	5	1,618	409	476	27	6,592	80	9,202
Hydrology	6	1,965	6,378	18	67	0	0	8,428
Hydrogeology	7	2,134	3,876	5	42	1	0	6,058
Pal(a)eontology	8	3,933	334	74	13	65	1	4,420
Exploration	9	2,065	1,911	123	17	86	0	4,202
Engineering	10	2,146	1,899	79	25	2	0	4,151
Subject Keyword								
System(s)[g]	1	1,859	3,026	20,123	2,111	38	4	27,161
Vertebrat[h]	2	4,067	738	17,656	603	0	1	23,065
Mammal	3	3,238	575	16,436	420	87	0	20,756
Environment(s)	4	3,088	5,685	6,538	3,385	161	11	18,868
Water	5	4,089	10,212	1,865	1,659	6	1	17,832
Sediment	6	6,330	9,610	491	282	148	7	16,868
Region	7	3,087	5,049	6,058	2,124	189	20	16,554
Hydro	8	4,147	10,090	886	484	3	0	15,590
Human(s)	9	925	825	11,727	236	734	10	14,457
Morphology	10	1,322	938	7,906	2,017	54	2	12,239
Cainozoic or Cenozoic	11	7,141	4,429	307	79	0	0	11,956
Ground(-)water[i]	12	2,803	8,333	126	271	3	3	11,539
Quaternary	13	6,766	3,128	451	98	102	4	10,549
Limeston	14	3,157	5,097	343	311	12	1	8,921
Carbon	15	5,528	1,088	503	522	59	3	7,703
Development	16	1,400	2,315	2,579	1,240	15	3	7,552
Strat	17	3,342	2,778	812	245	297	10	7,484
Species	18	581	209	4,808	1,838	8	0	7,444
Pleistocene	19	3,877	1,548	1,238	180	294	9	7,146
Deposit(s)	20	2,137	3,214	896	412	193	2	6,854
Isotop	21	1,785	1,574	2,733	154	41	2	6,289
Mine(s) or mining	22	1,248	2,935	1,162	868	55	5	6,273
Evolution	23	1,838	2,676	1,210	243	242	4	6,213
Mineral(s)	24	1,749	2,251	1,046	839	28	4	5,917
Radio	25	1,316	839	3,394	108	184	5	5,846
Invertebrate(s)	26	289	19	4,619	907	0	0	5,834
Aqui	27	1,138	4,393	72	227	2	1	5,833
Fossil	28	2,636	674	1,654	388	412	4	5,768
Reproduce	29	57	36	5,138	424	1	0	5,656
Model	30	1,277	2,374	448	448	28	0	5,644

[a] Search included entire reference.
[b] Topic search.
[c] Keyword search.
[d] The search string, cave, includes the word cave and all derivatives that use cave as a prefix.
[e] The search string, karst, includes the word karst and all derivatives that use karst as the root word and have prefixes or suffixes.
[f] The search string, arch(a)eology, includes archeology and the alternate spelling archaeology. This construction applies to all search strings with similar format.
[g] The search string, system(s) includes the word system and the plural form systems. This construction applies to all search strings with similar format.
[h] The search string, vertebrat, includes all terms that begin with the root vertebrat. This construction applies to all search strings with similar format.
[i] The search string, ground(-)water includes the forms groundwater, ground-water, and ground water.

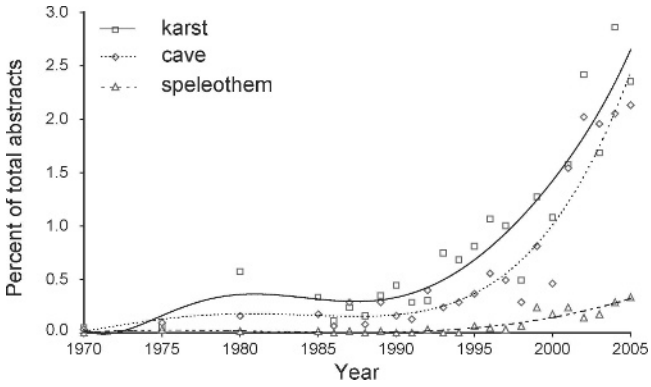

Figure 1. Percent of abstracts related to caves and karst at Geological Society of America meetings. Prior to 1985 percentages are averaged over five years.

karst as a science. Papers in the *Journal of Cave and Karst Studies* and other karst-oriented journals now reach a much broader community of scientists and resource professionals, facilitated by current trends in on-line publishing. Furthermore, all three points reflect upon a conscious effort over several decades by dedicated cavers and karst professionals to advance the science to a point of acceptance by the greater scientific community, particularly within the earth science disciplines. Overall, the numbers from this study elaborate on a statement that karst scientists are gratified to hear:

> Cave geology has come of age. The geological study of caves is now an integrated part of the geological sciences rather than a portion of an exotic borderland science called speleology.
> - White and White (1998, p. 41)

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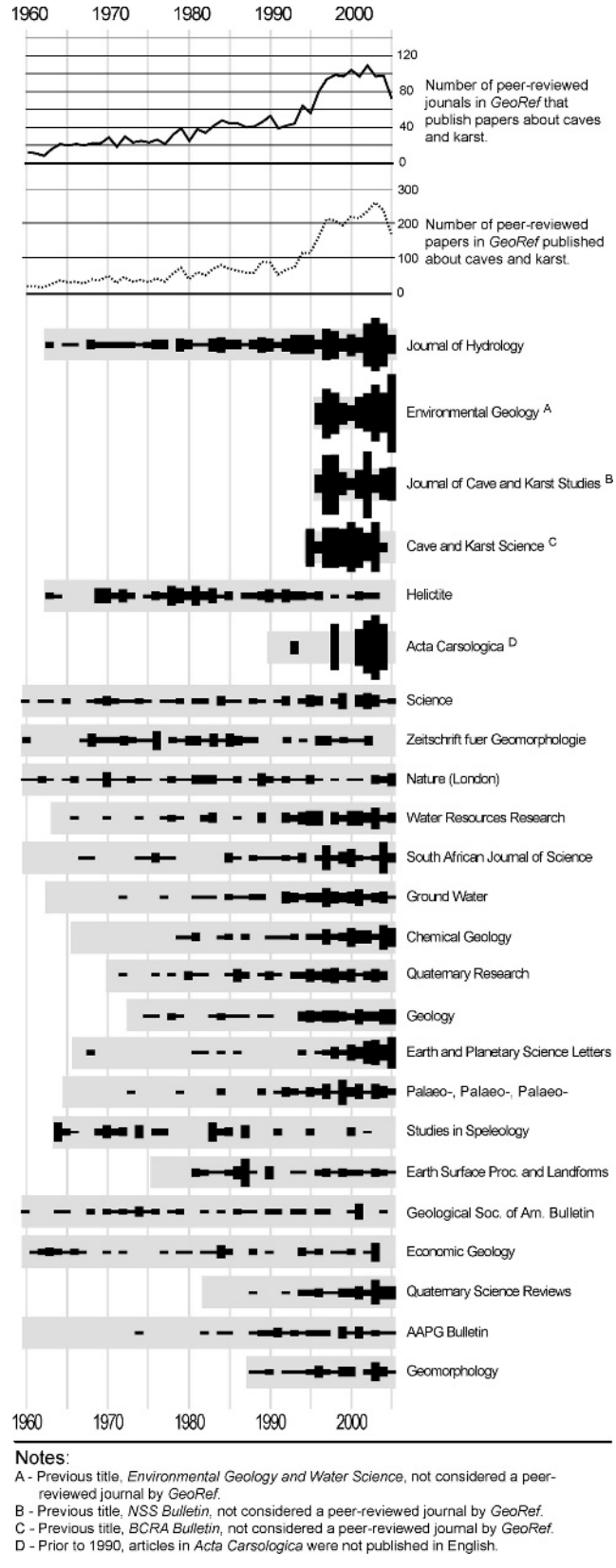

Figure 2. Ranked summary of the number of cave- and karst-related publications each year by journal. The top graph is the number of peer reviewed journals in *GeoRef* that publish papers about caves and karst, and the lower graph is the number of peer-reviewed papers in *GeoRef* about caves and karst. Each bar graph provides information on the cave and karst publication history for an individual journal. The total height of a single black bar represents the number of relevant papers for that year. For scale reference, the total height of each horizontal, gray bar corresponds to ten articles. The length of each gray bar spans the lifespan of the journal.

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