"The Universal Recipe,
Or How To Get Your Manuscript Accepted By Persnickety Editors"
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THE RECIPE

Overview

Despite the enormous diversity of the many branches of science and technology, the manner of reporting scientific and technical information seems to have resolved itself over the years into a rather standard format—a format that appears to be just about the same regardless of the particular area of science being discussed. This format has emerged by trial and error and today seems to be the most universally accepted means of conveying scientific ideas and information. Although minor variations may be found, the standard format or recipe for acceptable manuscripts consists of the following major parts:

1. Title
2. Authorship
3. Abstract
4. Introduction
5. Experimental (or Methods & Materials)
6. Results
7. Discussion
8. Conclusions (or Summary & Conclusions)
9. Acknowledgments
10. References Cited

At this point, a few readers of this article will undoubtedly say to themselves that this standard format or recipe is all well and good for most papers and for most authors, but "my" work is different and therefore "my" manuscript should be organized in a "different" or "special" way. In answer, this editor says "not so," or at least not so for 99.99% of the manuscripts he has ever dealt with. Rarely does a scientific investigation require a reporting style that differs substantially from this standard format. Granted, some manuscripts may benefit by a separate Theory section or Theoretical Background section (probably inserted after the Introduction), or a Regional Geology section (inserted either before or after the Experimental section), or even an extended Literature Review section (inserted after the Introduction), but the presence of such extra sections does not change the overall organization of the manuscript, nor do such sections detract (if they are properly written) from a straightforward, "eins, zwei, drei" manner of presentation. The standard format or universal recipe allows authors to tell the reader specifically what problem they attempted to solve (Introduction), how they went about solving it (Experimental section), what they found out (Results), and how they interpreted these results (Discussion). It also allows them to tell the reader something about the significance of their findings (Summary and Conclusions).

The key to writing an acceptable scientific paper is organization. Most editors, technical referees, and critical readers agree that disorganized writing may reflect a disorganized investigation, and a disorganized investigation is tantamount to a poor investigation, of little use to anyone. This editor strongly suggests that authors organize their reports into the standard format here. I also recommend that authors prepare extended hierarchical outlines of their reports before they put pen to paper (or finger to keyboard). I recognize that many authors do not need outlines before they write, but as a minimum I suggest that their final manuscripts be reduced to outline form as soon as they are completed. In this way any lack of organization becomes readily apparent.

The major sections of such an outline are, of course, the major sections of the universal recipe. These sections are discussed below in terms of the purpose, the kind of information that should or should not be reported, and the pitfalls that should be avoided in preparing each section. Although I would like to claim them as my own, few of the ideas expressed here originate with this editor. Almost all are well discussed in numerous books on technical or scientific writing, some of which are listed at the end of this article. I strongly urge all authors or potential authors to read or re-read one or more of these works and to refer to them constantly as they prepare their next manuscript.

Title

The title of a scientific paper should tell the reader what the paper is all about. It should not be too short or too general (the title of Theophrastus' treatise "On Stones" would be considered inadequate today), or too long (the title "Unit-Cell Dimensions of Potassium Feldspar in Early to Middle Pleistocene Rocks of Southeastern North Dakota as a Function of Alkali Element Composition of Circulating Ground Waters and of Organic Carbon Content of Overlying Lignitic Shales" might put the readers to sleep before they get into the body of the paper). Because everyone who picks up the journal will undoubtedly read the title of the paper, the title is the author's first chance (and maybe the only chance) to tell the readers what the paper is all about and thereby convince them to read on.

In addition to being not-too-long and not-too-short, the title should tell the reader just what will be covered in the paper. It should not give the reader the impression that an entire field will be treated in the paper when in reality only a small part of that field is discussed. Thus, the title "Adsorption of Amino Acids on Kaolinite in Ethyl Alcohol" is more informative than "Amino Acid-Kaolinite Reactions." Moreover, words that do not contribute specifically to the subject of the paper have no place in the title. For example, the first four words of the title "Preliminary Results on the Effect of Magnesium in the Formation of Chlorite" add nothing, and the title is better written "Effect of Magnesium in Chlorite Formation." The title also should not be an alphabet soup of abbreviations or acronyms, many of which may not be understood by the non-expert reader.

Authorship

Authorship of technical papers is a delicate subject and one that most editors are happy to avoid. For the most part, the individuals to be listed as authors and the order in which they are listed should be settled well before the manuscript is submitted for publication. From an editorial point

of view, however, a few comments are in order. First, it is perplexing to see long lists of individuals named as the authors of a technical paper, even in this age of cooperative or group research. Lengthy lists of authors suggest unresolved problems of laboratory politics, rather than accurate accounts of the principal contributors to the work at hand. Conversely, some works appear to cry out for additional authors, especially those that draw heavily on student theses or that are based on unpublished information obtained from another party. Hence, the list of authors should include the principal contributors to the project; those who participated in the project in a peripheral manner or only briefly should not be forgotten, but recognized with appreciation in the Acknowledgments section. I will not attempt to state what is an acceptable number of authors, but merely state that credibility decreases as the number increases beyond five or six. Nor will I spell out specifically the meaning of "principal contributor" or "peripheral manner," but leave interpretation of these somewhat ambiguous terms to the authors (or potential authors) themselves.

One subject concerning authorship does merit serious consideration, and that is that *all* authors of a paper are responsible for the content of that paper. If a particular coauthor does not agree with what has been said in the paper, that coauthor should divorce himself or herself from that paper. In this regard, the principal author (generally the writer) should make sure that *all* authors of the paper have an opportunity to review, criticize, and contribute to the preparation of the manuscript before it is submitted for publication and before it is resubmitted after having been revised to address the referees' comments. Fulfilling this obligation in itself should drastically limit the number of authors.

Abstract

Not enough can be said about the importance of the Abstract. With the exception of the Title itself, more people will read the Abstract than any other part of the paper. In this era of megapublications, few researchers have time to read everything, even in their own fields of specialization. I am loathe to admit it, but the editor is probably the only person who reads every word of every article in each issue of a given journal. Most of us scan the titles in the table of contents and then turn to the abstracts of the papers that seem to be of interest. If the abstract turns out to be uninformative (i.e., if it really doesn't summarize the highlights of the paper), or if it is merely a table of contents of what is to be found in the rest of the paper, most of us will grumble a little about authors who try to keep their findings secret and probably move on to *another* paper.

Only the true expert or avid lover of the subject will read the entire paper, and these people will read it regardless of how well or how poorly the abstract is written. It is therefore not for the expert in the subject that authors prepare informative abstracts—it is for everyone else who might read them. Because most of these non-experts will not read beyond the abstract, it is vital that authors convey everything they can about the paper—the rationale for undertaking the investigation, the important findings (including specific data, rather than arm-waving generalities), and the pertinent interpretations of those findings—in the abstract. In short, the abstract should be a fact-filled condensation of the entire paper. Many editors and reviewers take the attitude that if a subject is not of such significance as to be summarized in the abstract, perhaps it does not belong in the main body of the paper either.

Note that in the above discussion I haven't said that abstracts are easy to prepare. They are not. For me at least, the abstract is the most difficult part of the manuscript, chiefly because I am forced to condense each part of the paper into a sentence or two and to construct those sentences with great care so that each contains the maximum amount of information. The author part of me says that surely my colleagues will want to read my wonderful paper in its entirety, and, therefore, I don't have to tell them everything in the abstract, but the editor part of me knows differently; hence, if I want the maximum number of people to benefit from or be aware of the results of my investigation, I must make sure that the abstract says as much as possible.

To illustrate the difference between uninformative and informative abstracts, I recommend reading the abstracts in the program of some past scientific conference and *then* reading the abstracts of these same papers as they are published in the conference proceedings or in a primary journal, after a persnickety editor and a couple of referees have had a chance to work on them.

Introduction

Magazine advertisements and television commercials must arouse interest in the first few words—otherwise the audience will turn the page or go to the kitchen for a cold beer. Likewise, the Introduction of a scientific paper must in a few short sentences convince the reader that it is worthwhile to read on. The Introduction must set the stage for the paper to follow and convey to the reader the rationale for undertaking the investigation. It should spell out the specific objectives of the investigation and describe the nature and scope of the problem, why that problem is important, how the author attempted to solve that problem, and of what significance are the results that the author expected to obtain. Some Introductions also mention *very briefly* the principal findings of the investigation, so as not to keep the reader in suspense until the Conclusions. If all these questions are addressed in the Introduction, the reader will know what to expect in the rest of the paper. Authors must recognize that their scientific results may be of enormous significance and that their interpretations may be truly awe-inspiring, but if readers cannot grasp why the investigation was conducted in the first place, they may never bother to read about these wonderful results or these revolutionary conclusions.

The Introduction is generally the place to review the literature, at least to the extent of demonstrating how the present investigation relates to past work. Every paper ever written on the subject, however, need not be mentioned; the author should cite only those papers that bear directly on the problem to be attacked in the present investigation. Authors should also be careful to indicate exactly why a particular work was cited and exactly how the cited work relates to the subject under discussion. It is frustrating, for example, to read in the Introduction of a paper on "Hydrolysis of Manganese During the Weathering of Ultramafic Rocks" that "Jones and Smith (1978) noted manganese hydroxides in weathered serpentinites." I sometimes want almost to shake the author to learn what it was that Jones and Smith found out *about* manganese hydroxides in such rocks or what Jones and Smith discussed that is germane to the problem being investigated in the present paper.

Authors should also avoid citing the literature for information that is common knowledge. I once noted the statement in the Introduction to a paper submitted to *Clays and Clay Minerals* that "Clay minerals are abundant in sedimentary rocks and soils (Grim, 1953)." Such information

was, of course, mentioned in the cited work, but was it really necessary for the author to cite Professor Grim's book—or any published work for that matter—for such common knowledge? On the other hand, because one of the purposes of the Introduction is to show the reader how the present investigation meshes with or fills a gap in our current knowledge, authors should not overlook important works on the same subject by other researchers. Even if the author doesn't agree with them, fairness requires that other points of view be recognized and considered. Furthermore, simply because an important work happens to be published in a language not understood by the author is no excuse not to include it in the review of the literature.

Well-written Introductions invariably end with what many have called a "succinct statement of the problem." Here, in one or two sentences the author should state precisely what the rest of the paper will be about and, perhaps, exactly what will be shown as a result of the investigation. For example, the closing statement in the Introduction to the paper on the hydrolysis of manganese mentioned above might be: "To investigate the hydrolysis reactions of manganese during the weathering of ultramafic rocks, samples of fresh serpentinite and peridotite were treated with weak acids at room temperature for periods ranging from weeks to years. Reactions were followed by analyzing solid products and residual solutions and plotting the results on appropriate Eh-pH diagrams." The "statement of the problem" at the end of the Introduction is therefore analogous to a speaker saying: "I've told you what subject I'm going to discuss, and I've told you why that subject is important. Now I'm going to give you specific details on the subject and then my interpretation of them. Pay attention—you don't want to miss what's coming next!"

Experimental section

The Experimental section of any scientific paper is probably the easiest to write and is often the first section to be tackled by the author. It is no less important, however, than any other section, inasmuch as a basic criterion of scientific publishing is that the reader be able to duplicate an author's results using the same procedures. The Experimental section should therefore be a straightforward presentation of what materials were used in the investigation (reagents, rock, water, soil, or mineral samples), how these materials were treated (chemically, thermally, electrically), how starting materials and products were characterized (by X-ray powder diffraction, nuclear magnetic resonance, infrared spectroscopy, optical microscopy, transmission electron microscopy, or extended X-ray absorption fine-structure spectroscopy), and how the data were "massaged" and evaluated (statistically, mathematically).

The locality, source, and properties of all starting samples should be reported in as much detail as possible to allow the reader to compare the author's results with other data reported previously on the "same" material. In so far as the locality is concerned, note, for example, that "Germany" hardly suffices as a precise locality of a nontronite from Clausthal-Zellerfeld, Federal Republic of Germany. Samples obtained from reference collections, e.g., from the Source Clay Repository of The Clay Minerals Society, should be so indicated and designated with their assigned reference numbers. Standard methods used should be referenced, but need not be described in detail; however, new methods or modifications of standard methods should be described in as much detail as necessary to allow them to be used by the readers. The brand name and model of the instruments used should be stated, not as an endorsement of that product, but so that the reader can evaluate the quality of the data being reported. The precision of all

measurements should be stated, and the statistical methods and computer programs used to evaluate the data should be identified and referenced.

Except as they add to the characterization of the starting materials or samples, results generally should not be reported in the Experimental section.

Results section

Despite the fact that many *authors* find it convenient to combine the experimental results obtained by a particular technique or on a particular suite of samples and an interpretation of these results in the same section, most *readers* find it extremely difficult to follow a paper written in this manner. The reader generally wants to see the results of the investigation neatly presented in a separate section, unencumbered by discussion, interpretation, or comparison with the literature. The reader would *then* like to see the author's interpretations of these results in a separate section. In this way, the author's new data can be distinguished from information that is common knowledge or that has been reported by earlier workers. Although a few papers lend themselves to combining results and discussion in the same section, most do not, and, in general, interpretations and discussions should be presented in a section separate from Results.

The results themselves should be presented preferably in tables or as curves, graphs, or halftone illustrations. Details of experimental procedures should not be included in the Results section, but gathered together in the Experimental section, as noted above. Descriptions of the results should be as brief as possible and devoid of interpretation, although particular trends or ranges of the data should be pointed out. Some authors believe that because certain information was obtained in the course of their investigation, this information should be reported in their paper regardless of whether it is germane to the subject under discussion. Only those results relevant to the purpose of the paper, however, should be reported. Extraneous data, fascinating as the authors might find them, should be saved for another day and another paper.

Editors frequently encounter manuscripts that present exciting new experimental techniques, in which samples from several unrelated subject areas have been tested to demonstrate the universality of the method. Unfortunately the authors of many of these papers have tried to address major *research problems* on the basis of these new, but limited results in this same paper. The net result is that the major contribution, i.e., the new experimental technique, all but gets lost in the shuffle, and the authors do a woefully inadequate job with respect to the research problems. The moral of the tale is to limit a manuscript to a single subject and not try to solve all of the world's problems in a single paper. Use these preliminary data to begin a whole new investigation.

Discussion section

The Discussion is probably the most important section of the paper and should be carefully organized into specific subsections, each dealing with a different subject. In each subsection, the author should critically evaluate the data, show how they agree or contrast with published works, and interpret them for the reader. It is not sufficient for the author to point towards a table or graph and expect the readers to interpret the data themselves; the author must do the interpreting and, in so doing, must solidly base these interpretations on specific data reported in the present paper or on a combination of published information and current results.

Technical reviewers and editors have a habit of downgrading manuscripts if interpretations are not (or do not appear to be) strongly supported by data reported in the paper. All too often, authors make sweeping statements or draw broad conclusions without telling the reader specifically on which data these statements or conclusions have been based. Others merely refer the reader to "the data in Table 1" or to "the results reported above," and some only say "therefore" or "thus" as a means of specifying the data on which conclusions are based. Such tactics leave the reader wondering whether or not the author truly has evidence to support these statements or if the statements are more wishful thinking than data-based interpretations.

Authors should keep in mind that readers are not obliged to believe what they are told, but they will be more inclined to do so if they are provided with specific results and evidence every step of the way. Therefore, authors should present their specific data or information on which a conclusion will be drawn *first* in a sentence or paragraph in the Discussion section, and *then* discuss or interpret these data. Nothing is quite so annoying as being presented with what appears to be a statement of fact and then having to read on to discover the data on which the statement was based.

Many papers phrase all statements and discussion in the present tense, leaving the readers to determine for themselves whether the statements refer to the author's present findings or to facts already known. No hard and fast rules apply, but, in this editor's opinion, the author's results are best described in the past tense, reserving the present tense for information currently known or for information taken from the literature. Objects still possessing particular properties or characteristics, however, may properly be described in the present tense. For example, an author describing a rock sample might write that "The rock *is* red and *has* a granitoid texture," but that its density "*was* determined to be 3.00 g/cm3"; likewise, that the "bands characteristic of Al-O bonding *were noted* in the infrared spectrum," but that the "infrared spectrum in Figure 3 *shows* bands characteristic of Al-O bonding."

Conclusions (or Summary and Conclusions) section

Authors often confuse "Summary" with "Conclusions." A Summary section by definition sums up the results and interpretations of the paper, and, in some degree, may duplicate part of the Abstract. In some papers, the results of the investigation and the discussion of them are summarized in a final subsection of the Discussion; in others, a separate section is warranted, usually combined with Conclusions.

A Conclusions section is the section in which authors should discuss the importance of their findings. The conclusions should not merely repeat various points of the discussion, but should tell the reader *why* these points are important, something about their broad meaning, how they contribute to our understanding of the field being examined, and where more work is needed. A combined Summary and Conclusions section may be the appropriate place to summarize the findings of the investigation and to point out their overall significance.

As an author prepares the Summary and Conclusions section of the manuscript, the Introduction should be reexamined, especially the part in which the objectives of the investigation were spelled out, to see whether or not these objectives have been met. If they have not been met, the

author should tell the reader why not, or should consider rewriting the Introduction to contain a different set of objectives.

Acknowledgments section

Although a necessary part of any scientific paper, the Acknowledgments section should be brief and to the point. It is only proper to recognize individuals and institutions that contributed financial support, samples, specific analyses, and technical assistance to the investigation, however, thanking everyone whom the author has ever been associated with over the last 20 years, like an Academy Award acceptance speech, is inappropriate. Unquestionably, the individuals who critiqued the manuscript before it was sent to a journal and the referees (identified and anonymous) who reviewed it for the journal should be acknowledged with appreciation. The journal editor need not be thanked, because everyone knows what a wonderful job this person does all the time.

References Cited section

Little can be said about the References Cited section, except that authors should submit their list of references cited in the *exact* style of the journal, down to the last jot and tittle of punctuation, spacing, etc. I am painfully aware that every journal has its own style, and wouldn't it be nice if they all used the same style, but they don't, and that's a fact of life that authors must live with. Keep in mind that editors will insist that authors follow the prescribed style of the journal, so why not do it right the first time? Most journals spell out the style to be used in their Instructions to Authors. If such instructions are not available, authors are advised to examine a recent issue of the journal in question to see how it's done.

In general, only works that have actually been published (or, perhaps, that have been formally accepted for publication by a journal) should be listed in the references. All others should be cited in the body of the text in the form of a personal (or written) communication, which includes the full name, institution, and current address of the individual from whom the information was obtained. Such information is necessary to allow the reader to communicate directly with that individual for clarification, verification, or further information. Authors should also check the final manuscript to make sure that each item in the list of references has actually been cited in the text and that each citation in the text is listed in the References Cited section.

RECAPITULATION

These ideas for the ideal manuscript for publication in *Clays and Clay Minerals* or for any other technical journal are offered to help authors write reports of their investigations that will be read, understood, and appreciated by their colleagues. No matter how great the experiment or how revolutionary the results, nothing is added to that vast accumulation of information we call science, if the author's work is not published or if it is published and still cannot be understood. Even worse, mankind reaps no benefit. My discussion has concentrated only on the main parts of a "Universal Recipe" for scientific manuscripts. In the final analysis, no two papers are exactly alike, and authors may wish to modify the universal recipe (but not too much) to fit each investigation.

The final word. Every manuscript submitted for publication should be critically reviewed by a third party who can be depended on to "tell it like it is." Authors should not submit manuscripts that represent anything less than their very best efforts, and critical reviews by colleagues for

both technical content and manner of presentation are a vital part of the manuscript-preparation process. Remember, dear author, the sole purpose of a scientific paper is to convey information in a succinct and unambiguous manner, and the data and discussion must be presented in concise, understandable statements. Anything that gets in the way of fulfilling this purpose—flowery prose, personal "style," imprecise words, tortuous sentence structure, or jargon-filled paragraphs—must be ruthlessly deleted from the manuscript by the author. Don't make the referees or the editor do this for you.

Raw, unreviewed manuscripts, best described as "rough drafts," place an excessive burden on the journal, its editor, and its technical referees. Many of the questions raised by the referees could probably have been answered beforehand by the authors if they had only asked a colleague to review their papers. Internal or external review prior to submission of the manuscript to a journal is an excellent means of catching poor organization, verbose explanations, convoluted reasoning, unwarranted interpretations, and unsupported conclusions. It also speeds up publication of that world-class paper we all strive to produce.

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I am grateful to past and present associate editors of *Clays and Clay Minerals* and to dozens of other scientific and editorial colleagues for their comments over the years about the need for and means of achieving good writing in scientific papers. R.A. Sheppard and Diane Schnabel of the U.S. Geological Survey, Denver, Colorado, significantly improved my "unimprovable" first draft. The following texts on technical writing focused my own thoughts on this subject and provided a base for the present note, especially Robert A. Day's *How to Write and Publish a Scientific Paper*.

SELECTED TEXTS ON TECHNICAL WRITING

Barnett, M.T. (1974) *Elements of Technical Writing*: Delmar Publishers, Albany, New York, 232 pp.

Bishop, E.E., Eckel, E.B., and Others (1978) *Suggestions to Authors of the Reports of the United States Geological Survey*: 6th ed., U.S. Government Printing Office, Washington D.C., 273 pp.

Day, R.A. (1983) *How to Write and Publish a Scientific Paper*: 2nd ed., ICI Press, Philadelphia, Pennsylvania, 181 pp.

Dodd, Janet S., ed. (1986) *The ACS Style Guide: A Manual for Authors and Editors*: American Chemical Society, Washington D.C., 264 pp.

Hayes, Robert (1965) *Principles of Technical Writing*: Addison-Wesley, Menlo Park, California, 324 pp.

Hoover, Hardy (1980) *Essentials for the Scientific and Technical Writer*: Dover Publications, New York, 216 pp.

Katz, M.J. (1985) *Elements of a Scientific Paper*: Yale University Press, New Haven, Connecticut, 130 pp.

Tichy, H.J. (1966) *Effective Writing for Engineers, Managers, Scientists*: Wiley, New York, 337 pp.