Science Writing Styles

Learning With Data Workshop

Writing the paper

The following sections explain, in great detail, how to put together your short science papers. Please read it carefully. This format is very common in science writing and will help you present your thoughts in an organized and clear way.

This description is specific to a plate tectonics paper. However, the principles will be the same for other topics.

General writing tips:

1) The paper should be organized carefully. Follow the structure discussed below.
2) Each section of your paper will be composed of paragraphs. Each paragraph should begin with a topic sentence which states the point you will make in that paragraph. Every sentence after that should support the topic sentence. Paragraphs are typically four to eight sentences long and each sentence should address only one point.
3) Make your sentences simple, but vary their length to make the paper interesting.
4) Avoid the passive tense. It is boring. An example of the passive tense is: "It was shown that....." An example of the active tense is: "I have shown that ....."
5) Avoid contractions. These are for more informal writing, like that in this workbook. Say "can not" instead of "can't."
6) Be careful with “Replace All” on your word processor. You may replace words that you don’t intend to replace.

Visual Presentation:

You can use any word processor to write your paper. Your course instructor will ensure you have the tools to write the paper.

All figures will be captured from the **Map** software and annotated using the **Image Editor**. If you can’t find the images that the Image Editor saves, select **Where are my images?** From the **Lib** dropdown menu of the Image Editor. A window will appear that tells you where they are.

Your paper should be thoroughly proofread. Use a spell checker, but be careful because some words may not be in the spell check dictionary.

Do not scan in figures from the book. Your work must reflect your own thinking and the book may provide beautiful images, but a crude sketch that shows that you understand the material is preferable.

Headings

Technical writing follows a specific format. This format varies, depending on the subject and requirements of the magazine or journal publishing the article. But, there are common features

to all formats. The format described here will be. **Your paper must have headings matching those described below**.

- Abstract
- Introduction
- Methods
- Observations
- Interpretation
- Discussion
- Conclusion
- References

Abstract

The abstract is a short summary of your paper, including the conclusions. It should be self-contained. This means that there are no references to the paper or to figures in the paper. The reader who wants to see whether the paper is of interest will read the abstract first. Different journals and publications vary in their abstract requirements. For this paper, make it less than 1/2 page. It should be the last section you write.

Here is an example of an abstract from a recent publication in a professional journal. It is longer than your abstract should be, but shows important components that must be included.

Sample Abstract

The recent intermediate-depth earthquake activity in northern Columbia and western Venezuela was analyzed to understand its origin and its presumed relationship to a subducted lithospheric slab in northwestern South America. The study area is located to the north and east of the Bucaramanga nest, which is a particular region in northern Columbia that presents a high concentration of intermediate-depth earthquakes. To the north of the nest, the seismicity of the area is sparse, and most of the events are of low magnitude (M_b<5.1). Thus only 23 earthquakes were large enough to be investigated using existing data. The pattern of earthquake hypocenters reflects a slab striking in the NNE-SSW direction and dipping approximately at 25^o- 32^o to the southeast. This observation is corroborated by more detailed analyses of the seismograms (fault plane solutions). These results indicate that the intermediate-depth earthquakes in western Venezuela and northern Columbia are apparently related to the presence of a continuous lithospheric slab subducted near the Northern coast of Columbia. The two largest earthquakes, located at a significant distance from the from the Bucaramanga nest, present similar fault plane solutions. Moreover, they also agree with those of the two largest earthquakes reported inside the nest. This similarity suggests that the Bucaramanga nest lies on the same subducted slab where the other earthquakes occur. There is not enough shallow seismic activity to define the location where the Caribbean lithosphere is subducted beneath the South American plate. However, the extension of the slab toward the surface, inferred from the intermediate-depth seismicity, suggests that the subducted lithosphere may still be attached to the Caribbean plate.

(Modified from: "Intermediate-depth seismicity in northern Colombia and western Venezuela and its relationship to Caribbean plate subduction" by Gustavo Malave and Gerado Suarez TECTONICS Vol 14, No 3, p.p. 617-628.)

Practice: Find and mark sentences in the above abstract that tell:

- What the author did for his/her experiment

- Why the experiment is interesting or useful
- The observations that the author made
- Interpretation of the observations
- Discussion and conclusions

Introduction

A very important part of a science paper is the introduction. You should orient the reader. Why are you writing this essay? In just a few sentences, explain the topic of the paper and why it is important or interesting.

Here are some examples of weak and strong sentences that might appear in an introduction:

Strong statements:
I will discuss the general shape of the sea floor and discuss how the motion of the plates affects that shape. I will show how the topography is related to the distribution of volcanoes and earthquake and how these data can be used to determine the kind of boundary between the various plates.

Weak statements:
Plate Tectonics is really a neat subject. I'm writing this to satisfy the writing requirement and will discuss lots of interesting features.

Introduction checklist
The Introduction should cover:
___ What is the topic of investigation in your paper?
___ Why should anybody care? Don't just say it's interesting and important. Say *what's* interesting and *why*.

Methods

This section is where you discuss how and where you got the data. Maybe you made your own measurements, for example, if you went to sea and measured depth profiles, or possibly you measured earthquakes with seismic equipment. For this course, you will be accessing data from existing databases. You should describe those databases and explain any of the inherent limitations of the data.

Here are some examples of statements that might appear in a Methods section:

Strong statements:
This study is based on sea surface temperature data acquired by the Nimbus satellite. The data are available from NASA at *http://www.mySpecifiedWebsite.gov/ and are accurate to about 0.5 C. The temperature data are available on a 5km grid spacing at 1 week intervals.*

Weak statements:

The software used in this course is really cool. It shows the locations of volcanoes and earthquakes, and the topography can be displayed using the ETOPO5 database, which is on the "LearningWithData" CD. This is a really cool course and I will learn a lot from these data.

Methods checklist

The Methods section should contain:

___ A description of how the data were collected (reference any web sites or the "LearningWithData, MAP" module.

___ State the source and accuracy of the basic data that you will use

___ References to data sources (see further below)

Observations

Your observations or "data" are described in this section. Do not add any of your interpretations here—keep them for the Interpretation section.

Qualitative Observations:

Qualitative observations are not really specific, often relating to some arbitrary and unspecified reference. For example: "the waves are big," or "that hill was quite steep." To an experienced big wave rider, the waves may be quite small, but to a non-surfer, they may seem quite large. Steepness of a hill on a hike is also very subjective. A person who hikes a lot may find a hill much less steep than a couch potato. Qualitative observations are not very useful in technical writing, unless you are specifically discussing your reaction to an observation (which is rarely done).

Quantitative Observations:

Quantitative means you are actually observing **Quantities**. For example: "the waves are between 10 and 12 feet high," or "the hill rises at a 45 degree angle," or "the hill rises at a 50% grade."

Clarity of Observations:

The discussion on "Using Figures" should be read carefully. You should be sure to first tell the reader where you made your observations. The location could be marked on a map. When maps are of a very local area, an inset showing a larger area that is more familiar to the intended reader will be provided.

Your observations should include statements that:

- describe the data you are presenting (including figures). Note that figure captions should point out the most important features in a figure. Use the figures you need, but be economical with figures. See the discussion on figures.
- name features that are evident in the data
- describe relationships between observations

Examples of observations:

Strong observations:

Many volcanic mountain ranges (chains) such as the Andes, the Aleutians, and the Japanese Islands run parallel to deep, long oceanic trenches.

The Japan-Kuril trench is ____ km long and ranges in depth from ____ to more than 9000 m.

The East Pacific Rise begins at about 56°S 118°W and ends near the end of the Gulf of California. It has a typical elevation of -2800m, significantly higher than the surrounding seafloor which is typically 4000m or more beneath the sea surface

Weak observations:

Volcanoes are next to trenches.

The trench near Japan is deep and long.

Observations checklist:

The observations section should contain:

___ A description of each observation
___ Figures illustrating your data
___ A reference to each figure in the paper. Don't assume that the reader knows why you put in a particular figure. Explain, in the text, what the figure shows.
___ Quantitative observations, whenever possible
___ Figures must be in the order they are referred to in the text. Refer to Figure 1, then 2, etc.
___ Make sub-headings, if appropriate, for observations in different areas. For example, you might have, for area subheadings: *South America, Tonga-Fiji Region, Global Observations*, etc.
___ Use more than one profile to characterize a linear feature. There may be interesting variations along the feature that will add substance to your paper.
___ Use multiple kinds of data to support your interpretations. For example, elevations, quakes, volcanoes, and seafloor age can usually all be used to support a plate tectonic interpretation.

A good way to get a C or less on this paper is to ignore the data on the CD-ROM "LearningWithData" and make a book report on plate tectonics. This kind of paper misses the point of the assignment.

Interpretations

Here is where you relate your theory or model to the observations. You may need to adjust the theory to fit the data. Generally, this is an iterative process of creating a model or prediction of the outcome, taking data, and then modifying the model to fit the data—**not the other way around** (see below).

Each interpretation must be backed up by one or more observation(s). Simple sketches or cartoons should be used at this point.

Conflicts in the data:
Unfortunately, the real world is not so nice as your textbook. Data rarely agree perfectly with your interpretation. Data also have errors, so may be expected to disagree to some extent. It is important to be forthright about where the data disagree with your model. Maybe you can refine or improve your model if you expand your thinking to consider modification or complexities in your model.

You will find that earthquakes do not always produce "classic" textbook patterns, and the volcanoes dataset may be missing volcanoes where observations are not available.

Honesty:
It is very important to refrain from over-interpreting your data, or exaggerating its accuracy. It is also important to include all of your data, rather than only select data which agree with your preconceived ideas. Sometimes we observe data that do not fit with our expected conclusions. It is very tempting to just forget about it or blame it on a malfunctioning measuring instrument. Discarding good observations is a way to miss a very important discovery that might just disagree with preconceived ideas.

Science has a very high "trust factor." This is because the ethics of science are based on honesty and openness of reporting. Experiments must be repeatable by others, and important experiments are always checked or repeated. Journal articles are critically reviewed by other scientists who are experts in the field. Of course, there may be great debates about the meaning of the observations. These debates are part of the scientific process. Scientific honesty means that the person making the observations is scrupulous in reporting "just the facts." The facts are not only the observations, but also the accuracy of the observations.

Your interpretations section should include statements:
- emphasize relationships between observations (e.g. volcanoes and trench, earthquakes and volcanoes, elevation and age, etc)
- describe your plate tectonics model (**a sketch, not a figure from a book or web page**)
- show correspondence between your model and the observations
- discuss areas where the observations do not support the model. This could occur from genuine conflicts between observations and model, or simply because there are no data that can tell you about it.

Example, Observation and following Interpretation:
The Observation: *The topography shows a trench-like feature (Figure 3) which plunges to a depth of 8,000 meters from a depth in the West of 3,000 meters. This trench extends along the full Western margin of South America, for about XXXXX km. The Andes Mountain Range lies to the West, along the western boundary of South America.* **The Interpretation:** *The many active volcanoes in this mountain range suggest that it was built by volcanic activity (Figure 4). Several cross-sections of earthquakes (Figure 5) show a descending pattern characteristic of subduction zones. Figure 6 shows a sketch of my model for this structure, which is a classic subduction zone.* **Note that these interpretations are backed by observations**.

You should be particularly careful to look at more than one profile in your study area. For South America, you would want to do a number of sections along its western boundary. This might allow you to make a more detailed picture of the shape of the descending slab.

Interpretations checklist:
The Interpretations section should contain the following:
___ Interpretation of each of the observations that you present in the Observations section
___ How your interpretations relate to those of others (e.g. your textbook)
___ References (see "References" discussion) to any material discussed from other sources
___ A sketch (model) of your interpretation of the observations
___ A discussion of the sketch (model) and how your observations support it.
___ A discussion of any data that disagree with your observations

Discussions Heading
Your findings are put into a broader context in this section. This is also where you can write about aspects of plate tectonics theory that are not supported by your investigation, and how these ideas add to an understanding of your investigation. For example, you could discuss mechanisms that cause plate motion, and other plate tectonics ideas that you have no data to support, but would like to discuss because it adds breadth to your paper. You are cautioned that this should not be a general review of plate tectonic theory just to pad the paper, so be sure that your discussion is relevant to your investigation.

Conclusions Heading
Here you summarize your findings without carefully explaining your logic or reasoning. The busy reader who is not a specialist may skip or skim the Methods and Observations section of a technical paper, focusing on the Introduction, Figures, Figure Captions, and Conclusions. So, leave out everything but "the Beef." Don't worry so much about paragraph structure in the conclusions, because you are supposed to summarize many results together.

Examples of phrases that might be used in Conclusions follow:

Strong statement:
The western boundary of the South American continent is a convergent plate boundary. This conclusion is supported by topography, volcanoes, and earthquake hypocenter locations.

Weak statement:
This study shows that the western boundary of South America has a trench, volcanoes, and lots of earthquakes.

I really learned a lot from writing this paper.

Conclusions checklist:

The conclusions section of your paper should contain:

___ A summary of each of your main conclusions, based on your observations and interpretations

___ Any speculation about interpretations that you would like to make, but are not fully supported by the data.

___ A discussion of what further research on the topic might be needed, and the significance of its possible outcome

Using figures to illustrate your paper:

The old cliché that says a picture is worth a thousands words applies especially in science and technical writing. This kind of writing can get complicated and extremely difficult to understand. Any time you can illustrate a point with a picture or sketch, the clarity of the presentation is enhanced. Most people are not really very good at visualizing geometrical shapes and physical phenomena that have been described with words. A picture fills in questions in the reader's mind and lessens the tedium of pages of text.

The busy reader may only look at your figures and read the captions. This underscores the importance of good captions. Figure captions should briefly describe what the figure shows. For this example, Figure 2 would have a caption that said something like: "Locations of the three studies discussed in this paper." That would be enough.

When writing a technical paper related to the Earth, it is important to show the reader where the study took place. Where is the study location on the Earth? Figure 2 shows how this can be done on a Mercator map of the world. Each study area is clearly marked so that you can refer to it in the text without requiring the reader to remember previous location descriptions. All locations that you mention in the text must be indicated on the location map.

Since you will be using profiles in your paper, you will want to use figures to show samples of profiles. Maybe you want to illustrate the geometry of a trench, or show profiles across a mid-ocean ridge. Figure 3 shows a representation that would successfully show the location of a number of profiles.

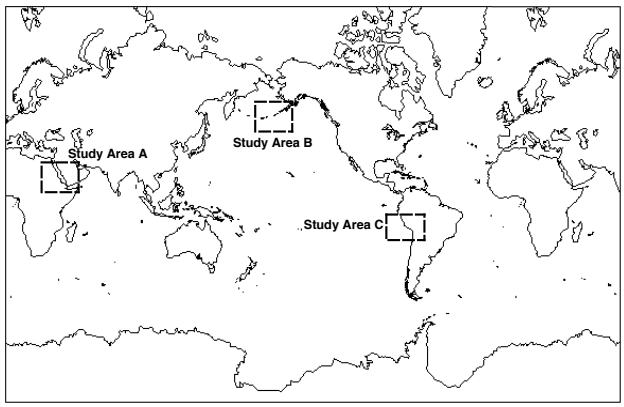


Figure 2. Areas of study.

Figure 4 shows an example of how you might print a series of detailed profile plots, which give vital information like the elevations and distances. You should think of the Figure 3 profiles as merely locating the profile positions, which Figure 4 shows the actual profile data.

Mistakes using figures:
Believe it or not, ***you can over-use figures***. A big pile of figures showing everything you did will simply not produce a good paper. It is the job of the technical writer to condense the information so that the reader can easily assimilate the information and come away convinced of the correctness of the conclusions. That is the main purpose of using figures, but don't overdo it. If you have lots of figures, you might try combining them. However, each figure should not be too complex. You have to exercise some judgment and restraint to keep the balance between having too many figures and having figures that are too complicated.

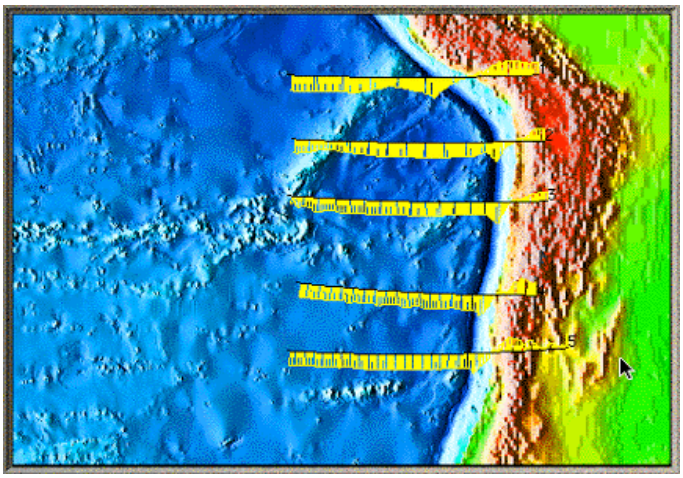


Figure 3. Locations of profiles in area C.

Notating figures: Another mistake is just using raw figures. A reader should be able to glance at the figure and caption and get a good idea of what the figure expresses. This means you should use to graphics editing tool to draw arrows to important features that you are examining in your investigation. Captions should also describe the purpose of the figure.

Figures 2, 3 and 4 illustrate how to create a location map for your study and illustrate the locations of elevation profiles within the study area. For readability, it is best to put the figures near to where they are referred to, rather than group them all at the end of your paper.

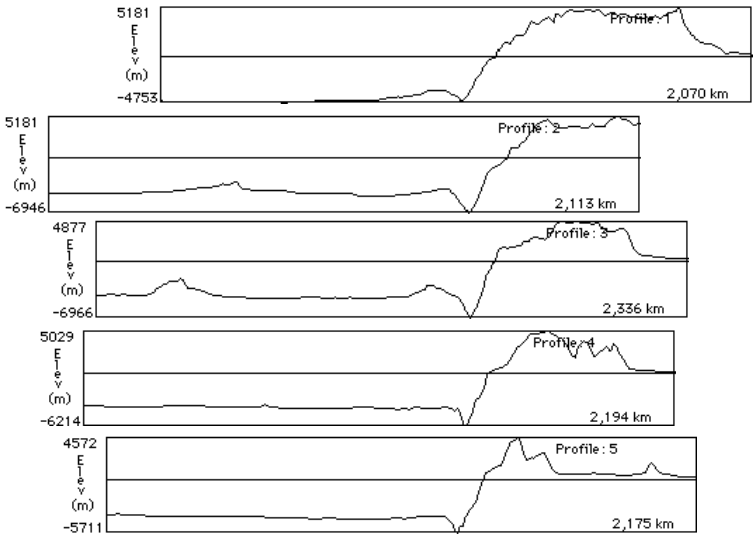
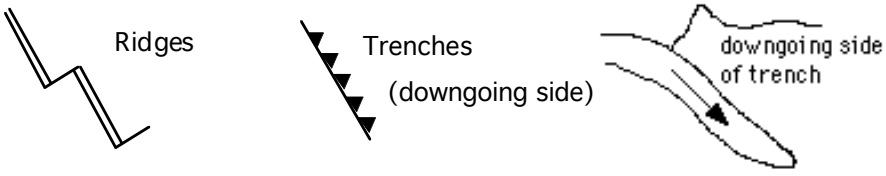


Figure 4. Detailed plots of profiles shown in Figure 3.

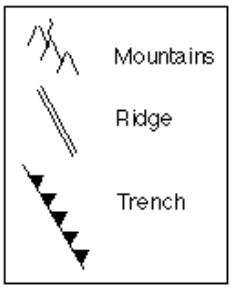
Symbols to use on maps:

The symbols to the left can be drawn on the map to indicate the presence of mountains. If the mountains are volcanoes, you could put a wiggly line indicating smoke coming out. Colored pencils can be used to advantage, to make your map more readable.



Map View Cross section View

The above symbols are used to represent ridges, which are places where the lithosphere is spreading apart, and trenches, where the plates are pushing together. The cross section view shows the geometry of the down-going side of the trench. The saw teeth are pointed in the direction of motion of the plate that is being subducted.



Legends:
Although the use of particular symbols may follow a convention, it is always important to include a "legend." This is a section on the map that shows the meaning of the symbols. An example of a legend is shown at the left. It is simply a listing of what each symbol, line type, or line color means. Other information that you should put on a map is an arrow showing the direction of north. For the world map, north is obvious, so you don't need it. Smaller maps require a north arrow.

Figures checklist:

___ Each figure shown has a numbered caption, which describes the figure.
___ Each figure is mentioned and explained in the text.
___ Figures are numbered according to the order in which they are mentioned in the text.
___ Figures are clear and easy to read. If the data do not show up clearly on the figure, mark on it with colored pen.
___ There are no figures that are photocopied/scanned from the text, or any other source.

References:

All data, text, and figures that you get from other sources must be referenced. When you speak of other peoples' work in the body of your text, you use a reference. For example:

> *In recent years, considerable effort has been directed towards investigating the biological consequences of climate change (see Bolin et al. 1986; Chapin et. al. 1992; Fautin et al. 1992, for reviews).*

Or:

> *Ocean uptake of carbon is simulated with the world ocean general circulation model (OGCM) of Toggweiler et al. [1989], as modified by Toggweiler and Samuels [1993]. etc.*

There are various styles for referring to others' work, and you may choose any style that is clear. Don't mix styles, though. Notice that you are referring to the author's name, and a date. This will identify a specific reference in the reference list, which must appear at the end of your paper.

Examples follow:

References:

Toggweiler, J.R. and B. Samuels, 1993. Is the magnitude of the deep outflow from the Atlantic Ocean actually governed by southern hemisphere winds? in *The Global Carbon Cycle*, edited by M. Heimann, pp. 333-366, *Springer-Verlag*, New York.

Hurley, P.M., (1968) Absolute abundance and distribution of Rb, K, and Sr in the Earth. *Geochem. Acta*, 32, 273-283.

Note that the first reference is to a book and the second is to a scientific journal article. Each journal requires a slightly different format for references. You may use the format above.

Form of book reference to use:
<Author>, <Year>, <Title>, <Title of book>, <editor or edition of book>, <page numbers of your reference>, <Publisher>, <City of publisher>.

Form of paper reference to use:
<Author>, <Year>, <Title>, <Name of journal>, <Volume number of journal>, <page numbers of article>.

Internet references:

An action-alert posted on the web:

American Psychological Association, (1995) *APA public policy action alert: Legislation would affect grant recipients* [Announcement]. Washington, DC: Author, Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/ppo/istook.html

An article from a newspaper on the web:

Sleek, S. (1996, January). Psychologists build a culture of peace. APA Monitor, pp. 1,33. Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/monitor/peacea/html

Be sure to reference quotes from your textbook and any other sources.

Final checklist:

__ Name, section, and ID number at the top.

__ All specified headings included (see “Format of Paper”).

__ The paper may include any number of figures and drawings. Small figures should be included in the text (drawing them on the computer is optional). Full page figures can be inserted at the closest spot where they are referred to.

__ Do not include any figures photocopied/scanned from the textbook.

