

# Tools of the Trade

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## Introduction

What is in your toolbox? The geological toolbox has grown considerably since the days of the Brunton Compass and Jacobs staff. Our advice for students is to embrace technological change but beware of the black-box syndrome. Remember that tools for measuring geologic properties are always best understood and most appreciated if you understand the basic physical science associated with what is being measured in the field or laboratory. Having been there and done that with our students at Northern Kentucky University and Western Kentucky University, using tools from the applied geophysical methods toolbox, we have a good understanding of what helps to properly use the tools.

Geophysical measurements in the field provide important tools for many geological applications whether they are for those seeking careers with Departments of Transportation and Public Works (geotechnical), with environmental consulting or regulatory agencies, or the oil and gas industry. Geophysics is an indirect, noninvasive series of techniques. It has been said that in order to be a good geophysicist you first need to be a good geologist. Therefore, using the basic geological knowledge such as sedimentology and stratigraphy, structural geology, and hydrogeology in conjunction with geophysical properties aids in cost-effective ways of characterizing site geology. We provide several examples in which we strongly encourage students to truly understand the theory of a given applied geophysical technique such as resistivity or seismic prior to field data collection, analysis and conclusion.

## Learn the Basics before Conducting Field Work

A tried and true method for beginners to learn more and retain better is to understand the basic theory, use the equipment and then delve deeper into

the theory. Thus our students prior to any field exercise are strongly urged to review properties being measured (cf. May and Gibbons, 2004) and how each piece of equipment works. Use of electrical resistivity tomography requires students to understand the concepts of Ohm's Law, resistance and resistivity, and have the ability to relate these concepts to others they have learned such as electrical current flow being analogous to groundwater flow. Instead of gallons (water molecules/minutes) it is coulombs (electrons/second). Armed with this knowledge, students will note that even though an instrument calculates apparent resistivity between spaced electrodes (Figure 1), physically the process is a repetitive measuring of differences in electrical resistivity at numerous nodes (and is iterative during the modeling phase).

A background in basic solution chemistry is required to understand that groundwater (aqueous solution in the subsurface) best conducts if there are dissolved ions in that solution. If you want electrical current to flow you need a way to move electrons along. In contrast, students can learn several hypotheses to explain why a certain apparent resistivity pattern is exhibited. Carbonate rocks (i.e., limestone and dolomite) are very electrically resistive when they are unfractured, but can have significantly lower resistivity values when fractured and/or weathered and affected by solution. In contrast, shale bedrock is very conductive.

The conditions of electrical conduction are very dependent on moisture and therefore equally dependent on precipitation and/or groundwater. Periods of drought can deplete the amount of water in a system changing its overall resistivity. Void spaces in a clay matrix could actually look more resistive than the clay. However, if after a protracted drought sufficient rain falls to fill in void spaces and the clay does not have



Figure 1. Students setting up a resistivity survey at a small cave in Mississippian rocks in Hart County, Kentucky near Mammoth Cave National Park.

sufficient time to absorb moisture, the resistive void can appear conductive.

The interpretation of geophysical data requires considering many lines of evidence. Students should have a basic knowledge of states of matter (i.e., solid, liquid and gas) and the relative expected abundance of various fluids encountered in soil, sediment and rock. It is necessarily required that students also have an understanding of the basic physics associated with the materials being tested. Students must also learn by doing and be willing to integrate their multi-disciplinary backgrounds to do so (e.g., Wulff and May, 2013). For example, seismic surveys (Figure 2) require a determination of the most appropriate method – refraction, reflection or surface wave analysis. Refraction relies on increasing acoustic velocities in each stratigraphic unit or layer to refract energy encountered with increasing depth otherwise, if this cannot be assumed or is not known to be the normal case, then an alternative method such as reflection should be proposed. Reflection relies only on velocity contrasts between encountered stratigraphic units or layers. Such decisions of even knowing which method would be the most advantageous obviously hinges on a basic knowledge of acoustic velocity trends associated with various physical media (e.g., dry sandstone, saltwater in sandstone, freshwater in sandstone, caves, highly fractured wet limestone, highly fractured dry limestone etc.). This is basic physics knowledge but applied



Figure 2. Students conducting a seismic survey in the Cincinnati metropolitan area of northern Kentucky in landslide-prone Ordovician strata.

to understanding subsurface geologic conditions.

### Avoid the “P” Word

Procrastination is perhaps one of the most difficult things to admit for students and faculty alike but we all necessarily place first on our “to-do” lists items we like to do and sometimes the priority system is not rigid. The normal human response is to put off those more difficult or unsure tasks. If you have a series of courses to take, make sure you are proactive in seeking out all the physical science courses or mathematics that will greatly aid you in those geology classes even if your particular program does not have for example, a physics, chemistry or calculus class as a pre-requisite for upper-level geology courses. Many programs in Geology and allied disciplines across North America naturally have a series of pre-requisite courses but we maintain that the physical sciences especially are most beneficial to encounter earlier rather than later under the guise of “finishing off the requirements for graduation.” High-tech tools of the trade require more than a basic knowledge of geology. Students are necessarily required to know chemistry and physics in order to understand field and laboratory analytical or measuring devices. You may hear of the so-called “just in time learning” but our experience is that students struggle less in the field if they have had that physics and chemistry foundation prior to extended days of conducting resistivity, seismic, gravity and similar surveys.

### Success in the Field

Our experience from the standpoint of instruction of college students has been that the greatest success in the field of applied geophysics has been by those students who are doing more than “pushing buttons” or “laying out lines”

as field helpers but rather by those who have purposely sought out allied physical science basics and reviewed these concepts prior to conducting a given field survey. In particular, our students have also learned how such exercises not only bring things like physics and chemistry to life in the field setting but they also permit direct, first-hand knowledge of how such surveys can be used to solve problems associated with building roads, mitigating karst hazards, proactively assessing groundwater resources, site characterization and remediation, and the search for energy resources, just to name a few applications.

Perhaps one of the most important aspects of learning comes from students understanding the basic theory and then putting the theory into practice through applied geophysics. As such field methods by their very nature are indirect measurements of geologic conditions, students are challenged to construct multi-working hypotheses as they collect and analyze data. This is also good practice for a future career!

### Summary

Students should go beyond looking at the “hard sciences” such as physics, chemistry and mathematics as something that should be put off for later in their geology curriculum because these subjects are foundational in fully understanding exercises in the field such as applied geophysics. The seemingly disparate discussion of courses dealing with basic electrical properties, chemical characteristics and behavior of fluids, velocity of wave fronts, particle motion, vibration direction, frequency and similar physical parameters are all important to master prior to conducting geophysical surveys. The importance of understanding the various principles of physics and chemistry can be related to a positive feedback mechanism associated with learning the theory of each type of field survey. We suggest that students can also recognize that such thorough understanding is associated with field preparation, data collection, data processing and analysis, and ultimately geologic interpretation. These skills can form the basis for significant points of communication for not only colleagues and professors but also employers seeking out students who have learned by doing and who have established themselves as knowing not only the theoretical but also the applied.

### References

- May, Michael T., and Gibbons, M. G., 2004, Introducing students to Environmental Geophysics in a Field Setting. *Journal of Geoscience Education*, V. 52, no. 3, p. 254-259.
- Walt, A.H. and May, M.T., 2013, *Intentional Learning for Career Success. The Professional Geologist* March/April, p. 10-13.

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