If you have made it this far, to the end of this lab manual, congratulations! You have tackled material that takes serious work to learn. If you come from a typical undergraduate geology major background, this manual has introduced you to some tremendously important concepts and methods that are not typically, or adequately, taught to undergraduates in their first structure course. These concepts include powerful linear algebra methods such as transformations of coordinates, vectors, and tensors; the concepts of principal axes and invariants of tensors; the significant differences between stress, infinitesimal strain and finite strain. We have learned about material versus spatial coordinates and how important it is in the analysis of strain as well as in mechanics. We have seen that even the most basic structural geology calculation has significant uncertainty associated with it and gotten a glimpse of how to determine those uncertainties. Finally, you have seen that even the simple spreadsheet program is a powerful computing environment that enables you to solve problems that cannot be solved with traditional graphical methods. And now, a confession on my part: I hate spreadsheet programs! That is because I know how much more powerful, faster, and more capable traditional computer programming is. Hopefully this manual has given you the motivation to acquire those skills as well.

If you come from an engineering or physics background, you are probably wondering what all of the fuss is about! Most of the topics that we have touched on in this manual are treated in the first two years of a typical undergraduate curriculum in those disciplines. Structural geology is, fundamentally, solid mechanics applied to earth materials. Though the methods are the same, there are some significant differences in approach: an engineer might want to know the maximum load that a beam can bear and how much it will flex so that they can design a bridge to a particular specification. The structural geologist is more like a forensic scientist: they come upon the scene when the bridge has already collapsed and is lying in a heap on the valley floor. Our job is to extract from the chaos of a deformation that
has already happened — commonly many millions of years ago — what the key factors were and thereby what the Earth is capable of.

As forensic scientists, we have to go to the field which is the scene of the crime. There is a misconception that field geologists observe and map whereas quantitative or “theoretical” structural geologists stay at home and program their computers. The best structural geologists throughout history have done both: they go to the field (or lab) and make careful quantitative observations and they know how to analyze and probe their data quantitatively to extract meaningful conclusions. This is an iterative process. Initial observations may stimulate deeper mechanical analysis which provides a set of observables for testing with further observation, resulting in further refinements of the theory.

Let’s say you come from that typical undergraduate geology major background. After reading this lab manual, I flatter myself to think that a few of you might now be inspired to join the ranks of the best structural geologists. Where should you turn next on this journey? In no particular order, I suggest the following studies:

• Take at least four semesters of college math, which will take you through linear algebra and partial differential equations. The earth is a multivariate system with gradients of properties in all directions. Inverse methods, a branch of linear algebra, are extremely powerful. This is not just the minimum level of math required for structural geology but in fact the minimum level for anyone wanting to become a physical scientist or engineer in just about any field.

• Learn a real computing environment, whether it be Matlab, Python, Fortran, Basic, C++, etc. If you cannot program, you have to wait until someone else writes the program for you and it is unlikely that, by the time that happens, the problem you wanted to solve will still be cutting edge. Like the previous bullet, computing is a skill that all scientists and engineers should have.

• Take geomechanics or engineering mechanics courses. Because these courses require dedication and perseverance, they will be more approachable once you have some idea what the problems are that a
structural geologist wants to solve. This is a necessary step if, as mentioned in Chapter 12, you want to illuminate and not just simulate a structure of interest.

- Most of the problems that we wish to address in structural geology have a high degree of uncertainty due to incomplete data, subjective hypotheses and observation, and lack of knowledge about appropriate boundary conditions, initial values, and constitutive relations. Thus, you will need to learn some statistics; fortunately much of the mathematical background needed for statistics is the same as that needed for structural geology itself. Once you have armed yourself with statistical methods, remember that statistics can only help you eliminate models or hypotheses; they cannot “prove” a hypothesis. The “best” model is simply one that has not yet been eliminated.

Structural geology provides the basis for a tremendously rewarding career: we study deformation features in some of the most beautiful and remote places on Earth. However, we also are expert on problems of extreme societal relevance and interest: earthquakes, induced seismicity, hydraulic fracturing, surface instabilities, and so on. The background that I have described above will enable you to pursue either or both of these branches of our science at the highest level. Good luck!
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