

How fast were my rocks? Modeling Seismic Velocities for Exhumed Rocks

Overview

Who is this tutorial for and how does it work?

These tutorials were developed as part of an NSF-funded workshop (EAR-2419991) and teach graduate or upper-level undergraduate students how to model seismic velocities for exhumed rocks from thin section to map-scale using freely available toolboxes and Matlab. The tutorials start assuming minimal prior knowledge and take the students through basic calculations to more advanced modelling, including details on how to tailor the toolboxes to their specific area. We envision that these tutorials could be used either in a range of courses (e.g., as a case-study project in an upper-level undergraduate geophysics course, a Matlab-focused course, or a graduate-level senior seminar on topics such as microstructures, geodynamics, and/or subduction processes) or as a stand-alone exercise that could be incorporated into onboarding for students conducting research in these areas.

These tutorials walk students through the basics of seismic velocities and how to use two different Matlab toolboxes to model seismic velocities for exhumed rocks. The students complete three parts:

- Part 1: Basics of seismic velocities
- Part 2: Assuming isotropic rocks
- Part 3: Accounting for mineral anisotropy

By the end of the tutorial, students will be able to:

- Explain how lithology, P-T conditions, and mineral anisotropy affect seismic velocities
- Calculate seismic velocities for isotropic and anisotropic media by estimating mineral and lithologic modal abundances, and mineral orientations for a given area of interest.

These can be incorporated into many different research aims, especially when working between exhumed rocks and geophysical data. Geophysical data provide insights into processes happening below the surface of the Earth. Exhumed rocks also provide a window into processes but work on exhumed rocks is usually at a smaller scale (thin section to outcrop) than what geophysical data capture (commonly km-scale). One way to bridge these data is to model the seismic velocities of the exhumed rocks and compare the model results to geophysical data.

Researchers have developed multiple toolboxes (Abers & Hacker, 2016 covered in Part 2; Walker & Wookey, 2012 covered in Part 3) to facilitate calculation of seismic velocities in complex rocks. These include adjustments for pressure-temperature (P-T) conditions and accounting for mineral anisotropy, where the seismic wave velocity depends on how the wave passes through a mineral. This is especially useful for ductilely deformed rocks, where mineral crystal lattices may be aligned during deformation.

These tutorials explore background information and case studies to learn how to implement these different toolboxes and considerations for modeling their own exhumed terranes. These serve as a launch pad for subsequent research into an area of their own interest.

What if I or my students don't know anything about using Matlab?

Never fear! These tutorials do not include Matlab basics, but you don't need to be a Matlab pro to do the calculations in these tutorials. We recommend that you learn the basics before starting, and there are lots of free resources out there to help you out. This YouTube channel does a good job of teaching the basics as hands-on demos:

- [Basic Syntax](#) - how do you type things into Matlab to make it do stuff
- [Basic Arithmetic](#)
 - This also covers matrix division and multiplication, which is a special type of math that you'd learn about in Linear Algebra. Don't worry if you don't understand what it's doing for those calculations.

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- For just about anything that we do, we ***don't*** want matrix division and multiplication. We just want plain old division or multiplication. If you are using / * or a power with any variable, put a period in front of the symbol. For example: A.*B or A.^2
- If you don't, it will either give an error OR it will calculate something that you don't want
- When in doubt, add a .
- Ditto for any vector math (cross products, etc)
- [Functions & Constants](#) - how to use built in Matlab functions (similar to saying =average() in Excel)

You can also see what textbooks (digital or print) are available from you institution or from faculty members. If you are using this in a course, you might want to build a simple introduction exercise.

These Matlab basics allow for following of the tutorials and initial modelling. If students are interested in more complex lithologies, mineral behaviors, etc., we recommend spending a bit more time getting familiar with Matlab capabilities (e.g., learning how to implement for loops, etc.).