III. Virtual field exercises for Structural Geology and Volcanology classes: New approaches to enhancing undergraduate geology field instruction at the upper division level

Introduction

Field experiences and field exercises are widely recognized as an indispensable part of a geologic education. Not only are courses in geologic mapping and field methods an integral part of most undergraduate curricula, but field exercises and field trips are typically an important component of upper division geology courses (structural geology, sedimentology, igneous and metamorphic petrology, volcanology, etc.). Many geoscience educators have stated that students learn best when they are required to apply what they have learned in theory to solving real world problems (e.g. Elkins & Elkins 2007), and in geology this involves careful integration of lecture/topical material, with laboratory exercises, problem sets, and most importantly practical field exercises. When the COVID-19 pandemic emerged in 2020, many geology departments had to quickly adjust to an online education model where in-person field trips were not possible.

This paper describes in detail how we tried to solve this problem by creating virtual field exercises and field trips for upper division courses in Physical Volcanology and Structural Geology – virtual exercises that we believe were successful substitutes for our regular field exercises associated with these classes. These were done under severe time pressure and were our first attempt at field education in an "online world" – attempts that improved steadily as we gained experience and from which we have learned what is effective and what is not. Going forward, we will undoubtedly have ideas about how to do this even better. More importantly we have learned that there are a few things that the students actually learn better in this format, even as we continue to believe that there is no substitute for a real field experience. In the future, we will use these same videos and associated virtual field instruction modules in conjunction with actual field trips to strengthen the overall experience, better prepare students for the actual trips, devote less time to lecturing in the field, and as a way of making the field experiences available to those who, either for physical disabilities, medical reasons, or family situations cannot attend the actual field excursions. We also suspect these virtual field exercises might be very useful for students attending universities that are far removed from outcrop exposures of the type of geologic features that are being covered in equivalent structural geology and volcanology classes. We believe that the types of videos we present here are far more effective at communicating information and clarifying concepts than simply using a series of still photos in a PowerPoint presentation – photos taken by the professor during travels to far flung places. This paper is less about a pedological philosophy and more about providing concrete examples of virtual field instruction in two upper division courses in Structural Geology and Physical Volcanology. We did this by integrating videos filmed in the field with follow up exercises that could be carried out online to simulate as closely as possible what the students would have been doing in a pre-COVID world.

Statement of the problem: how does one give students a realistic field experience, one where they get a very good sense for what the rocks look like in nature, their textures, scales, appearance from different angles and at different distances, while also providing a "how to" tutorial on what kinds of data and observations they should be making if they were at the field site. The challenge is figuring out how to do this while adequately:

- Emphasizing the ambiguity of real rocks, in contrast to textbook illustrations and photographs that tend to show only flagrantly obvious relationships.
- Recognizing the difference between what they actually see versus what they infer - i.e. learning to describe things as they are, instead of seeing what they think they should be seeing.
- Providing guidance on the types of observations and measurements they could and should be making if they were present at the site.
- Keeping the students engaged and thinking deeply about how field observations and data can be used to solve problems. Encouraging students to develop multiple working hypotheses.

Our approach was to couple carefully crafted field videos with rigorous assignments and problem-solving exercises and thus engage the students to do more than just watch a "show and tell" type video.

Background

Fieldwork is widely considered an essential part of undergraduate education in the earth sciences and for good reason; geology is fundamentally a field science where nature has already performed innumerable experiments, and our role as observational scientists is to carefully reconstruct the parameters of the experiment, how it proceeded, and what the final results tell us about processes. Examining rocks in their natural setting is often far more effective for learning than watching a lecture or reading a textbook (Elkins & Elkins, 2007; Mogk & Goodwin, 2012; Petcovic et al., 2014). Fieldwork provides the opportunity for students to see different rock types and geologic relationships in person, make their own observations, collect their own data, and make their own interpretations. This type of direct interaction with the natural environment has been shown to be important in facilitating cognition, critical thinking and spatial-reasoning skills (Hutchins & Renner, 2012; Kastens & Ishikawa, 2006). Field trips also play an important role in inspiring budding geologists by kindling their scientific curiosity and passion for the study of geology while at the same time exposing them to enjoyable outdoor/wilderness experiences, often in places of great natural beauty. Moreover, fieldwork skills are often valuable after graduation as many academic and industry careers in geology involve significant fieldwork and many job listings require prior fieldwork experience. Most state "professional geologist" credentials require extensive coursework in geologic mapping and field investigation.

It is clear that fieldwork is a critical component of an undergraduate education in the earth sciences; however, field learning experiences are often unavailable or severely limited to many undergraduates due to the logistical and financial challenges of in-person field trips. Field trips require a significant time commitment for both professors and students and can be disruptive of students' class and work schedules. They can also present difficulties with budget constraints, liability issues and transportation logistics (Behrendt & Franklin, 2014). These problems are exacerbated by the recent trend of increasing class sizes and tightening budgets at many U.S. universities (Diette & Raghav, 2015; Mitchell et al., 2016). Moreover, many schools face a lack of good field localities close to campus, making it nearly impossible to run effective in-person day or weekend trips.

A particularly acute problem with in-person geology field trips as they have traditionally been taught is their inaccessibility for people with disabilities. Geoscience is the least diverse STEM field and has one of the lowest rates of participation by persons with disabilities (Huntoon & Tanenbaum, 2015; Locke, 2005). Field-focused disciplines can be intimidating to students who don't have prior experience in remote outdoor settings, and unfortunately this is particularly common amongst minorities and marginalized groups (Ghimire et al, 2014; Schwartz & Corkery, 2011; Sherman-Morris & McNeal, 2016). Students with disabilities are especially affected by this problem as there are often physical barriers preventing them from engaging in the outdoors (Carabajal et al., 2017; Hall et al., 2002). A lack of flexible and accessible learning environments and opportunities appears to be one of the principal factors in the underrepresentation of students with disabilities in geoscience (Atchison and Libarkin, 2016). Most existing literature on this problem suggests modifying field trips to make them accessible for disabled students. However, many of the projects and localities for higher-level geology field trips simply don’t afford the option of making them accessible for students with mobility disabilities.

We believe that virtual field trips are an effective means of mitigating the logistical and financial challenges of in person field trips, providing an accessible alternative for disabled students, and maximizing the amount of field experiences students can have. They broaden access to field learning to schools that otherwise wouldn’t have the funding or resources to run their own trips. They also allow students with disabilities to travel virtually to the best field sites, work with real datasets and analyze real-world geologic problems without impacting the educational experience for the rest of the class. We are not advocating that virtual field trips should totally replace in-person field trips. Rather, we believe they can be used to broaden access to field learning and also be used in conjunction with in-person trips to maximize the amount of field experiences students can have with limited time and budgets. They can also enhance in-person trips by allowing students to become familiar with the geology of the area by watching a field video before they visit, thus reducing lecture time in the field, or watch it after to reinforce the concepts learned on the trip.

There are many published examples of geology virtual field trips made by other authors that have a range of teaching styles and use various technologies (e.g. Dolphin et al., 2019; Mead et al., 2019; Bursztyn et al., 2015; Lenkeit Meezan & Cuffey, 2012). Most use a combination of photos and short videos from field areas with some using more high-tech methods such as 3-D computer models, rotatable 360° images, and mobile learning games on smartphones. These virtual field trips appear to be quite effective, however the vast majority are for introductory geology courses and don't cover higher-level topics or require significant data analysis and interpretation on the part of the student. Our virtual field trips take a somewhat different approach as they are geared toward upper division students, opting for longer, more in-depth videos, giving the students real datasets from the field areas, and typically requiring fairly extensive data analysis and interpretation based directly on the field videos.

Design and Implementation

The virtual field trips presented in this paper were all originally in-person field trips and field exercises in upper division courses taught by Gans, and were adapted to be virtual during the lockdowns of the COVID pandemic in Fall 2020 and Winter 2021. Normally students would go to these field sites in person, be given an overview lecture and some guidance by the professor (Gans) at the beginning, and then make their own observations, collect their own data, and make interpretations based on these data and observations. Obviously, this was no longer possible for a virtual field trip. Instead, we attempted to replicate this experience by providing high-quality videos from the field areas and combining them with exercises that give students experience analyzing and interpreting field data and observations. The style of trip varies depending on the topic being covered, with some being more “show-and-tell” and others requiring more data analysis and interpretation.

In addition to their application for an entirely virtual class, the field videos were also used the following year when the structural geology and physical volcanology classes were back to being in-person. In this case, students watched the videos prior to the in-person field exercises to familiarize them with the geology of the field locality and to show them how to collect the appropriate data for the project. The goal was to have the students be better prepared to hit the ground running and to minimize the amount of lecture time needed in the field so more time could be spent looking at the rocks. For the extended 4-day trip near the end of the class, students watched the field video after returning to solidify the concepts learned in the field and help them complete a worksheet and prepare for an exam on topics covered on the field trip.

Video production

The field videos were filmed on a consumer grade interchangeable-lens DSLR camera in 4k resolution using both a standard zoom and a wide-angle zoom lens (Figure 28a & 28b). Exposure settings were set manually for consistent results and both manual and auto focusing were used depending on the type of shot. Of particular importance was accurate representation of color and contrast so a white balance card was used during filming and minimal color and contrast adjustments were made when editing the footage (Figure 28c). Audio was recorded using a clip-on lavalier microphone with a remote transmitter for clear

Figure 28: Camera equipment used for filming the field trip videos. a) Mirrorless DSLR camera body. b) Wide angle and standard zoom lenses. c) White balance card. d) Clip-on lavalier microphone and remote audio transmitter. e) Lens filters. f) Tripod with fluid head.

real time in-camera audio recording (Figure 28d). A microphone wind-muff proved to be very helpful for reducing wind noise in outdoor environments. A tripod with a fluid head was typically used to ensure the footage was stable and allow for smooth panning (Figure 28f). The footage was edited in Adobe Premiere Pro and involved trimming clips, aligning them in the timeline, fine-tuning white balance and contrast, adjusting audio levels, and adding titles, annotations, animations, and figures.

Video content

The virtual field trips can be broadly divided into two types based on whether they are project-based or a “show-and-tell” style. For the project-based field trips, the videos focus on how to collect specific types of data or make specific types of observations relating to the project that the students then complete with data from the field area. Examples of this include how to collect orientations of joints and interpret their relative ages, how to collect data on fault surfaces and interpret slip sense, or how to interpret the relative ages and flow direction of lava flows. The “show-and-tell” style trips don’t have a project associated with them but instead aim to provide a detailed overview of the geology of an area, often focusing on concepts learned in the lecture material from the class.

In all the field videos we aim to walk students through how to approach each outcrop as if they were there: *What relationships are illustrated by the outcrop and what questions are raised by what you are seeing? What types of observations can be made to answer these? What types of data can be collected?* It is important that the students think critically about these types of questions rather than just being fed the answers. Of particular importance is differentiating between factual observations and interpretations, and clearly explaining what types of data and observations can support various interpretations. Additionally, many of the localities visited on the virtual field trips aren't "textbook" examples but instead provide real-world examples of typical rocks where the key features and relationships are usually much less apparent. This forces students to learn how to interpret geological relationships that aren't entirely obvious and gives them practice recognizing subtle clues and features.

A main goal of these virtual field trips was to provide students with as much of a real-world field experience as possible and a key component of fieldwork is the ability to look at the rocks at many different scales. To replicate this, we combined wide panoramic shots with footage of outcrops as well as close-up macro shots of hand-samples and in some cases even inserted photomicrographs from petrographic thin sections. The close-up macro shots have a particular advantage over in-person trips in that they allow the entire class to synchronously look closely at the same rock while being guided through its important features (Figure 29a). This is nearly impossible to do effectively in-person with a large class all trying to see fine details in a small hand-sample.

Figure 29: Screenshots from various virtual field trip videos that highlight some of the techniques used. a) Closeup shot of a hand sample. b) Annotations of a series of folds. c) Labels showing the different rock units, highlighting stratigraphy, and showing the location and sense of slip of a fault. d) Inset diagram showing the relationship of R-shears to the main fault plane.

The majority of the video footage was filmed in the field looking at the rocks, but interleaved PowerPoint style Zoom recordings were used to provide background and context to the field sites and to show maps, satellite imagery, photomicrographs, and other figures. This effectively replaces the use of posters in the field and provides the ability to quickly change perspective and "zoom out" to look at satellite imagery or maps or "zoom in" to look at photomicrographs of the rocks from the field areas. Annotations over the video footage are also used extensively to label features and areas of interest, show the traces of faults and folds, and highlight key points (Figure 29b). Particularly effective is their use in pointing out features in wide panoramic shots that would otherwise be hard to identify (Figure 29c). Figures and diagrams are also commonly inset directly into the videos to help clarify the material and relate it back to concepts learned in lecture (Figure 29d).

The videos are hosted on Vimeo for ad-free 4k open access viewing and can be accessed at https://vimeo.com/user130110709. The assignments and associated datasets can be accessed via the supplementary files of this paper and answer keys can be obtained by emailing the authors.

Assignments and deliverables

The assignments and deliverables associated with each virtual field trip vary considerably according to whether they fall into the into “show-and-tell” or project-based categories. The show-and-tell style field trips typically require students to fill out a simple worksheet or questionnaire while watching the video to motivate them to pay attention, reinforce the most important concepts, and encourage them to think critically about the topics being covered. They are designed to be relatively straight forward and don’t require much more time than just watching the video itself. Timestamps for each of the questions are used to indicate where in the video each question is referring to, preventing confusion and making it easier for the students to navigate.

The project-based virtual field trips typically require that students analyze and interpret a dataset from the field area that is provided by the instructor and present their results as figures, maps or tables accompanied by a short report (Figure 30a and 30b). For the structural geology labs, the datasets that are provided to the students usually consist of tabulated structural data, such as orientations of bedding, joints, faults, fold axes etc. These data are georeferenced and thus can be easily plotted in Google Earth or stereonet software (Figure 30c). Project-based volcanology virtual field trips don’t typically use structural datasets, but instead have the students interpret the field relationships from the videos, make

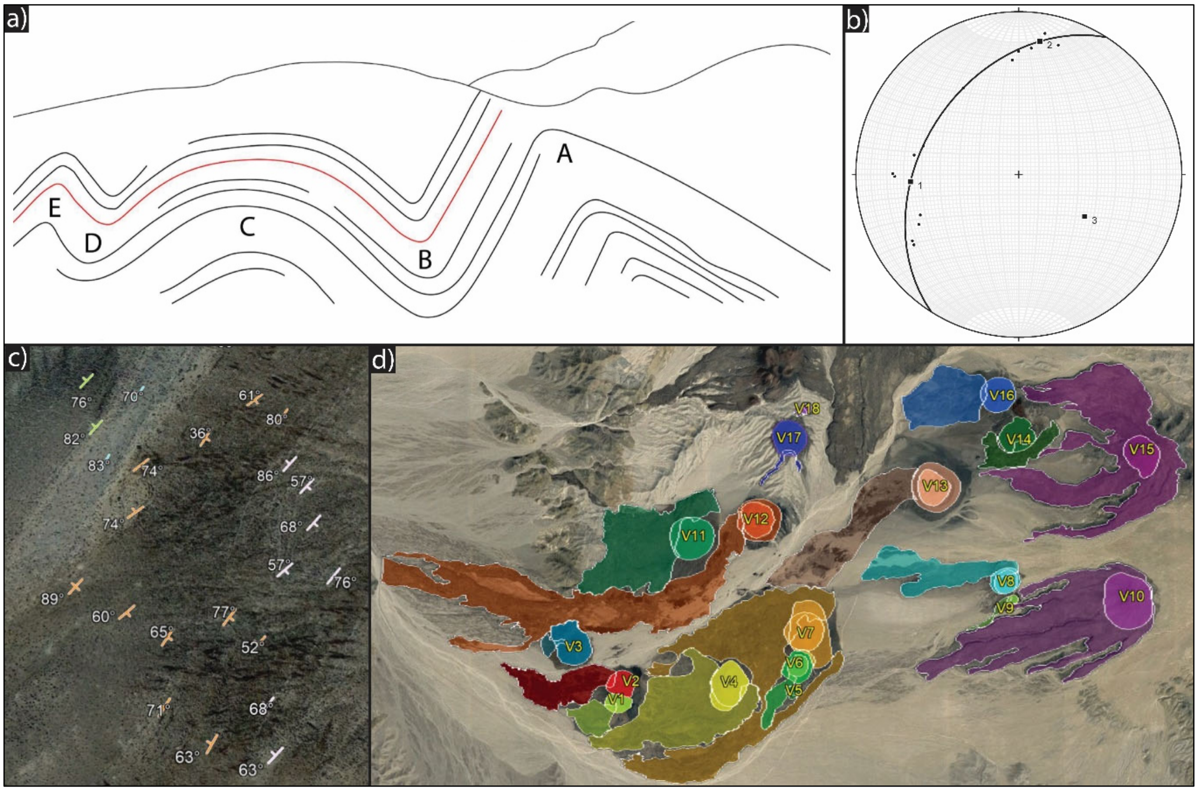

Figure 30: Examples of the types of deliverables and datasets that are used for the virtual field trips. a) Line drawing of a series of folds that was traced from a photo. b) Stereonet showing poles to bedding with a calculated cylindrical best fit fold axis. c) Georeferenced bedding orientations plotted in Google Earth. d) Geologic map of a portion of the Cima Volcanic Field made using Google Earth.

maps using Google Earth, examine photomicrographs of samples from the field areas, and so on (Figure 30d).

Field based exercises for Structural Geology

1) Structural analysis of the Monterey Formation at Ellwood and Hendry's Beaches

This virtual field exercise is designed to be an introduction on how to collect basic structural data in the field and use it to solve simple geologic problems. For the first part of the lab, students travel virtually to Ellwood Beach in Santa Barbara, California and are shown how to use a Brunton compass to collect bedding attitudes as well as how to calculate the thickness of a tilted stratigraphic section by constructing a simple map and cross section

(Figure 31a). The second part of the lab examines folds exposed in the wave cut terraces along Ellwood and Hendry's beaches. The field video includes various shots of the folds and discusses the types of structural data to collect and observations to make when working with folds in the field. Students are given real georeferenced datasets of bedding and fold axis orientations from the two field areas and tasked with 1) plotting the data on lower hemisphere stereographic projections (stereonets), 2) calculating fold axes from a cylindrical best fit to poles of folded bedding, 3) making simple geologic maps showing fold axis orientations and representative bedding attitudes, and 4) making a schematic cross section of one of the fold trains. By the end of this lab, students should be able to make observations in the field, collect basic structural data, calculate the true thickness of a tilted stratigraphic

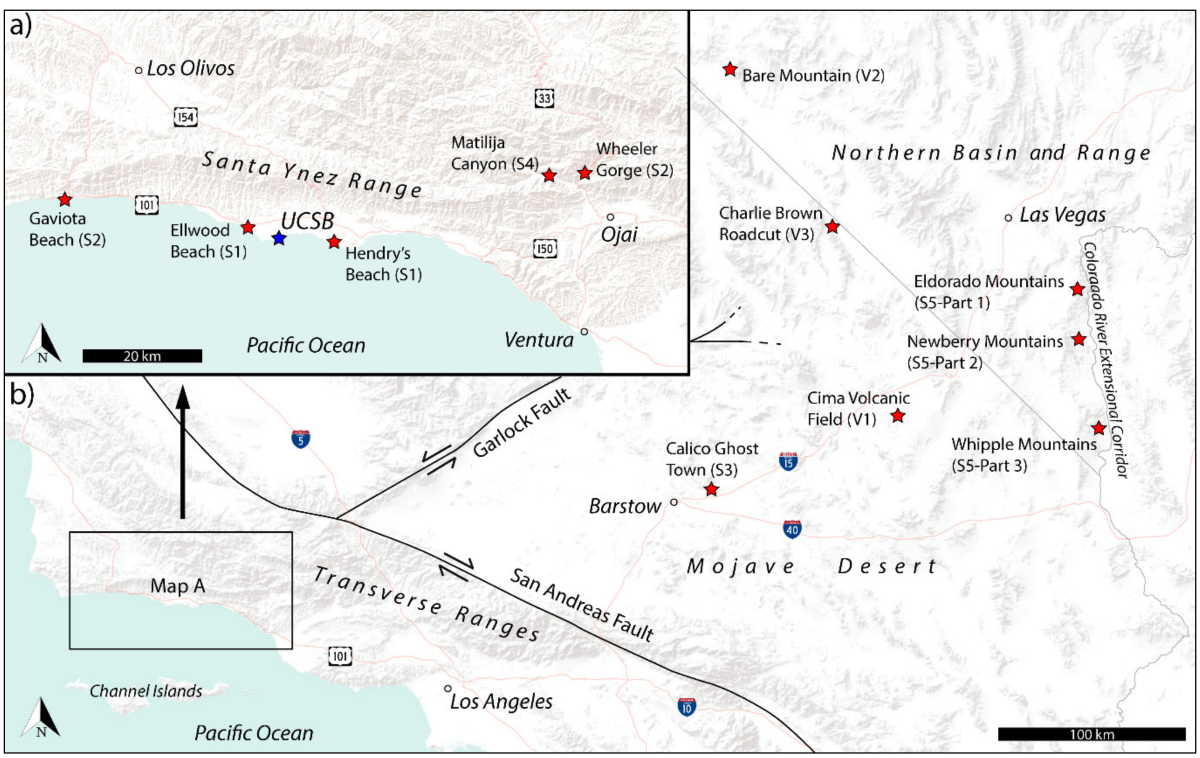

Figure 31: Maps showing the locations for each of the virtual field trips (red stars). Structure virtual field trips are labeled with (S-field trip number) and volcanology field trips are labeled with (V-field trip number). a) Map of the Santa Barbara area. b) Map of southeastern California and southern Nevada.

section, present structural data in stereonet format, calculate the orientation of a fold axis, and make a simple geologic map and cross section. The field video can be viewed at https://vimeo.com/664454133.

2) Analysis of joints in the Santa Ynez Range

This virtual field exercise investigates jointing in the Santa Ynez Range of the California Transverse Ranges and is designed to familiarize students with collecting joint data in the field and using this data to interpret joints in the context of a regional geologic framework. In the field video, students travel virtually to two localities in the Santa Ynez Range and are shown how to identify systematic joints, group them into distinct sets, collect their orientations, and interpret their relative ages (Figure 31a). The video also includes a brief tectonic history of the area and a discussion on how joints form and what they can tell us about paleo-stress fields. Students are given datasets of bedding and joint attitudes from the two localities and are tasked with 1) plotting the data in stereonets, 2) categorizing the joints into distinct sets, 3) rotating joint attitudes to determine their orientations prior to tilting of bedding and clockwise rotation of the range, 4) making an interpretation of the sequence of geologic events, and 5) writing a short report presenting their data and interpretations. The field video can be viewed at https://vimeo.com/670764679.

3) Structural analysis of folds near Calico Ghost Town, western Mojave Desert, CA

This virtual field exercise is focused on folds exposed near the Calico Ghost Town in the west-central Mojave Desert and teaches students the types of data to collect and observations to make when working with folds in the field and how to analyze and interpret this data (Figure 31b). The field video shows a number of outcrop scale folds with a variety of morphologies and discusses the terminology that can be used to fully describe them (fold axis and axial surface orientations, interlimb angle, hinge angularity, wavelength and amplitude), the types of structural data that can be collected, and how to calculate the amount of shortening. For the lab exercise, students are given high-resolution images of an exceptionally well exposed train of folds as well as datasets of bedding orientations around the fold hinges and are tasked with 1) providing a complete description of each fold using all the appropriate fold parameters terminology, 2) calculating fold axis and axial surface orientations using stereonets, 3) making a simple line drawing overlay of the folds to calculate the amount of shortening, 4) interpreting the kinematic mechanisms of folding, and 5) writing a short report summarizing their observations and interpretations. The field video can be viewed at https://vimeo.com/682563005.

4) Kinematic analysis of fault slip-data associated with the Santa Ynez Fault

This site exposes a plethora of variably oriented small-scale faults with beautifully developed slickenlines in a Cretaceous conglomerate adjacent to the left-lateral/reverse Santa Ynez Fault near Ojai, California (Figure 31a). The virtual field trip is designed to familiarize students with recognizing assorted features on fault surfaces and collecting various data from faults, including fault plane and slickenline orientations and sense of slip criteria (Riedel shears). They then analyze the data from a large number of small-scale faults in the area using the FaultKin program (Allmendinger, 2019), and make interpretations on fault kinematics to determine if the small-scale faults are related to the nearby much larger Santa Ynez Fault. The video introduces the regional geology of the area and the slip history of the Santa Ynez Fault, and shows how to identify faults and slickenlines in the field, measure their orientations, and interpret their senses of slip, and includes a short lecture on using FaultKin to perform a kinematic analysis of fault slip data. Students are given a dataset of fault plane and slickenline orientations and slip senses and tasked with making stereonet plots showing faults and striae, P and T axes, kinematic tensor axes, the best-fit fault plane solution, and tangent lineations. Students use these plots as figures in a geologic report that discusses the data and provides an interpretation on the kinematics of small-scale faulting at the site and how it relates to slip on the Santa Ynez Fault. The field video can be viewed at https://vimeo.com/672558015.

5) A virtual field trip through the lower Colorado River Extensional Corridor: Examining the interplay between magmatism and large magnitude extension in a failed continental rift

The Colorado River Extensional Corridor (CREC) is an area of large-magnitude extension along the California-Arizona border south of Las Vegas and is a world-class study site for investigations into extensional tectonics (Figure 31b). This three-part virtual field excursion to the CREC is designed to tie together many of the concepts covered throughout the structural geology course and apply them to a classic real world geologic/tectonic study area. The video consists of three parts ranging in length from 50 to 100 minutes and is mostly of a “show-and-tell” style. Some of the major topics covered include domino style rotational normal faulting, detachment faults and metamorphic core complexes, and the interplay between magmatism and extension in this failed continental rift. Not surprisingly, this wide-ranging virtual field excursion covers many additional topics, including tilted calderas, overturned unconformities, dike swarms and magmatic foliations as paleo stress and tilt indicators, and even what burros like to eat! Students are not required to complete any major projects or reports but instead must fill out a lengthy questionnaire while watching to ensure they are understanding the concepts and engaged in the geology. By the end of this virtual field trip, students should have an in depth understanding of the geology of the CREC, have seen a wide array of brittle and ductile structures in their regional geologic context, and be confident in applying their newly acquired knowledge of structural geology to solve complex geologic problems. Throughout this video, students are forced to think about how various structural and stratigraphic features observed at outcrop scale help inform and constrain the broad geologic context of Miocene extension and magmatism in this part of the Basin and Range. The field videos can be viewed at https://vimeo.com/680624227.

Field based exercises for Physical Volcanology

1) Deciphering eruptive products and eruptive histories in young monogenetic basaltic cinder cones and lava flows of the Cima Volcanic Field, Mojave National Preserve

This virtual field investigation is focused on the southern portion of the Cima Volcanic Field in the eastern Mojave Desert and is designed to familiarize students with mapping and interpreting the products and eruptive histories of small monogenetic basaltic eruptions (Figure 31b). Eleven short georeferenced videos from various key locations in the volcanic field provide insight to what the different types of deposits look like, how to assess the relative ages of different lava flows and which vents they are associated with. Students are directed to carefully synthesize the information provided by the videos and use the site specific information as “clues”, in conjunction with extensive analysis of Google Earth imagery at different magnifications and view obliquity to 1) make a geologic map of the various vents and associated lava flows, 2) estimate the volumes of erupted magma from each vent, 3) determine the relative ages of 18 different vents and associated lava flows, and 4) write a report summarizing the eruptive history of the volcanic field. By the end of this exercise, students should be able to identify the different types of vent facies explosive deposits and effusive basalt flows, identify different vents and assess which lava flows were derived from them, interpret flow directions, relative ages, and evolution of the landscape, estimate volumes of erupted magma, and produce a highly professional geologic report on the physical volcanology of a young basaltic cinder cone and lava field. The field videos can be viewed at https://vimeo.com/822486501.

2) Ignimbrites associated with large-scale caldera forming eruptions and their internal zoning, associated fall and surge deposits, and map relations: An examination of Miocene ignimbrites from the SW Nevada volcanic field, southern Bare Mountain, NV

The southwest Nevada volcanic field is a classic example of multiple nested large-scale silicic caldera systems in the Basin and Range Province, and the outflow sheets from these calderas provide outstanding exposures of the different types of zonation observed in ignimbrites (Figure 31b). This virtual field trip takes students on a transect through four ignimbrites exposed in a canyon in southern Bare Mountain/Yucca Mountain and is designed to familiarize them with the internal stratigraphy of large ignimbrites. The video walks the viewers systemically up-section through the stack of ignimbrites and provides detailed descriptions of each of the different welding, glass preservation/devitrification, vapor phase alteration, and compositional zones in each ignimbrite. This virtual transect helps students appreciate the considerable variations in color, texture and crystal content in a single ignimbrite and provides a conceptual basis for why these internal variations are observed. Students are given a suite of photomicrographs from the ignimbrites and are tasked with answering various questions about phenocryst assemblages, devitrification, vapor phase alteration, hydration, etc. By the end of this exercise students are familiar with the eruptive history of the southwestern Nevada volcanic field and are very comfortable identifying and describing the different internal zoning patterns of ignimbrites as well as identifying and discriminating other types of pyroclastic deposits. Specifically, students are shown excellent examples of fallout and surge deposits associated with each ignimbrite and learn to recognize the many compositional and textural features that distinguish these different types of pyroclastic deposits. The field video can be viewed at https://vimeo.com/807699601.

3) Geology of the Charlie Brown Roadcut, Resting Springs Range, CA: A virtual field trip and examination of Miocene silicic pyroclastic deposits and Basin-Range faulting in a roadcut along CA hwy. 178

The roadcut along the Charlie Brown Highway near Shoshone, California is an outstanding locality for looking at pyroclastic deposits and Basin and Range faulting and is a classic destination for geology field-trippers in the southwestern United States (Figure 31b). The fresh roadcut exposes a spectacular cross-sectional view of the Resting Spring ignimbrite, with its textbook zonation that would otherwise be covered with a thick coat of desert varnish. The ignimbrite buttresses against and is draped over an aesthetically pleasing normal fault scarp that cuts an older sequence of lakebed and pyroclastic deposits. This show-and-tell style virtual field trip teaches students how to describe ignimbrites, determine the sense of slip and amount of offset of faults, and reconstruct the geologic history of an area. The field video begins by introducing the general layout of the roadcut, describing the different types of volcanic deposits exposed and characterizing the faults cutting them. Throughout the video, the viewers are challenged to "see what's there" and to think carefully about what the various stratigraphic and structural relations exposed in this outcrop imply about the sequence of geologic events. It then zooms in to thin-section scale and discusses a suite of photomicrographs from the different zones within the ignimbrites, highlighting various key features of each zone. It ends by proposing a sequence of geologic events that emphasizes how to use objective (factual) field observations to reconstruct a plausible interpretive geologic history of this very intriguing area. This exposure is a classic little geologic puzzle and there are many subtle details that are overlooked by most geology groups that stop here. We anticipate that this video will be widely used by many different groups including introductory classes – not just physical volcanology classes. The field video can be viewed at https://vimeo.com/822390940.

Evaluation

Methods

To assess the efficacy of the virtual field trips, students from the 2022 Structural Geology class were asked to complete a short anonymous survey with eleven questions about their general impressions of the videos. This class was taught with a hybrid model, with the first field exercise being fully remote and the others being in-person but with the field videos used to prepare the students prior to going to the field or to solidify their understanding after returning from the trip. The survey was hosted using the online survey application SoGoSurvey and was given during the last week of class with all twenty-five students participating. It consisted of nine multiple choice and two short answer questions for more open-ended feedback. A shorter, more informal survey was given to the previous year's structural geology class that was fully remote but the volcanology class wasn't able to be surveyed.

Results

The results of the survey confirm that the students generally liked the field trip videos and thought they were effective at teaching them the skills and background (conceptual) material necessary for geologic fieldwork. The first three questions assessed their overall impression of the field videos as well as the quality of the video content and the filming and audio. The overwhelming majority of the students chose "excellent" for all three questions with 12-20% choosing "good" and none choosing neutral, bad or very bad (Figure 32a-c). It also appears that most of the students enjoyed watching the field videos more than a typical in-class lecture, with 64% agreeing with the statement, 28% feeling neutral and 8% disagreeing (Figure 32d). We believe that a big advantage of field videos is that they are more engaging and enjoyable to watch than a typical in-class lecture and this data supports this claim to an extent.

The next question assessed how effective the students thought the videos were at preparing them for collecting data and making observations during the in-person field exercises, and the majority of the students agreed with this statement, highlighting the videos' utility in being used in conjunction with in-person trips (Figure 32e). The majority of students also thought that watching the CREC video after returning from the in-person visit to the area helped solidify their understanding of the concepts learned while in the field

(Figure 32f). The hybrid model of combining in-person field trips with virtual field videos appears to be well received with the students with 96% either agreeing or strongly agreeing that it is an effective way of teaching field geology (Figure 32g).

The students' opinions of whether the field videos are an acceptable substitute for an in-person trip are much more mixed, with 36% disagreeing or strongly disagreeing with that statement (Figure 32h). This highlights that although these videos can be an effective way of teaching field geology to some extent, many students feel strongly that there is no good substitute for actually getting out into the field and interacting with the rocks directly.

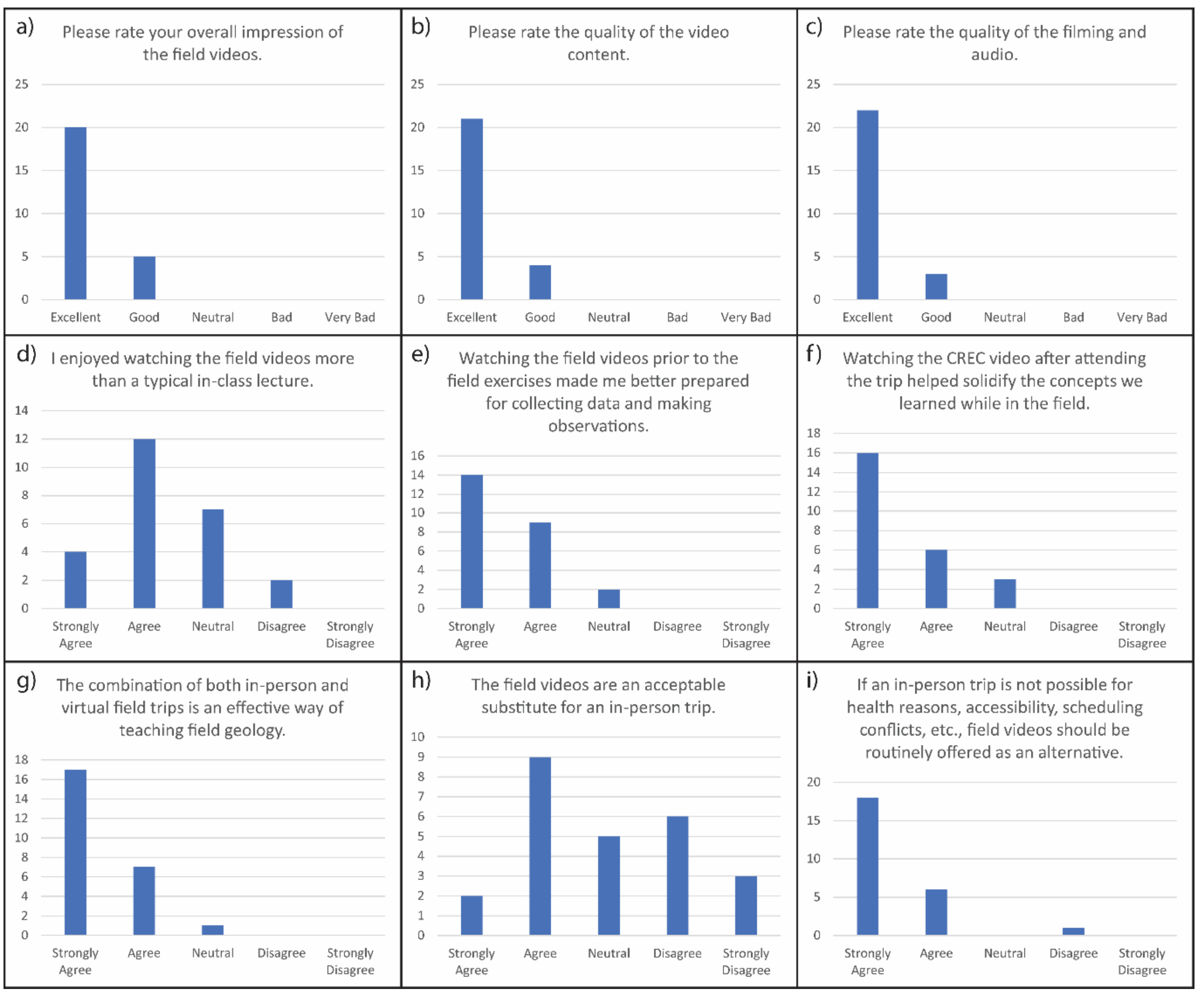

Figure 32: Responses from the survey given to the 2022 Structural Geology class to assess the efficacy of the virtual field trips.

However, the majority of the students do believe that if an in-person trip is not possible, field videos should be routinely offered as an alternative (Figure 32i). We believe that this is one of the biggest advantages and most important applications of these virtual field videos.

Perhaps the most important feedback that was received from the survey was from the two open ended questions. The first asked students what they liked about the field videos, and although there were a variety of responses there were a few common themes. Many students said that the ability to pause and rewind the videos was very helpful and allowed them to work at their own pace and take notes without rushing. The annotations and embedded figures were also viewed as being quite helpful at pointing out features and clarifying concepts, and is something that isn't possible with in-person trips. Students also enjoyed the variety of perspectives shown in the videos, especially the close-up shots of hand samples that pointed out the subtler features that can be easily missed. Many also noted that it was easier to pay attention to the content in the comfort of their home than while hot and tired in the field. The following response from one of the students summarizes much of the positive feedback that was received: "The videos were well produced and the content delivered was in-depth, well-structured and informative. These videos are not quite a full substitute for an in the field experience, but are extremely useful for a follow up to being out in the field. Being able to review the material covered in the field and being able to append notes taken in the field and reinforce concepts that might have not been quite solidified due to typical field work factors, like being hot or tired."

The second open ended question asked students what they thought could be improved with the virtual field trips. Many students thought some of the videos were too long at times and could be shortened a bit. We agree with this and believe the videos should be as short and concise as possible without sacrificing too much content. As we reviewed the videos ourselves we also felt that they are too long and chalked this up to the fact that they were made at the last minute (under severe time pressure) with almost no preparation, and no prior experience in making such videos. Besides that, the narrator tends to be fairly long winded, or at least his kids say so! Adding more timestamps to make navigating through the videos easier was another common recommendation, especially for the longer videos. Other feedback included adding more figures, annotations and diagrams, transcribing the videos to make it easier to take notes and get the correct spelling of terms, and adding an inset map in the corner to show the location of each field spot and possibly have an interactive map that could be opened in Google Earth. Perhaps the most notable critique was that although the students thought field videos were good, there is no real substitute for being out in the field. This is summarized well by a comment from one of the students: "Field videos are great for just conveying information or teaching a lesson in structure, but we obviously wouldn't have had the experience of what it is really like to do field geology. I think that taking field measurements/camping/hiking/seeing y'all cook in the field is an important component of a field class. That being said, the videos were notably high quality and very informative." We agree with this sentiment and believe that these videos are best used to augment in-person trips and only to fully replace them when absolutely necessary.

Limitations

Although the survey provided some informative feedback about the students' impressions of the field videos, there are some limitations to this dataset. Most importantly,