**Sage Hen Flat module: An introduction for students**

Authors

B. Tikoff & R. Williams (University of Wisconsin – Madison)

T. Shipley, C. Wilson, & K. Bateman (Temple University)

S. Morgan (University of Michigan – Dearborn)

M. de St. Blanquat (University of Toulouse, France)

Welcome to the Sage Hen flat module. Sage Hen flat is a real place in the White Mountains in eastern California. Many fieldcamps do go to this area, because there is a University of California field station on the north end of the field area. Also, the Bristlecone pines – the worlds’ oldest living species – thrives in the high elevations of the White Mountains. Two of the most commonly visited groves are about 5 miles south and 1 mile north of the field area. Hence, many of you will likely to visit this area at some point in your life.

What make this a particularly good exercise is that there are two published maps of the region that do not agree with each other: (1) Ernst and Hall (1987); and (2) Bilodeau and Nelson (1993). For this module, you already know that you have two good (published) models. The question becomes which of them is more correct, or is the best model some combination of the two. You will be given new datasets – that neither of the previous mapmakers had – in order to help you figure out a good model. Moreover, you are going to have to explicitly deal with uncertainty, because the two maps agree on neither the data nor the model.

This module came about because we were doing two simultaneous research projects at Sage Hen Flat. A small group of us had been working for an embarrassingly long time on the emplacement of the Jurassic Sage Hen flat pluton. It was interesting because it is a “cookie cutter” pluton; it does not appear to deform the surrounding wallrock at all (hence the analogy to a cookie shape taken out of a sheet of dough). It is unique among the plutons in the White-Inyo range for this behavior. The second research project involved an interdisciplinary project between cognitive scientists and geologists about how two groups of professionals could use the same information and come to two different conclusions. How does that happen? As a result of these two projects, we had both unpublished data and had thought through the process of what it means to be a professional geologist for this area. We hope that you will be able to use this information to learn the actual process of science, although you will be spared the tedium of actually collecting the data and will just use the results. The problem is real, the data is real, and the ambiguity is real.

We hope that this module gives you the insight of “how to think like a geologist”. In particular, here are some of the learning goals associated with this module:

1. Learn how to incorporate uncertainty into both observations and interpretations, realizing that no interpretation is certain.
2. Acceptance that published work is not “fact”, even if published by scientists with strong reputations.
3. Develop the ability to assess your uncertainty, as this is a direct result of your ability to work as an independent scientist.
4. Ability to provide evidence to support an interpretation or claim. The evidence itself has uncertainty and the interpretation necessarily has more uncertainty.
5. Get insight into the process of science as it is done by professionals.

You will generally be working with GoogleEarth, which is a great way of viewing the geology. You will need to download the desktop version to your computer and import a .kmz file. This activity is straightforward and described in the teaching materials. In this mountain range, much of the geology is clear when viewed on satellite images.

Here is one more point that is true about education in general, but even more true about distance learning: What you get out of it is proportional to what you put into it. The region is geologically fascinating, and good geologists have spent a career working on it. With a little curiosity, the field area contains a lot of enticement.

We hope you have fun and enjoy learning about this very interesting part of the world. We provide a schedule below, so you know what to expect each day.

**Fieldcamp schedule for Sage Hen Flat module, White Mountains, California**

**Day 1: Overview of White Mountains**

Activity 1: Pre-module assessment

Activity 2: Overview of this module

Activity 3: Optional reading assignment of **Cargo Cult Science** (with supplied reading guide)

Activity 4: **Video overviewing the White Mountains geology (video with Sven Morgan, University Michigan – Dearborn)**

Activity 5: Student-lead exploration of stratigraphy and overall geology of the White Mountains: Detailed examination of published geological maps (worksheet)

Activity 6: Using vegetation and color in GoogleEarth to determine rock type/stratigraphy (worksheet)

Activity 7: Developing a stratigraphic section of units in the field area (stratigraphic section)

At the end of the day, students turn in:

1. Quiz/Reading Guide
2. Worksheet on pre-Jurassic units and geology of White-Inyo mountains
3. A 1-page summary of geological history of White Mountains
4. Worksheet on GoogleEarth investigation of the field area
5. A stratigraphic section

Materials needed:

1. Pre-assessment of exercise
2. Overview of the White Mountains geology video
3. Worksheets

**Day 2: Data uncertainty and Sage Hen Flat pluton**

Activity 1: **Powerpoint overviewing granitic fabrics**

Activity 2: **Data uncertainty module**: Instructor-led or student self-directed powerpoint about data uncertainty

Activity 3a: Student-lead exploration of granitic AMS fabrics in the Sage Hen Flat pluton, including using Google Earth to plot granitic fabrics in Sage Hen Flat. Role of dispersion.

Activity 3b: Student-lead exploration of mineralogy of Sage Hen Flat pluton, including using Google Earth to understand granitic fabrics in Sage Hen Flat. Role of interpolation.

Activity 3c: Student-lead exploration of microstructures of Sage Hen Flat pluton, including using Google Earth to understand granitic fabrics in Sage Hen Flat. Role of interpretation/inference & interpretation.

Activity 4: Student activity: Making a schematic cross section through Sage Hen Flat pluton (pluton only) using fabric, mineralogy, and microstructure data

At the end of the day, students turn in:

1. Cross-section through Sage Hen Flat (pluton only)

Materials needed:

1. Overview of granitic fabrics (field and microstructure) video
2. Data uncertainty module powerpoint

<https://docs.google.com/presentation/d/1Chtcrj5gxQRdm_UNQkzCtBNVqBSRwlh_ZwxPp9M4tAY/edit?usp=sharing>

1. Transition to AMS data powerpoint
2. Google Earth dataset with orientations
3. Template/Instructions for cross-sections through plutonic bodies

**Day 3: Model uncertainty and western contact of Sage Hen Flat pluton**

Activity 1: **Model uncertainty module**: Instructor-led or student self-directed powerpoint about model uncertainty

Activity 2: Self-evaluation of each student’s cross-section through Sage Hen Flat pluton

Activity 3: Using uncertainty in workflow. Exploring western ridge (GoogleEarth). Students work in small groups. Give examples of the use of interpretational uncertainty.

Activity 4: Evaluation of model uncertainty for B&N map & E&H map on the western contact of the Sage Hen flat pluton

Activity 5: Student activity: Make a geological map of the western contact of Sage Hen Flat pluton

Students produce:

1. Evaluation of cross-section through Sage Hen Flat pluton
2. Worksheet of uncertainty in the field
3. Worksheet for evaluation of B&N vs E&H geological map
4. A geological map with contacts in the western field area

Materials needed:

1. Digital copies of two published maps of Sage Hen Flat
2. Model uncertainty powerpoint

<https://docs.google.com/presentation/d/1RU2PHXFQkreJK8VqYoWbxit4zHhYgcWp28skArUbCEQ/edit?usp=sharing>

1. Google Earth dataset with orientations
2. Digital copies of two published maps of Sage Hen Flat
3. Blank map of western area for students

**Day 4: Gravity data and inversion model of Sage Hen Flat pluton**

Activity 1: Powerpoint overviewing gravity data

Activity 2: Instructor-led discussion of uncertainties of gravity data

Activity 3: Individual. Make “sketch” cross sections of the Sage Hen flat pluton and answer questions.

Activity 4: Student working in small groups: Creating structure contour maps for the lower contact of Sage Hen flat pluton.

Activity 5: Individual: Making a cross section through Sage Hen flat with correct pluton geometry.

Materials needed:

1. Powerpoint
2. Guided questions
3. Bilodeau and Nelson (1993) map.

Students produce:

1. Two “sketch” diagrams of NS and EW cross sections through Sage Hen Flat pluton.
2. Guided work through Sage Hen Flat gravity inversion (comparison to other data sets)
3. Structure contour maps for the lower contact of Sage Hen flat
4. Detailed cross-section through the field area

**Day 5: Normal faulting within and adjacent to the Sage Hen Flat pluton (optional)**

Activity 1: View powerpoint about faults in the area.

Acitivity 2: Students work in small groups. Using GoogleEarth, explore Tres Plumas area to N of Sage Hen Flat, where there are Neogene basalt flows. Compare faulting in basalts vs faulting in granite, for assessment of uncertain of faults in different rock types.

Activity 3: Students work in small groups. Using the criteria developed for the Tres Plumas area, apply the same logic to the possible locations of faults around Sage Hen Flat. Evaluate the proposed fault, and provide evidence for the location and extent of the faults. For each fault, propose an uncertainty ranking.

Activity 4: Individual. Constrain the timing of the faults (if present). Are all there only normal faults? If so, are they all associated with Basin and Range extension? Are there older, pre-existing faults?

Activity 5: Individual. Make a cross-section across the entire B-B’ line of Bilodeau and Nelson. Use all available data. This will be the final cross-section for this project.

Materials needed:

1. Powerpoint
2. GoogleEarth maps of proposed faults near Sage Hen flat
3. USGS geological maps of Mt Barcroft and Blanco Mountain
4. Bilodeau & Nelson (1993); Ernst & Hall (1987) geological maps

Students produce:

1. Evaluation of each proposed fault near Sage Hen flat
2. A tectonic history of faulting in the Sage Hen flat area
3. A cross-section through Sage Hen flat area, with faults if appropriate

**Day 6: Write-up of results**

Activity 1: Individuals create cross sections and final map

Activity 2: Individuals write up a page on tectonic history

Activity 3: Individuals write up a report on the two published interpretations and their own interpretation. Evidence is cited for the different models. Criteria are outlined to distinguish favored hypotheses. (This is similar to a discussion section of a published geology paper.)

Activity 4: Post-module assessment

Materials needed:

1. Clean sheets for maps
2. Topographic profile
3. Post-module assessment

Students produce:

1. Geological map of the Sage Hen flat area (the extent of B&N map)
2. Cross sections through the Sage Hen flat area (the extent of B&N map)
3. A 2 page tectonic history
4. A 3-6 page report (in addition to the tectonic history) that explicitly provides comparison of maps. Cite evidence and use uncertainty. Report must include report of positive and negative attributes of all discussed models.
5. References list. This includes all materials used in writing the report, including maps. Use the GSA format for references.