Chapter 1

INTRODUCTION

One of the most fundamental goals of geological science is the identification and temporal organization of natural events that define the history of the Earth. While radioactive dating is a reliable method for determining ages of some terrestrial material, the required minerals and/or rock types are not always conveniently present. This has motivated the discovery of other methods, such as those based on tectonic subsidence of the crust of the Earth, for measuring geologic time. Another fundamental goal in geoscience is reconstruction of crustal movement. Many independent methods have allowed us to determine the motion of tectonic plates, which is nearly imperceptible on timescales relative to the human experience. Of great interest to Earth scientists are measurements of fault motion that has accumulated over geologic timescales, as well as other processes that have shaped the landscape.

The geographic locations of the study areas in this thesis are all located in Nevada and southern California, but the research covers a variety of geologic settings. During the Ediacaran period, siliciclastic and carbonate sediments accumulated on a thermally subsiding passive margin on the equatorial coast of Laurentia; these sediments are now the lithified and tilted strata of the Johnnie Formation in Nevada. Sometime during the early Pliocene to Micoene, regional tectonic deformation triggered the inception of many distinct right-lateral faults, including the active Lavic Lake fault, in what is now the eastern California shear zone. Finally, geomorphic surfaces continue to develop due to San Andreas fault motion, coupled with the warm and arid environment of the Coachella Valley in southern California. A diversity of time periods and tectonic activity were considered in this compilation of projects.

In Chapter II of this thesis, we used tectonic subsidence modeling to investigate the specific timing and duration of a globally-recognized chemostratigraphic anomaly: the Shuram carbon isotope excursion. The Shuram excursion is an extreme deviation in the ratio of ^{13}C to ^{12}C found in carbonate rocks. Metabolic pathways involve mass-dependent fraction of carbon isotopes, so it is possible that the excursion signals an event that influenced the evolution of animals. While not well dated, the excursion is present in the Ediacaran Johnnie Formation, a section of siliciclastic and carbonate rocks located in southern Nevada and California. At the Johnnie Formation type locality near Pahrump, Nevada, we performed detailed field mapping and stratigraphic measurements. On carbonate rocks that we sampled, we performed carbon and oxygen isotope fraction measurements, which allowed us to correlate the chemostratigraphy of the Johnnie Formation with sub-Shuram-excursion chemostratigraphic profiles from the Khufai Formation in Oman. While the correlation in itself did not yield an age for the Shuram excursion, the correlation helped us bracket the age of the Shuram excursion within Johnnie Formation to somewhere between 600-550 Ma. We then combined the stratigraphic thickness we measured for the Johnnie Formation with the thicknesses of overlying formations (some of which have been dated) that span through end Devonian time. With the complete stratigraphic thickness, and some known ages at specific stratigraphic positions in overlying formations, we constructed a tectonic subsidence model for this ancient passive margin environment. We used this model to extrapolate ages for stratigraphic positions within the Johnnie Formation, and other key Ediacaran horizons of unknown age in the section. We found that the Shuram excursion within the Johnnie

Formation occurred from 585-579 Ma, and that incision of the Rainstorm Member shelf occurred during the 579 Ma Gaskiers glaciation.

In Chapter III, we combined fieldwork with thermal hyperspectral airborne remote sensing imagery to investigate the long term cumulative slip of the Lavic Lake fault in eastern California. The Lavic Lake fault ruptured in the 1999 Mw 7.1 Hector Mine earthquake with >5 m of coseismic right-lateral slip, but the long-term bedrock offset is not well-defined. While the Lavic Lake fault is located on military-restricted government land, we gained access in 2012 and 2014 to collect new field data. The field lithologic samples we collected, in addition to field photographs, served as ground truth for geologic maps we produced using supervised and unsupervised classifications of airborne remote sensing imagery. We also incorporated data from older geologic maps of the same area into our analysis. In comparing our classification maps with older geologic maps, we discovered a boundary between units in our supervised classification map that correlated with a lithologic contact from the older map. This lithologic contact is cut and displaced by the Lavic Lake fault, and there is also an older cross fault that is cut and displaced by the Lavic Lake fault: we used these two displaced features to measure the vertical and horizontal components of the slip vector. The net fault slip of the Lavic Lake fault is 960 +70/-40 m, which is significantly less than a previous estimate of cumulative offset that was based on an offset magnetic gradient. The disparity between our measurement and the displaced magnetic gradient can be at least partially explained by off-fault deformation along proximal smaller structures, as well as the unknown depth and nature of the source of the magnetic contrast. Our cumulative displacement can be combined with bedrock ages to calculate the Lavic Lake fault's geologic slip rate, and it can also be included in a tectonic reconstruction of the eastern California shear zone.

Chapter IV of this thesis is about a potential new method for the relative dating of Quaternary geomorphic surfaces. The development of features that increase with time, such as desert varnish coatings and smoothed topography known as desert pavement, are characteristic to many geomorphic surfaces. We used thermal hyperspectral airborne remote sensing imagery of geomorphic surfaces to investigate a spectral feature at 9.16 μm with band depth that generally increases with surface age. The 9.16 μm feature is indicative of clay minerals, which can be found in abundance in desert varnish. Supplemental field data show that desert varnish and desert pavement scores (where a higher score is given to more advanced development), as well as vegetation spacing estimates, all correlate positively with surface age. In ground-based lithologic spectra that we collected, an absorption feature at 9.2-9.4 μm is also indicative of clay minerals, albeit at a slightly different position than that for the airborne data. All of the spectra indicate a mineral mixture that includes clay, quartz, and feldspars. Furthermore, ground-based vegetation spectra are generally flat and featureless: this could be why sparse vegetation correlates with increased spectral contrast in the airborne data. Taking everything into consideration, the positive correlation between surface age and spectral contrast in airborne spectra can perhaps be used for relative dating of varnished Quaternary geomorphic surfaces with desert varnish and desert pavement.

While the individual chapters of this thesis cover disparate topics, the driving motivation in each is related to quantifying geologic time and/or tectonic displacement. Moreover, each chapter is a complete study, offering a unique contribution to the breadth of knowledge that we use to tell the story of the Earth.