
NATURAL
SCIENCE.

BRAIN CLOCKS & DENDRITIC SPINE MORPHOLOGY

Will Stritzel

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ABSTRACT

Daily cycles in behavior and physiology, called circadian rhythms, have profound effects on health and well-being. Circadian rhythms emerging from local molecular clocks in the prefrontal cortex regulate learning and memory. My goal in this study was to determine if genetically encoded fluorescent proteins can produce sufficient signal in dendritic arbors and spines to measure and characterize dendritic spines accurately and reliably. I also aimed to link dendritic spine morphology with time-of-day differences in the learning and recall of cued conditioned fear extinction. Neurons were labeled using an intersectional viral strategy, and dendritic segments were imaged using confocal microscopy. Apical dendritic segments and spines were analyzed with Imaris image analysis software. My results show that fluorescent protein signals can indeed be used to measure dendritic spines in select cases. In addition, the data suggest that circadian rhythms in fear extinction behavior may be driven, in part, by time-of-day differences in distal apical dendritic spine density. My work provides evidence that dendritic spine analysis can be accomplished using widely available transgenic techniques and points to one mechanism by which circadian rhythms regulate extinction behavior.

LAY SUMMARY

Circadian rhythms are daily patterns in behavior and physiology. The timing of when to sleep, eat, exercise, and many more behaviors, is mediated by circadian rhythms in the body and brain. Dysregulation of circadian rhythms has been associated with many mental and physical health risks including heart disease, metabolic disruption, depression, and anxiety. Our lab studies the effects that circadian rhythms in the brain have on emotional learning and memory. In this experiment, we studied extinction learning: a process where repeated exposure to cues associated with a fearful memory in a safe context decreases the fear response elicited by exposure to those cues. Our lab has shown that this type of learning is superior during the active phase than during the inactive phase. The aim of this project was to identify a potential mechanism by which superior extinction learning occurs during the active phase. Neurons primarily send signals to one another through features called synapses. Synapses are tiny gaps between the axon terminal of one neuron and the dendritic spine of another. The number and structure of dendritic spines on a neuron can dramatically affect its activity. My research suggests that superior active-phase extinction learning may be due to the greater density of long thin dendritic spines during the active phase than during the inactive phase.

INTRODUCTION OF A LIN-65 MUTATION INTO A C. ELEGANS TRANSGENIC REPORTER STRAIN AND ITS EFFECT ON HPL-2 LOCALIZATION

Zuhair Chaudhry

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ABSTRACT

Current theory suggests that repeat noncoding intracellular element transcripts (RE transcripts) lead to excess levels of double stranded RNA (dsRNA) and could play a part in the development of neurodegenerative diseases. These RE transcripts could activate immune responses leading to neuroinflammation often seen in neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS). Two genes correlated with transcriptional regulation in Caenorhabditis elegans are HPL-2 and LIN-65. Since both genes have been linked to transcriptional regulation, here we investigate if these two genes interact with each other. What we found was that deletion of LIN-65 did not affect HPL-2 localization; however, further studies need to be performed to see if this is true.

SIMULATION OF ELECTRON DRIFT PROPERTIES AND TRACK RECONSTRUCTION FOR THE DEEP UNDERGROUND NEUTRINO EXPERIMENT

Aaron Mutchler

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ABSTRACT

The Deep Underground Neutrino Experiment (DUNE) is a new cutting-edge experiment that will be fundamental in the study of neutrino oscillations and physics beyond the standard model. DUNE will be the flagship neutrino experiment, with the longest neutrino beamline of 1300 kilometers, using state-of-the-art near and far detectors to measure neutrino flavor at the start and end of the beam. In the near detector hall, DUNE will implement a High Pressure Gaseous Argon Time Projection Chamber (HPgTPC). A crucial step in studying oscillations is understanding the flux of neutrinos and their interaction crosssections in the near detector. Neutrinos will interact with the argon and produce charged particles, which liberate electrons that drift across the HPgTPC. To extract the necessary information about neutrino interactions, details of the drift electrons must be known, such as the drift velocity, diffusion, and attachment. For this thesis, I will simulate electron drift properties in DUNE's HPgTPC. Using the new PyBoltz simulation code, I determine the allowed region of operation for the HPgTPC. With this, I will further study how changes to the electron drift properties, namely the diffusion, will impact the reconstruction efficiency of muon tracks through GArSoft simulation.

LAY SUMMARY

The Deep Underground Neutrino Experiment (DUNE) is a new cutting-edge experiment that will be fundamental in the study of neutrino oscillations and physics beyond the standard model. DUNE will be the flagship neutrino experiment, using state-of-the-art near and far detectors to measure neutrino flavor at two separate points. A crucial step in studying oscillations is understanding the flow rate of neutrinos and how they interact in DUNE's detectors. In the near detector, neutrinos will interact with a gas composed of argon and methane producing charged particles. Those charged particles will free electrons in the detector which we can easily detect. We then use properties of those produced particles to extract the necessary information about neutrino interactions. In order to extrapolate these details, information about the newly produced particles in the detector must be known. This includes 'drift properties' about how the freed electrons move through the detector until they are detected. In this thesis I simulate these electron drift properties in DUNE's near detector. In doing so I set bounds on the detector's operation parameters. I then investigate how altering one of the drift property parameters impacts the detector's ability to reconstruct the interaction event and particle trajectories.

FUNDAMENTAL STUDIES OF A-KETO ACIDS AT THE AIR-WATER INTERFACE AND THEIR IMPLICATION ON ATMOSPHERIC AEROSOLS

Brianna Hopper

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ABSTRACT

The focus of this thesis is surface area isotherms obtained using a Langmuir-Blodget trough which are used to qualitatively determine surface partitioning and, in some cases, surface orientation. Though the results and discussion are placed within the context of aerosols, this thesis can exploit the flat surface of a Langmuir-Blodget trough due to the relative size difference of an aerosol and individual molecule. To better understand the behavior of the above atmospherically relevant organics, surface partitioning was studied as a function of concentration, nonpolar chain length, polar head group, state of ionization, and photochemical processing. In addition, UV absorption spectra are presented for lactic acid and sodium lactate, molecules which are photoactive at wavelengths outside the actinic spectrum but whose absorption spectra have not been well-documented in the literature.

SYNERGISTIC POTENTIAL OF COMBINING EMERGING THERAPIES FOR POST-TRAUMATIC STRESS DISORDER

Richard Sangmin Park

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ABSTRACT

Post-traumatic stress disorder (PTSD) is a complex, multi-faceted psychological disorder involving dysregulation of systems that govern stress and immune response, and affecting civilians and military personnel alike. An increased prevalence of PTSD and an incomplete understanding of its underlying mechanisms makes treating, and even diagnosing PTSD challenging. Diagnostic criteria for PTSD are in flux due to the ambiguity surrounding this disorder. This literature synthesis presents a comprehensive overview of the current treatment options for PTSD to identify common targets and synergies (potent multiplicative benefits rather than merely additive effects). This insight is then used to suggest combinations of synergistically acting components for use in novel integrative therapies. Chronic inflammation, resulting from dysfunction of the immune system, is identified as a defining characteristic in PTSD patients and a target of multiple external modulators. These modulators of the immune response include dietary factors as well as many other aspects of lifestyle. For example, omega-3 fatty acids and antioxidants such as Vitamin E can mitigate chronic inflammation and the associated dysregulation of the hypothalamic pituitary adrenal axis. Other novel therapies like trauma sensitive yoga, cannabinoids, therapy dogs, virtual reality exposure, electroacupuncture, probiotics to promote a healthy gut microbiota, exercise, and pharmacology can also be linked to immune-modulatory effects and may thus contribute further to synergistic benefits when used in conjunction with other immune-modulatory therapies. This literature synthesis suggests that a combination of multiple therapies, medications, and lifestyle management has the potential to exert multiplicative benefits in restoring balanced immune and stress responses and thereby treat PTSD. Furthermore, suggestions are formulated for further research and development which is necessary to fully realize the untapped potential clinicians and medical professionals can use to better diagnose and treat PTSD.

LAY SUMMARY

Post-traumatic stress disorder (PTSD) is a debilitating mental health condition that affects millions of people worldwide. This psychiatric disorder has comorbidity with other disorders like eating disorders, major depressive disorder, sleep disorder, and suicidal ideation, to name a few. This mental health condition is triggered by a severely traumatic event, which can range from a near-death experience to cases of sexual assault. What makes PTSD one of the most difficult disorders to diagnose is due to the fact that things that are perceived as a traumatic event vary considerably from person to person. One common misconception held by the public was that only service-members in the armed forces developed PTSD, but this condition affects both military personnel and civilians alike. It involves dysregulation of physical and mental systems within our bodies designed to deal with stress. An increased prevalence of PTSD and an incomplete understanding of its underlying mechanisms makes treating, and even diagnosing, PTSD challenging. As a result, this literature synthesis is aimed to give a comprehensive overview of the current treatment options available for patients suffering from PTSD and discusses what common targets these treatments are used for. From there, the literature synthesis uses these common targets to suggest combinations of different treatment options which could offer a multiplicative effect on a patient's treatment regime. It combines different therapies, medications, and lifestyle management choices to help restore a balanced immune and stress response, thereby treating PTSD.

CHANGES IN MEDIAL GASTROCNEMIUS ACTIVITY UNDER DIFFERENT SENSORY CONDITIONS WHEN DANCERS PERFORM A BALANCE TASK

Amy Megan Malacalza

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ABSTRACT

The medial gastrocnemius, an important calf muscle, plays a role when dancers seek to maintain balance. In order to balance, the somatosensory, visual, and vestibular systems work in conjunction to control muscle activity. The activation of skeletal muscles can be recorded with high-density surface electromyography, which allows for a dynamic assessment of the amplitude of the muscle activity in millivolts through calculating the root mean square (RMS) of the signal. The purpose of the study was to measure medial gastrocnemius activity in dancers during single-leg balance when standing on either a foam surface with eyes open or a rigid surface with eyes closed. The data and methods drew from a study by Davis et al. (2021) and provided the basis for this research. Nineteen participants with dance experience performed the single-leg balance tests and the data were pooled from before and after a 4-week exercise intervention. The results revealed significantly higher medial gastrocnemius activity during single-leg balance on the rigid surface with eyes closed as compared to the foam surface with eyes open, when measured as both monopolar ($p = 2.98x10\text{-}06$) and single differential ($p = 0.003$) RMS amplitude. The results demonstrated the influence of visual feedback on calf muscle activity in dancers when performing different types of single-leg balance activities.

LAY SUMMARY

Dancers continually experience challenges to balance that require muscle activity controlled by the brain, which uses somatosensory, visual, and vestibular systems. The medial gastrocnemius, an important calf muscle, plays a role in balance for dancers and its muscle activity was evaluated in this study through high-density surface electromyography (EMG). Dancers perform on a variety of surfaces with little known about how surface influences muscle activity. Furthermore, to the best of our knowledge, there have not been studies using the more advanced method of high-density surface EMG in the setting of single-leg balance in different surfaces. Therefore, the purpose of this study was to use this method to measure activity of the medial gastrocnemius when dancers perform a single-leg balance on a rigid surface with eyes closed versus a foam surface with eyes open with the data and methods drawing from a study by Davis et al. (2021). Participants were found to have significantly higher medial gastrocnemius activity during single-leg balance on the rigid surface with eyes closed as compared to the foam surface with eyes open. These results demonstrated the influence of visual feedback on calf muscle activity during single-leg balance, indicating dancers have greater activation of the medial gastrocnemius with their eyes closed rather than open.

RADIATION PRESSURE INSTABILITY DRIVEN ERUPTIONS IN LOW MASS X-RAY BINARY DISKS

Eleanor Gentry

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ABSTRACT

Low-mass X-ray binary (LMXB) systems comprise a compact object (a neutron star or stellar-mass black hole), a main sequence star and an accretion disk. The accretion disk forms as the more compact object's gravity pulls mass from the secondary star (see Figure 1). Some LMXB accretion disks go through cycles of eruptions in which the luminosity increases rapidly. This project analyzes these eruptions numerically to study the mechanisms that cause and affect the eruptions, and uses that analysis to explain observational phenomena in LMXBs.

In the following, we first review the observational background for this project (Section 2). Next, we discuss the fundamentals of accretion theory (Section 3) and the specific instabilities thought to be in our system (Section 4). We then discuss the framework of our specific model as well as the numerical methods used (Section 5). Finally, we present results from a series of simulations (Section 6) and the conclusions made from those results (Section 7).

LAY SUMMARY

Low mass X-ray binary (LMXB) systems are binary systems with a compact object like a black hole or a neutron star at the center, and a secondary solar-type star. The accretion disk between these two objects accretes matter from the secondary star onto the compact object. This project investigates the role of the radiation pressure instability in the thermal evolution of LMXBs. The disk will go through cycles of increased luminosity over time, during which the frequency of emission from LMXBs also changes. In order to understand the role of the radiation pressure instability, which develops in the accretion disk very close to the compact object, we focus on running a simulation in the inner part of the accretion disk. We study two types of disk: strongly magnetized disks and weakly magnetized disks.

We find that for strongly magnetized disks, higher rates of mass flow through the disk are needed than for weakly magnetized disks to observe the radiation pressure instability. The higher accretion rate is needed because a strongly magnetized disk is colder than a weakly magnetized disk for a same accretion rate, so it will not reach the thermal regime necessary to have radiation pressure dominate over gas pressure in the disk. Hence if the inner parts of LMXBs are strongly magnetized, LMXBs may never reach the regime where the radiation pressure instability dominates and the radiation pressure instability may not play a role in the evolution of the disk.

MAPPING THE MANCOS SHALE BADLANDS IN CAINEVILLE, UTAH USING HISTORIC AERIAL IMAGERY

Keely Lawrence

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ABSTRACT

Recent advances in remote sensing capabilities have created opportunities for us to observe and analyze landscapes in ways that were not feasible before using aerial imagery. By obtaining high-resolution aerial imagery of a region, three-dimensional landscape models can be generated using Structure from Motion (SfM) photogrammetry. These landscape models can be used for a variety of applications, but, of particular interest, they can be used to observe geomorphic changes that a region undergoes over time. To analyze erosional processes within a specific region, it is often more useful to us to be able to view localized small-scale landscape changes through the recent past. A limitation we encounter in this query is that SfM photogrammetry software is optimized for building models with modern digital imagery. Further limitations arise in accessibility of necessary data, such as a lack of quantity or quality of historic aerial imagery for an area, a lack of in-situ GPS measurements to aid in the geo-rectifying process, or a lack of modern digital aerial imagery to serve as a reference. In this study, my objective is to test whether it is possible to generate coherent three-dimensional models from historic imagery dating back as far as the 1950s with SfM photogrammetry and access to limited data. I have selected the Mancos Shale badlands in Caineville, Utah as a remote field site based on its unique landscape, lack of vegetation, and previously documented erosion rates from an in-situ experiment. As data, I use historic aerial imagery from 1954 and 2001 and positional information obtained from Google Earth Pro. Using Agisoft Metashape Pro to perform photogrammetric processing, I successfully generate two three-dimensional models, one for each historic landscape. To further experiment, I see if it is possible to geo-rectify the image sets sufficiently well by differencing the models using the open source software CloudCompare and conclude that access to more data, such as in-situ position measurements, may be required for success in future experiments.

LAY SUMMARY

Rare earth elements (REE) are materials that are important in many of today's complex technologies, including those we use every day, such as cell phones and computers. However, they can be difficult to find and only occur in commercially viable concentrations in a few places on Earth. In this thesis, two occurrences of igneous rocks, located about one kilometer apart in the Front Range of Colorado, each containing some of the same unique REE-rich minerals are studied and compared, in part, to help contribute to a better understanding of how these minerals form and where they can be found in the future. A combination of analytical techniques is used to gather critically important information about these rocks, including their mineral assemblage, chemical makeup, age, and spatial and genetic relationship to the older, surrounding rocks in which they have intruded, as well as their relationship to each other. These methods show that these occurrences are the same age, genetically related and, at some point in their emplacement, split from one another and evolved differently. This created two sets of very rare rocks that share many similarities but also contain some key differences that require continued study. The need for economically viable REE-rich minerals will continue to grow and the study of geological occurrences such as those in this thesis is an important part of furthering our knowledge and understanding of how they form and where to find them.

ASSESING THE PERFORMANCE OF HELIANTHUS ANNUS IN URBAN COMMUNITES

Roy Rutherford

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ABSTRACT

Global urbanization and habitat fragmentation continues to endanger ecosystem sustainability and biodiversity worldwide. The loss of biodiversity and habitat drives extinctions, hinders ecosystem services, and reduces ecological productivity necessary for long-term sustainability. While urban environments can impose both novel and intense ecological stress, many species are preadapted to thrive in urban settings. Better understanding the resilience and the evolutionary trajectories of urban plant species could inform future environmentally-considerate land use. Helianthus annuus (common sunflower) is a native species that thrives in disturbed habitats and is also capable of providing mediatory services to its surrounding environment. To assess the performance of H. annuus in various habitats along the Colorado Front Range, several fitness-related traits, as indicators of potential fitness performance, were observed for relationships with various anthropogenically-driven environmental impacts (AEIs). Significant but weak-to-moderate correlations and positive relationships were found for most size and quantity-related traits when compared to the number of seeds per individual, suggesting that potential fitness can be indicated by trait values of larger sizes. Additionally significant positive relationships of weak-to-moderate correlation strength were observed between fitness-related traits and greater amounts of AEI intensity, suggesting that H. annuus has higher potential fitness in heavily urbanized habitats. Further investigating common sunflowers' adaptations to urban environments could position H. annuus as a partner for environmental remediation in urban habitats.

LAY SUMMARY

Global urbanization and land development continues to threaten natural areas and the species that call these areas home. While transformed and now urbanized areas may no longer be the home many species were accustomed to, some seem to thrive in urban settings. Urban environments represent a novel habitat for many and are heavily fragmented in terms of available habitat and available, hospitable habitat. Though a complex and dangerous mosaic of habitat for some, urban environments can be advantageous for others. Helianthus annuus (common sunflower) is a flowering plant that can be seen at home along urban roadsides, sidewalks, and near other human-made structures, taking full advantage of growing areas that other plants could not hope to survive in. Sunflowers not only thrive in urban environments, but can provide remedial services to their surrounding soils and ecosystems, improving soil health, removing soil toxins, and keeping invasive species at bay. The goal of this project was to assess H. annuus' reproductive potential in urban and natural environments as prospective partners in urban conservation and land use. We found that traits related to reproductive success (number of seeds, flower buds, number of leaves, and plant height) seemed to benefit in environments with more human-made disturbance. Sunflowers growing closer to roads and sidewalks tended to be taller and produce more seeds on average when compared to individuals growing in less disturbed habitat. Further investigating the sunflowers' urban success could be informative for future urban conservation and environmentally-conscious land use.

TO BREAK OR NOT TO BREAK, THAT IS THE QUESTION: INDUCING DNA DAMAGE IN THE T. THERMOPHILA GENE TTHERM_00459400 RESULTS IN POSSIBLE INCREASED MRNA EXPRESSION

Regan L Fenske

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ABSTRACT

The DNA Repair pathway is a part of the central mechanism of the cell, repairing thousands of DNA lesions every day. DNA repair pathways including homologous recombination (HR) and non-homologous end joining (NHEJ) maintain the health and genetic stability of the cells. Many genes in the DNA Repair pathway have yet to be identified, so genes from Tetrahymena thermophila have been tested to reach a further conclusion. T. thermophila organisms show increased DNA damage and repair during mating, and gene TTHERM_00459400 showed promising gene expression levels during mating. To determine whether the gene expression of candidate gene TTHERM_00459400 increases after being exposed to a DNA damaging agent, custom primers for the gene were designed using Primer-3Plus and then verified using a PCR. T. therm cells were split; half were incubated with the DNA damaging agent HU and half without. More PCRs were conducted to test the mRNA expression of the gene, and the results were then visualized using a Gel Electrophoresis. After the primers were validated, it was found that the gene expression of TTHERM_00459400 possibly increased after DNA Damage was induced. Gene expression has not been confirmed, so further testing needs to be conducted to conclude whether or not mRNA expression increased. If mRNA expression increases, the gene can be studied further to see if it is a part of the DNA Repair pathway. Answering the many questions regarding the DNA Repair pathway is important to gather an understanding of cellular health and could even lead to breakthroughs in cancer research.

LAY SUMMARY

The DNA Repair pathway is central to the health of cells, repairing thousands of DNA breaks every day to maintain the health and genetic stability of the cells. Many genes in the DNA Repair pathway have yet to be identified in humans, but genes in other organisms that have a similar function have been identified. If some of these genes can be related back to genes in humans, then they can be identified as belonging to a repair pathway. One such organism is the single-cell eukaryote Tetrahymena thermophila. T. thermophila organisms have shown increased DNA damage and repair during mating, so they are a promising organism to use because gene expression can be easily measured during this specific stage of the organisms' life. One gene in the organism, TTHERM_00459400, showed promising gene expression levels during mating. To determine whether the gene's expression increased after being exposed to a DNA damaging agent, custom primers for the gene were designed and verified using various PCR experiments with and without the damaging agent. The results of the experiments were then visualized using a Gel Electrophoresis. After the primers were validated, it was found that the gene expression of TTHERM_00459400 possibly increased after DNA Damage was induced. Gene expression has not been confirmed, so further testing needs to be conducted to conclude whether or not mRNA expression increased. If mRNA expression increases, the gene can be studied further to see if it is a part of the DNA Repair pathway. Answering the many questions regarding the DNA Repair pathway is very important to gather an understanding of cellular health; this research could even lead to breakthroughs in cancer research.

DESCRIPTION, AGE, PETROCHEMICAL ANALYSIS, AND A COMPARISON OF TWO REE-RICH MINERALIZATION OCCURRENCES NEAR JAMESTOWN, CO

Shea Joseph Burnham

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ABSTRACT

Two occurrences of rare earth element (REE) mineralization occur near Jamestown, Colorado in the 1.4 Ga Silver Plume-type Long's Peak-St. Vrain pluton and 1.7 Ga Idaho Springs Group schist. There is a northern locality and a southern locality which are about 1 km apart. These occurrences were first described by Goddard and Glass (1940) and then later by Allaz et al. (2015) and Stern et al. (2018). This thesis will be the first to focus primarily on the southern locality and to compare it to the other locality. Samples of schist, REE-rich rock, amphibole-bearing rock, and an unidentified felsic rock were analyzed by petrographic microscope, whole rock analysis, and electron microprobe. The felsic rocks contain a fine-grained, granular matrix of quartz and plagioclase with minor biotite, and quartz phenocrysts up to 2 cm long; this is compared to the aplite of the north, which is fine-grained, granular, and contains quartz, plagioclase, K-feldspar, and minor biotite, but no phenocrysts. The REE-rich rocks are massive and fine-grained and contain a complex mixture of REE minerals and allanite rims, compared to the north, where zoned nodules and veinlets form inside aplite. The amphibole-bearing rock is not found in the north and contains amphibole, quartz, and minor allanite, but is mixed with more complex REE species in some samples. Whole rock analysis shows that the southern locality has higher Fe in the system than the north, with REE-rich core averaging 2.1 wt. % Fe2O3, compared to 0.51 wt. % Fe2O3 in the north. Southern REE core samples have an average of 1.7 wt. % F, compared to 9.3 wt. % in the north. The REE core samples of the south have an average LaN/YbN = 26, compared to 113 for the north. Rim samples show a reversed pattern with LaN/YbN = 1060 in the south and 207 in the north. This leads to chondrite-normalized plot of rim + core showing the same pattern with north and south samples. Nd-analysis of monazite and allanite grains from REE rock was done by laser ablation multi-collector inductively coupled plasma mass spectrometer (LA-MC-ICPMS). Nd-analysis shows initial Nd-isotopic compositions for the southern REE rocks and the northern REE rocks and aplite all fall between -2.2 to -1.0 and with 147Sm/144Nd ratios between 0.03 to 0.11. Nd-analysis also revealed that the southern locality is 1421.9 ± 24.9 Ma, compared to 1420 ± 25 Ma and 1442 ± 8 Ma ages for the northern locality determined by Allaz et al. (2015). These data suggest that the REE rocks from the southern locality are cogenetic with the REE rocks and aplite from the northern locality, but that the two magmas evolved differently near the surface.

LAY SUMMARY

Rare earth elements (REE) are materials that are important in many of today's complex technologies, including those we use every day, such as cell phones and computers. However, they can be difficult to find and only occur in commercially viable concentrations in a few places on Earth. In this thesis, two occurrences of igneous rocks, located about one kilometer apart in the Front Range of Colorado, each containing some of the same unique REE-rich minerals are studied and compared, in part, to help contribute to a better understanding of how these minerals form and where they can be found in the future. A combination of analytical techniques is used to gather critically important information about these rocks, including their mineral assemblage, chemical makeup, age, and spatial and genetic relationship to the older, surrounding rocks in which they have intruded, as well as their relationship to each other. These methods show that these occurrences are the same age, genetically related and, at some point in their emplacement, split from one another and evolved differently. This created two sets of very rare rocks that share many similarities but also contain some key differences that require continued study. The need for economically viable REE-rich minerals will continue to grow and the study of geological occurrences such as those in this thesis is an important part of furthering our knowledge and understanding of how they form and where to find them.