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14. ABSTRACT

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RPPR Final Report
as of 25-Oct-2022

Agency Code: 21XD

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DUNS Number: 092530369 EIN: 956006143

Report Date: 31-Oct-2022 Date Received: 24-Oct-2022

Final Report for Period Beginning 01-Jan-2021 and Ending 31-Jul-2022

Title: Spatial variability in aeolian abrasion

Begin Performance Period: 01-Jan-2021 **End Performance Period:** 31-Jul-2022

Report Term: 0-Other

Submitted By: Mackenzie Day Email: daym@epss.ucla.edu
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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 5 **STEM Participants:** 6

Major Goals: The primary scientific objective of this project is to quantify the magnitude of aeolian abrasion as a function of distance away from a sand source. We study this by measuring the mass loss rates of a variety of samples of different materials deployed in the field. The chosen study area is the Ibex Sand Dunes, in Death Valley National Park. One major goal of the project is to quantify erosion rates, another necessary goal is to understand the transport patterns in the study area. For the former, different materials were mounted to sample racks at 5 heights and the initial mass of the samples was measured. To quantify mass loss, the mass of each sample was measured at subsequent field visits. For the latter goal, to contextualize sediment transport in the area, two weather stations were placed to measure wind speed and direction, as well as other environmental properties, over the duration of the study. Each sample rack was also accompanied by a sediment trap that recorded the flux of sediment at 4 heights above the surface. Finally, ventifacts, naturally occurring wind-abraded cobbles in the study are, were measured to compare modern winds with winds over geologic time. By repeatedly visiting the study area and measuring the mass loss on samples, the team determined rates of abrasion as a function of distance from the sand dune field. All major research activities for this work were concluded by the submission of this report. The field monitoring period was extended through summer 2022 to improve the signal-to-noise ratio of the data. A final manuscript detailing the project is being drafted for submission to a peer-reviewed journal later this year.

Accomplishments: Overall Objective: Quantify the magnitude of aeolian abrasion as a function of distance away from a sand dune source

Task 1 Objective: Install abrasion samplers in the field and measure ventifacts for context

Timeframe: 0-3 months

Findings: Twenty-seven sampling stations were placed in the valley west of Ibex Dunes, between Ibex- and Saddle Peak Hills. The sample racks were placed in transects across the valley to capture the spatial variability in abrasion away from the dune sand source. Each sample rack was accompanied by a sediment trap that collected sand at different heights. Two weather stations were also placed in the field area to capture the wind speed, wind direction, and variability in both over the study period.

Understanding abrasion in the field area requires both direct measurements of abrasion and contextual information about the local sand-eroding winds. We found that the wind in the study area during our monitoring period was predominantly from the south-southwest, with two a additional subordinate modes from the north-northwest and from the northeast. Winds from the northeast were notably lower speed than the other two directions, but all exceeded sand-transporting thresholds.

Mapping of the region's ventifacts, wind-carved cobbles exposed at the surface, provided a test for whether our wind measurements were representative of the long-term wind behavior in the region. As wind-blown sand polishes and carves the surface of an exposed rock, the erosion bevels the faces of the rock into an aerodynamic shape that can be used to interpret the formative wind direction. Approximately 100 ventifacts were measured in the field. The wind directions inferred from the measured clasts show a bimodal population of wind directions, as opposed to the trimodal winds measured with the weather station. Ventifacts were dominated by winds that blew toward the north (i.e., southerly winds) and toward the southwest (i.e., northeasterly winds). Note that by convention winds are measured as the direction they are from in meteorology and reported as the direction they are toward in sedimentary geology. The wind directions inferred from the ventifacts match those measured by the weather station, except that the subordinate mode of winds from the north-northwest were absent in the rock record.

Changes in direction: Originally, the experimental setup called for 25 sample racks to be constructed from extruded aluminum. We added two additional sampling racks to monitor abrasion outside the valley along the entrance road to the south and southeast. These served as a control for abrasion happening in regions without clear evidence of aeolian erosion (ventifacts). Additionally, we opted to construct the sample racks from PVC instead of aluminum to better optimize cost and because the racks had to be carried into the field by hand. PVC was heavy enough to not be moved by the wind, but not so heavy as to make moving the racks on foot impractical.

Major accomplishments: Completing this task provided the context necessary to interpret the long-term abrasion measurements collected in Task 2. The weather station data and ventifact measurements demonstrate that the winds in this region have been constant over the timescales of rock abrasion. These timescales are longer than those affecting man-made structures and equipment, thereby demonstrating that our study area is in the necessary steady state. The wind direction measurements also suggest that samples on the south side of each cube will be the most representative of erosion maxima in the study area.

Task 2 Objective: Field monitoring of abrasion and sediment flux

Timeframe: 3-15 months

Findings: The mass loss on each sample was measured at intervals during the monitoring period, with the total mass loss used to assess the spatial trends in abrasion. Sample racks were composed of vertical PVC pipes connected into a cube with different sample materials on each vertical bar, repeated on each of the four vertical cube faces. Six samples were attached at different heights to assess how abrasion changed with height. Sediment was also collected at each abrasion monitoring location to assess the sediment flux in the region. The results of both the abrasion monitoring and the sediment flux measurements indicate a strong drop-off in activity both distally away from the dunes and vertically away from the surface. Initial results suggest that sediment flux decreases linearly with distance from the dune field, with sediment flux at the distal west end of the valley approximately two orders of magnitude lower than sediment flux at the proximal east end of the valley. Abrasion magnitude was less clearly trending in space, but showed significant decreases in magnitude vertically.

Changes in direction: The harsh environment of Death Valley caused the plastic sediment traps to degrade more rapidly than expected. Temperatures in Death Valley reached >120° F during the study period and the heat and UV exposure caused the bottles to crack. Data was collected from the sediment traps early in the study, before the summer of 2021. By the end of the summer, the sediment traps needed to be replaced. The traps were replaced and data was collected at shorter intervals but repeated during different seasons to capture the spatial and temporal variability in sediment flux. Similarly, the glue adhering the glass samples to the sample racks was not robust to the extreme environmental conditions. Data was collected for the glass samples during the first half of the study. During the latter half of the study, the focus pivoted to the other materials, each of which remained affixed to the sample racks.

Major accomplishments: The results of this task yielded a robust dataset connecting abrasion and spatial position.

Task 3 Objective: Data analysis

Timeframe: 15-18 months

Findings: At the end of the study, all sample racks were collected and the samples weighed a final time. The total mass loss on each sample constitutes the magnitude of abrasion during the monitoring period. Sample weights were calculated to the nearest milligram and because not all samples began with identical weights, the mass loss fraction is used to assess the trends in the observations. Sediment captured by the traps was dominated by medium sand sized grains as is common in aeolian settings.

Changes in direction: To improve the quality of the data, the sample abrasion racks were left in Death Valley for three months longer than initially planned. The additional duration improved the signal-to-noise ratio of the data, yielding more well-resolved spatial trends.

Major accomplishments: The objective of this work is to make a quantitative connection between a dune-field sand-source and abrasion in space. Measurements of wind and ventifacts provide the context in which the measurements of abrasion and mass loss should be interpreted. The major accomplishment of this work overall is the quantitative measurements of erosion as a function of space. These results are summarized in the figured included in this report. In addition, the results are being drafted into a manuscript for peer-reviewed publication later this year. The data collected in this work is sufficient to quantify erosion as a function of distance from an active source, and allow for predictive estimates of abrasion at other locations that can be applied to engineering and longevity constraints of future projects.

Training Opportunities: This award has supported two graduate students who are leading the field research and who will incorporate the results into their dissertations. During the project period, both students passed their doctoral candidacy exams using research and preliminary results from this work. One student presented preliminary results from this work at a national conference in December 2021 (American Geophysical Union Fall Meeting). In addition, during the field visits, undergraduate student field assistants were recruited to help measure samples. Ten undergraduate students participated in the field trips. For many of them this was their first exposure to field research. It gave the undergraduate students an opportunity to see research in action and gave the graduate students an opportunity to mentor junior students and practice leadership skills.

Results Dissemination: One of the graduate students funded by this work presented preliminary results at the American Geophysical Union Fall Meeting. The poster presentation is cited as:

Dorn, T. and M. Day, “Spatial Variability of Aeolian Abrasion: Early Results from Ibex Dune Field, Death Valley National Park” American Geophysical Union Fall Meeting, (2021).

The same student will share the final results of the work in an oral presentation at the 2022 AGU Fall Meeting. This student also created a website to inform the public about the research project. Each monitoring sample rack in the study area was labeled with identifying information and a link to the research website. Members of the public were invited to contribute to the research by sharing photos of the monitoring stations and several hikers to this remote location did reach out and engage with the project.

A final peer-reviewed publication detailing this work is being drafted by the students and PI with the goal of submission for review by the end of the calendar year.

Honors and Awards: The PI received two awards during the duration of this project:
2022 Ronald Greeley Early Career Award in Planetary Science from American Geophysical Union
2021 NSF CAREER Award from Geomorphology and Land-use Dynamics

The graduate students supported by this work also received several awards:

Taylor Dorn:
2022 Bakersfield College Faculty Diversification Fellowship
2022 UCLA Dissertation Year Fellowship
2021 UCLA EPSS Outreach Award
2021 UCLA EPSS Excellence in Teaching Award

Jordan Bretzfelder:
2022 Amelia Earhart Fellow from Zonta International
2021 NASA Space Grant Fellow, awarded by NASA representative at UCLA
2021 Eugene B. Waggoner Prize for Excellence in Original Research from UCLA
2021 Honorable Mention in the NSF Graduate Research Fellowship Program

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Mackenzie Day
Person Months Worked: 2.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Graduate Student (research assistant)
Participant: Taylor Dorn
Person Months Worked: 15.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Graduate Student (research assistant)
Participant: Jordan Bretzfelder
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Undergraduate Student
Participant: Diana Urda
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Project Contribution:
National Academy Member: N

Participant Type: Undergraduate Student
Participant: Morgan Carrington

Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Undergraduate Student
Participant: Siti-Nabila Nizam
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Undergraduate Student
Participant: Alana Archbold
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Project Contribution:
National Academy Member: N

Partners

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I certify that the information in the report is complete and accurate:
Signature: Mackenzie Day
Signature Date: 10/24/22 8:12PM

Final Report

Agency: Army Research Office

Award #: W911NF2110063

Project title: Spatial variability in aeolian abrasion

PI: Mackenzie Day
Assistant Professor, UCLA (daym@epss.ucla.edu)

Abstract: Wind-driven sediment transport dominates arid landscape evolution. In particular, wind-blown sand forms dune fields and erodes exposed surfaces through abrasion. Aeolian dunes often serve as a sand source for abrasion, however, the relationship between the magnitude of abrasion and distance from a sand source remains poorly constrained. Previous work on aeolian abrasion has focused on ventifacts, wind-carved cobbles and boulders that record the direction of erosive winds in their pattern of surface erosion. These geologic indicators provide robust evidence that wind-abrasion has occurred, but without more information provide little insight into the magnitude or rate of surface erosion. Aeolian abrasion can cause significant damage to both natural and engineered materials, but sometimes proximity to sand sources is unavoidable. A quantitative understanding of how aeolian erosion rates vary with material type and distance from a dune field would facilitate better-informed decision making in arid regions, and provide expected rates of degradation from aeolian abrasion that could be used in planning and risk management. The proposed work aims to address this gap in knowledge. We propose a 12-month field experiment in which we monitor the wind conditions in the Ibex dune field, capture saltating sand causing abrasion, and measure progressive abrasion-related mass loss on a variety of natural and synthetic materials at increasing distance from the dunes. The proposed work is divided into three major tasks completed over a total of 18 months: Assembly of sampling devices and deployment of those devices in the field (Task 1a), contextual mapping of ventifacts in the study area (Task 1b), field monitoring of sediment flux and abrasion (Task 2), and finally data analysis (Task 3).

Overall Objective: Quantify the magnitude of aeolian abrasion as a function of distance away from a sand dune source

Task 1 Objective: Install abrasion samplers in the field and measure ventifacts for context

Timeframe: 0-3 months

Findings: Twenty-seven sampling stations were placed in the valley west of Ibex Dunes, between Ibex- and Saddle Peak Hills (Fig. 1). The sample racks were placed in transects across the valley to capture the spatial variability in abrasion away from the dune sand source. Each sample rack (Fig. 1b) was accompanied by a sediment trap that collected sand at different heights (Fig. 1c). Two weather stations (Fig. 1d) were also placed in the field area to capture the wind speed, wind direction, and variability in both over the study period.

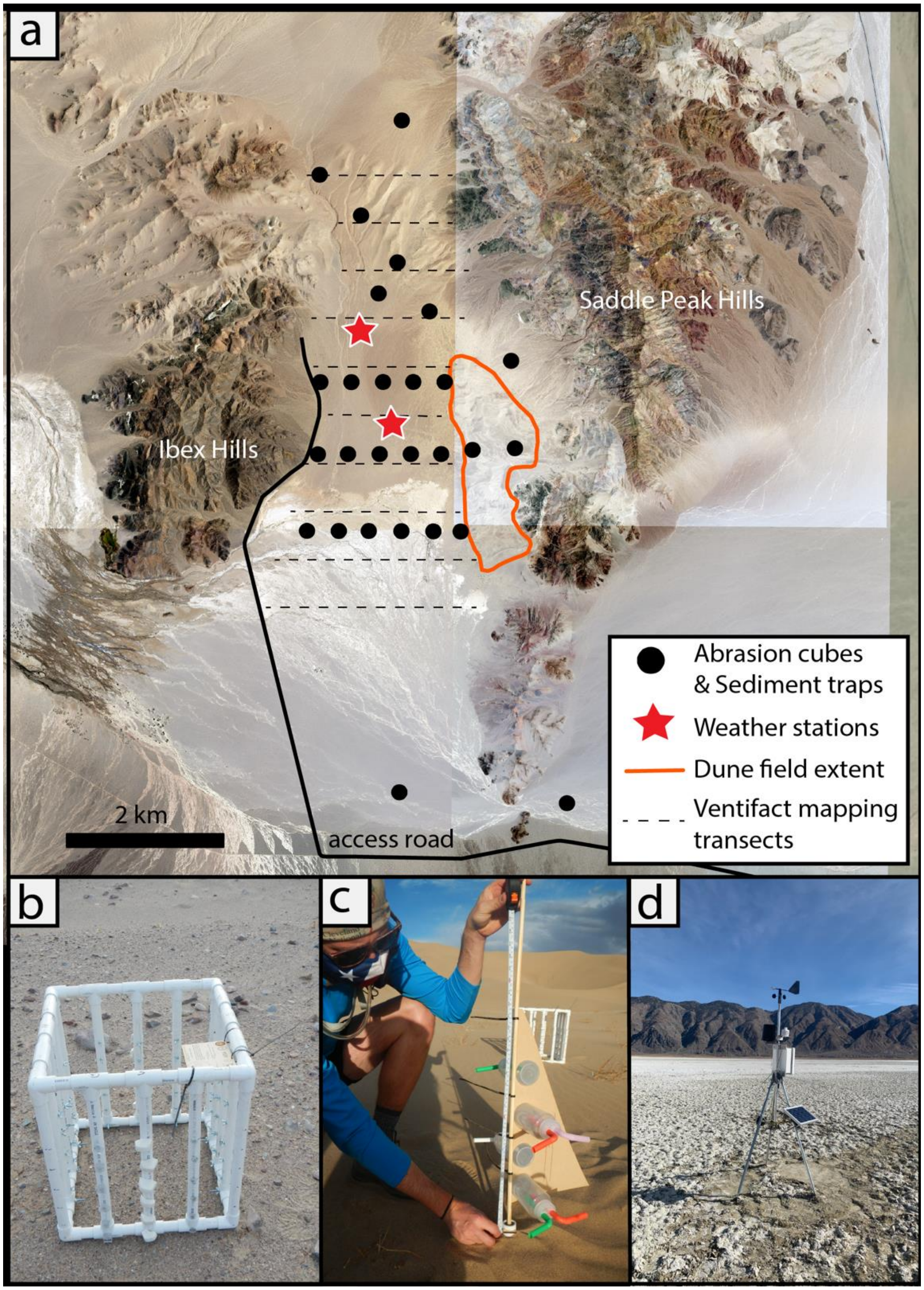

Figure 1: Study area and field monitoring equipment. a) The Ibex Dune Field (outlined in orange) sits in a valley between the Ibex and Saddle Peak Hills. b) Samples were mounted to PVC cubes and placed in the study area as shown in (a). c) Modified Wilson and Cook sediment traps accompanied each sample abrasion rack. d) Weather stations placed in the valley recorded wind speed and direction over the entire study period.

Understanding abrasion in the field area requires both direct measurements of abrasion and contextual information about the local sand-eroding winds. We found that the wind in the study area during our monitoring period was predominantly from the south-southwest, with two a additional subordinate modes from the north-northwest and from the northeast (Fig. 2). Winds from the northeast were notably lower speed than the other two directions, but all exceeded sand-transporting thresholds.

Mapping of the region's ventifacts, wind-carved cobbles exposed at the surface, provided a test for whether our wind measurements were representative of the long-term wind behavior in the region. As wind-blown sand polishes and carves the surface of an exposed rock, the erosion bevels the faces of the rock into an aerodynamic shape that can be used to interpret the formative wind direction. Approximately 100 ventifacts were measured in the field (Fig. 3). The wind directions inferred from the measured clasts show a bimodal population of wind directions, as opposed to the trimodal winds measured with the weather station. Ventifacts were dominated by winds that blew toward the north (i.e., southerly winds) and toward the southwest (i.e., northeasterly winds). Note that by convention winds are measured as the direction they are from in meteorology and reported as the direction they are toward in sedimentary geology. The wind directions inferred from the ventifacts match those measured by the weather station, except that the subordinate mode of winds from the north-northwest were absent in the rock record.

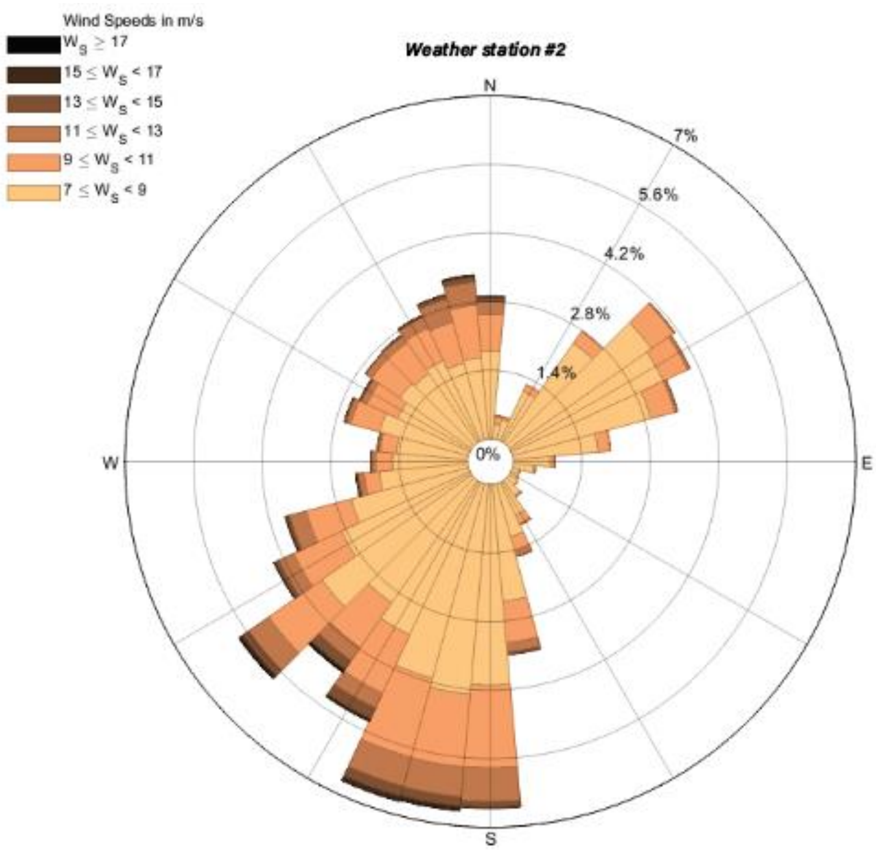

Figure 2: Wind directions measured by a weather station near the Ibex Dune Field, Death Valley National Park. Polar histogram with the wind speeds denoted by color and binned to 2 m/s increments. Note that by convention the wind direction indicated is the direction from which the wind blows.

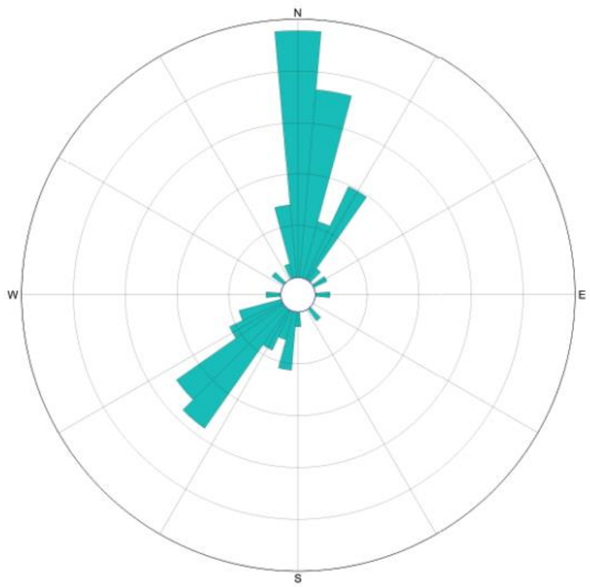

Figure 3: Ventifact measurements. A polar histogram (rose diagram) of the wind directions interpreted from ventifacts in the study area. Ventifacts are wind-carved cobbles of float rock that preserve a formative wind direction in their shape and orientation. Ventifacts in this study were most commonly composed of limestone.

Changes in direction: Originally, the experimental setup called for 25 sample racks to be constructed from extruded aluminum. We added two additional sampling racks to monitor abrasion outside the valley along the entrance road to the south and southeast. These served as a control for abrasion happening in regions without clear evidence of aeolian erosion (ventifacts). Additionally, we opted to construct the sample racks from PVC instead of aluminum to better optimize cost and because the racks had to be carried into the field by hand. PVC was heavy enough to not be moved by the wind, but not so heavy as to make moving the racks on foot impractical.

Major accomplishments: Completing this task provided the context necessary to interpret the long-term abrasion measurements collected in Task 2. The weather station data and ventifact measurements demonstrate that the winds in this region have been constant over the timescales of rock abrasion. These timescales are longer than those affecting man-made structures and equipment, thereby demonstrating that our study area is in the necessary steady state. The wind direction measurements also suggest that samples on the south side of each cube will be the most representative of erosion maxima in the study area (Fig. 4).

Task 2 Objective: Field monitoring of abrasion and sediment flux

Timeframe: 3-15 months

Findings: The mass loss on each sample was measured at intervals during the monitoring period, with the total mass loss used to assess the spatial trends in abrasion. Sample racks were composed of vertical PVC pipes connected into a cube with different sample materials on each vertical bar, repeated on each of the four vertical cube faces (Fig. 1b). Six samples were attached at different heights to assess how abrasion changed with height. Sediment was also collected at each abrasion monitoring location to assess the sediment flux in the region (Fig. 5). The results of both the abrasion monitoring and the sediment flux measurements indicate a strong drop-off in activity both distally away from the dunes and vertically away from the surface. Initial results suggest that sediment flux decreases linearly with distance from the dune field, with sediment flux at the distal west end of the valley approximately two orders of magnitude lower than sediment flux at the proximal east end of the valley. Abrasion magnitude was less clearly trending in space, but showed significant decreases in magnitude vertically (Fig. 4)

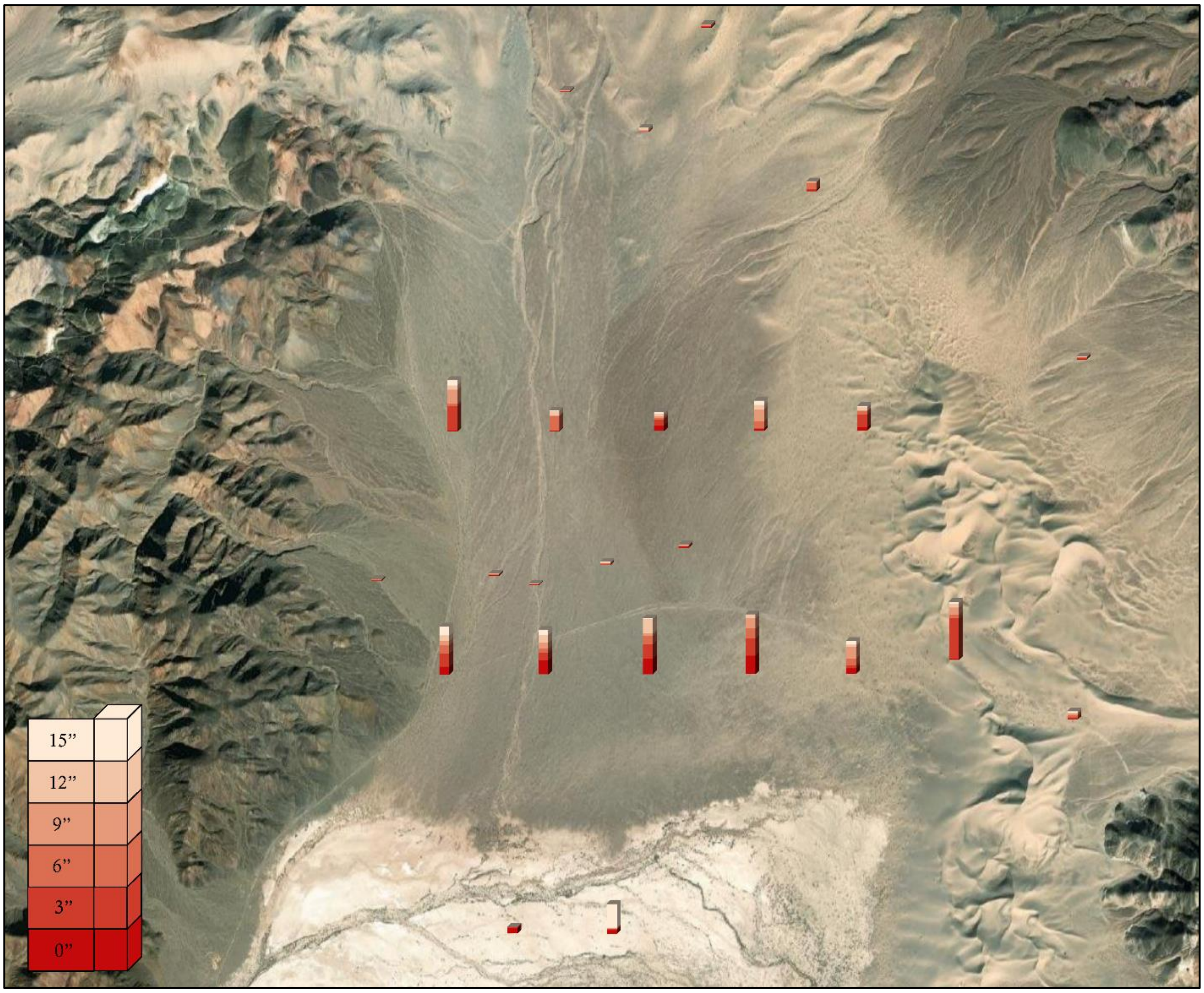

Figure 4: Abrasion magnitude (bar thickness) as determined from sample mass loss from gypsum plaster samples at six different heights (colors). The data shown are from the south-facing cube faces and are shown on the satellite image of the study area at the sampling location in the field. Note that abrasion is at its maximum 1) near the dune field in the east, and 2) within three inches of the ground.

Changes in direction: The harsh environment of Death Valley caused the plastic sediment traps to degrade more rapidly than expected. Temperatures in Death Valley reached >120° F during the study period and the heat and UV exposure caused the bottles to crack. Data was collected from the sediment traps early in the study, before the summer of 2021. By the end of the summer, the sediment traps needed to be replaced. The traps were replaced and data was collected at shorter intervals but repeated during different seasons to capture the spatial and temporal variability in sediment flux. Similarly, the glue adhering the glass samples to the sample racks was not robust to the extreme environmental conditions. Data was collected for the glass samples during the first half of the study. During the latter half of the study, the focus pivoted to the other materials, each of which remained affixed to the sample racks.

Major accomplishments: The results of this task yielded a robust dataset connecting abrasion and spatial position.

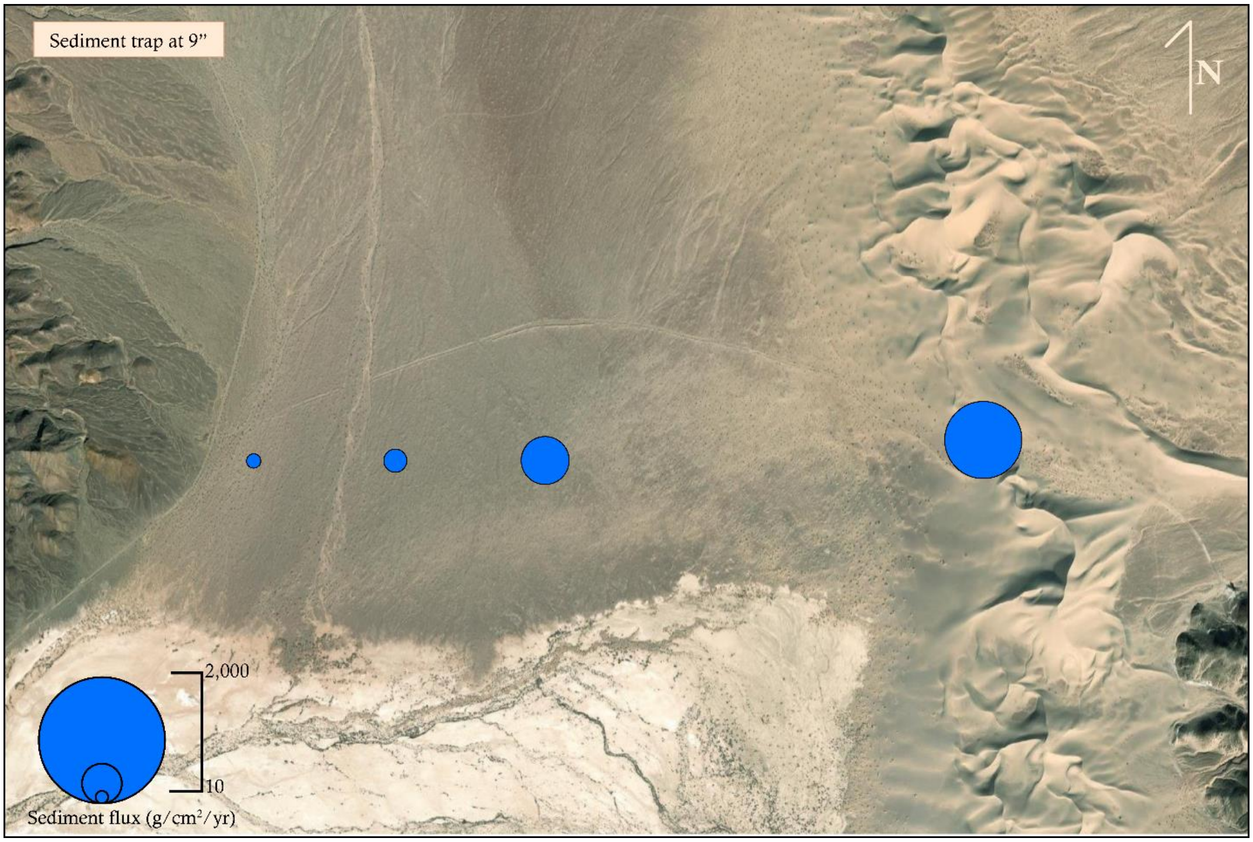

Figure 5: Sediment flux measured by sediment traps along the most active transect across the valley. Sediment collected at approximately nine inches above the surface shows a clear trend in sediment flux away from the dune field.

Task 3 Objective: Data analysis

Timeframe: 15-18 months

Findings: At the end of the study, all sample racks were collected and the samples weighed a final time. The total mass loss on each sample constitutes the magnitude of abrasion during the monitoring period. Sample weights were calculated to the nearest milligram and because not all samples began with identical weights, the mass loss fraction is used to assess the trends in the observations. Figures 4-6 show the initial results for this work and the spatial trends in both flux and abrasion. Sediment captured by the traps was dominated by medium sand sized grains as is common in aeolian settings.

Changes in direction: To improve the quality of the data, the sample abrasion racks were left in Death Valley for three months longer than initially planned. The additional duration improved the signal-to-noise ratio of the data, yielding more well-resolved spatial trends.

Major accomplishments: The objective of this work is to make a quantitative connection between a dune-field sand-source and abrasion in space. Measurements of wind and ventifacts provide the context in which the measurements of abrasion and mass loss should be interpreted. The major accomplishment of this work overall is the quantitative measurements of erosion as a function of space. These results are summarized in the figured included in this report. In addition, the results are being drafted into a manuscript for peer-reviewed publication later this year. The data collected in this work is sufficient to quantify erosion as a function of distance from an active source, and allow for predictive estimates of abrasion at other locations that can be applied to engineering and longevity constraints of future projects.

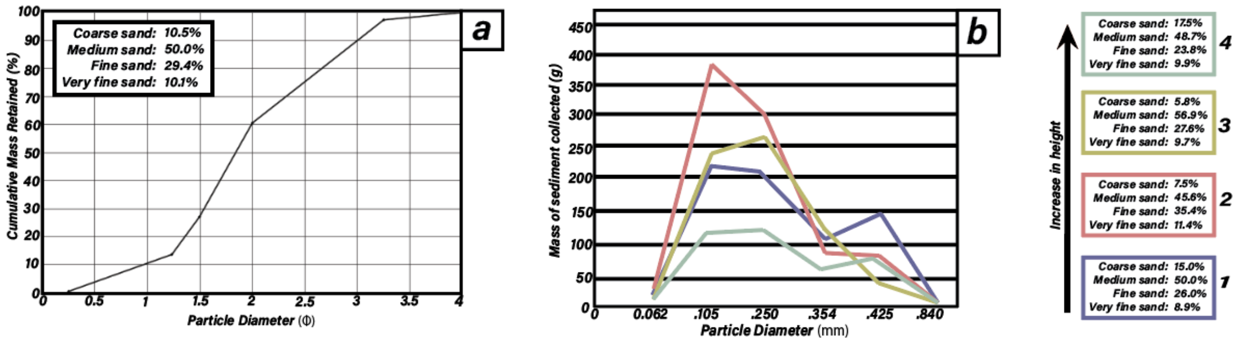

Figure 6: Size distribution of the sediment collected in sediment traps. The spatial trend is summarized in Figure 5. a) Cumulative distribution of particle size for all sediment trapped at the abrasion sample racks. b) Distribution of particle size by height above the ground at which the sample was collected.