Michigan Mars Rover Team

University of Michigan

Canadian International Rover Challenge

Michigan Mars Rover Team CIRC Report

Authors:

Emeline Hanna

Aida Ruan

Ashwini Joshi

Sydney Shanahan

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Abstract

Due to a power supply failure at the current settlement, our rover carried out a survey to explore and evaluate promising regions for future establishment. The purpose of this report is to document the findings of the rover for three distinct sites, where a soil sample was taken from each and analyzed to determine if the site has habitation capacity and scientific potential.

Each site was visually inspected using photographs to determine the suitability from the amount of space available and terrain. The soil sample for each site was investigated for metal resources, water content, and possible life.

The first site was chosen to be the outpost. This is because of its proximity to trees, the entrance for restocking, and cracked soil which is scientifically interesting. The second site was chosen to be the emergency shelter due to its proximity to a hill (for extreme weather protection) and its proximity to the habitation complex. The third site was chosen to be the habitation complex due to the better soil composition and large, flat area.

1 Search Procedure and Route

The region of interest was systematically searched to determine possible habitation areas. The area was scanned using the rover's on-board camera to determine a relatively flat and open location, since significant changes in elevation would create a barrier to building a structure. Water was a resource of interest, and if a body of water was found, proximity to it was weighed heavily in site selection. Geographical points of interest such as hills were identified. Additionally, the locations were evaluated based on the ease of route taken and the favorability of the terrain. If a location was deemed to be suitable based on these criteria, a soil sample was taken.

The following describes our thought process behind the rover's path. Near the entry point, the rover followed a pre-existing path due to its accessibility. The vegetation of this area was circled due to this being evidence of the suitability of soil in this region. The lot southwest of the starting point was considered as a site of interest due to its flatness and openness. The hill to the west of the lot was also geographically interesting and was examined.

A map with an overlay of the rover's search can be found in the map in Figure 1.

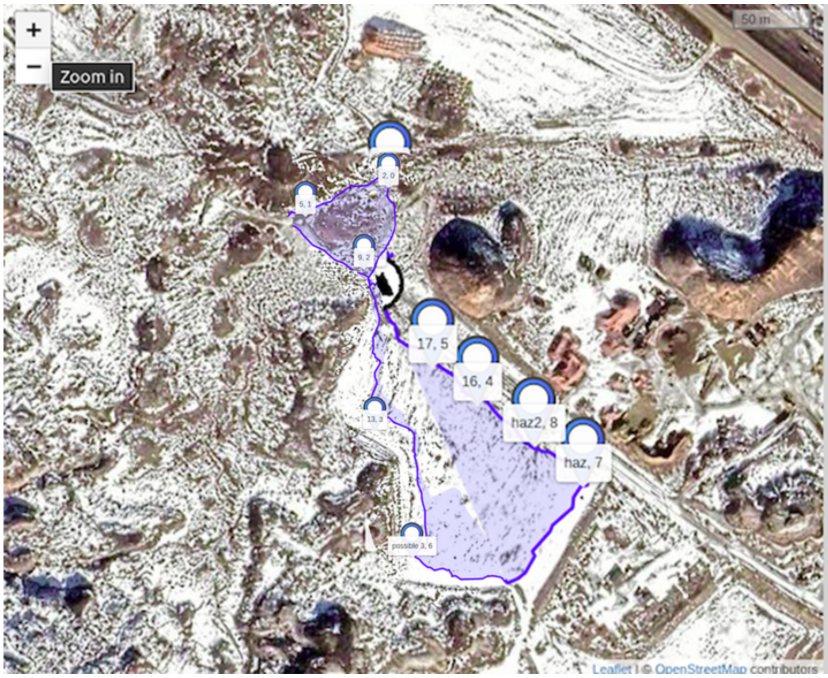

Figure 1: Map of the search area. The route taken by the rover is indicated with a blue line with waypoints taken along the way to indicate points of interest.

2 Report on Sites Examined

Three sites were examined using the rover. Observations for each site can be found in the following sections.

2.1 First Site

After leaving the entry point, the rover initially headed in a direction to avoid running over substantial vegetation. On the route, there was a large hill with distinctively steep slope that could be used as a landmark. Near the hill, trees were seen, emphasizing the viability of the soil in this site. The hill and the trees can be seen in Figure 2.

Figure 2: Camera image of a large landmark hill and trees near Site 1.

The GPS coordinate of the hill is estimated to be around 51.4228113, -112.64052841.

This route lead to an open area where the rover scooped up dirt. The route to this point can be seen in Figure 3.

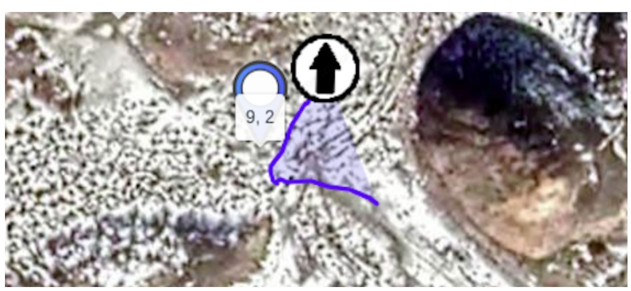

Figure 3: Route to get to Site 1.

The GPS coordinates representing the corners of this site, designated Site 1, can be found in Table 1. Additionally, in this table is the location where the panorama and scoop were taken.

Table 1: GPS Coordinates for Site 1.

Location	GPS Latitude Coordinate	GPS Longitude Coordinate
Site corner 1	51.423031	-112.641191
Site corner 2	51.422851	-112.641702
Site corner 3	51.422748	-112.641416
Site corner 4	51.422851	-112.641188
Panorama/Scoop	51.42296183	-112.64123563

These coordinates were visualized in a mapping program [1] that can be seen in Figure 4.

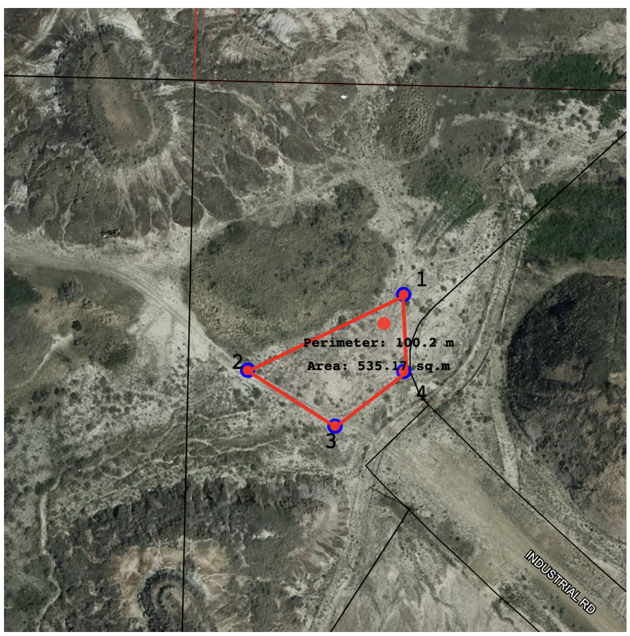

Figure 4: Map of the corners of Site 1, including a red dot indicating where the scoop of soil and panorama were taken.

The panorama photograph for Site 1 can be seen in Figure 5. The site was approached from the south, the direction indicated by a star in the figure.

Figure 5: Panorama for Site 1.

Due to the vegetation of the area, the flat open terrain, and the ease and closeness of the site to the start, a soil sample was taken here. The area where the soil sample was collected is captured in the camera photo in Figure 6.

Figure 6: Picture of area where sample was collected at Site 1.

The sample was relatively loose and not very compacted soil. This sample was chosen because of the ability of the rover's scoop to pick up this type of soil and the nearby bushes indicated possible signs of life.

As the rover continued on, a hazard was detected! The route to this metal hazard is shown in Figure 7.

Figure 7: Route where metal hazard was detected.

This hazard was found at the GPS coordinates of 51.42312072, -112.64209485. A camera shot of this hazard can be found in Figure 8.

Figure 8: Camera image of metal hazard.

The rover steered away, turning to soil that was near Site 1. It was noted this soil was very cracked, shown in Figure 9.

Figure 9: Camera image of cracked soil.

This soil indicates a previous drought and a region to be investigated.

2.2 Second Site

The rover then continued on southward, avoiding a rocky hill. The route up to this point can be seen in Figure 10.

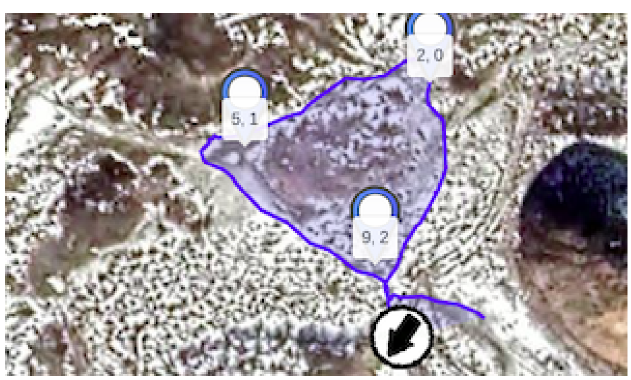

Figure 10: Route taken towards Site 2.

A camera image of this landmark can be found in Figure 11.

Figure 11: A rocky hill on the route to Site 2 that was avoided.

This route lead to an wide open rocky space. It was determined this would be a possible site location. The GPS coordinates representing the corners of this site, designated Site 2, can be found in Table 2. Additionally, in this table is the location where the panorama and scoop were taken.

Table 2: GPS Coordinates for Site 2.

Location	GPS Latitude Coordinate	GPS Longitude Coordinate
Site corner 1	51.422454	-112.641190
Site corner 2	51.422140	-112.641514
Site corner 3	51.421864	-112.641215
Site corner 4	51.422232	-112.640733
Panorama/Scoop	51.42227441	-112.64127514

These coordinates were visualized in a mapping program [1] that can be seen in Figure 12.

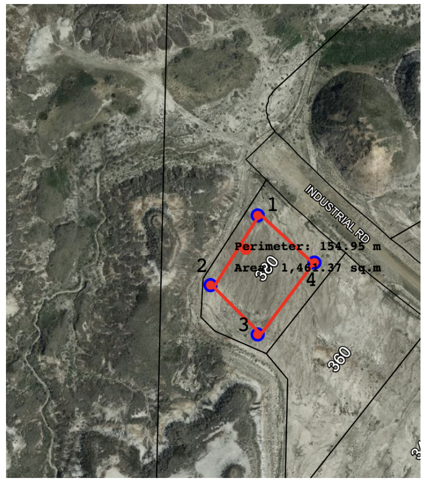

Figure 12: Map of the corners of Site 2, including a red dot indicating where the scoop of soil and panorama were taken.

The panorama photograph for Site 2 can be seen in Figure 13. The site was approached from the north, the direction indicated by a star in the figure.

Figure 13: Panorama for Site 2.

Site 2 is surrounded by a wash (dried up river bed). Shrubs were in the area, while the open area next to it had little vegetation, and a landscape filled with rocks. Unlike Site 1, this site did not contain deep cracks in the ground indicating a drought.

Unlike the first site, site two's vegetation was mostly confined to the dried river bed, while the area surrounded by the river bed was very rocky. However, due to the amount of available space, a soil sample was taken here. The area where the soil sample was collected is captured in the camera photo in Figure 14.

Figure 14: Picture of area where sample was collected at Site 2.

The sample was rocky but still loose enough soil for the scoop to collect it. The sample was chosen for this reason and also the closeness to a possible riverbed, indicating a likely past source of water. Additionally, the route to this location was noted by the large rocky hill, but relatively easy to navigate.

As the rover continued on, a large hill was found with tall grasses that could possibly trap a rover, shown in Figure 15.

Figure 15: Camera image of a hill with tall grass near the base.

This indicates a form of physical shelter and a possible hazard if the rover drove near.

2.3 Third Site

The rover forged on along the ridge, continuing further southward. The route up to this point can be seen in Figure 16.

Figure 16: Route taken towards Site 3.

A camera image of this ridge landmark can be found in Figure 17.

Figure 17: A ridge on the route to Site 3 that can be used for shelter.

The rover turned northeastward, away from the ridge. This was determined to be a good site location since it was not very rocky is was huge, flat, and open, and much more south than the first two sites. The GPS coordinates representing the corners of this site, designated Site 3, can be found in Table 3. Additionally, in this table is the location where the panorama and scoop were taken.

Table 3: GPS Coordinates for Site 3.

Location	GPS Latitude Coordinate	GPS Longitude Coordinate
Site corner 1	51.421787	-112.639983
Site corner 2	51.421086	-112.640757
Site corner 3	51.421008	-112.639925
Site corner 4	51.421519	-112.639395
Panorama/Scoop	51.42106848	-112.64016277

These coordinates were visualized in a mapping program [1] that can be seen in Figure 18.

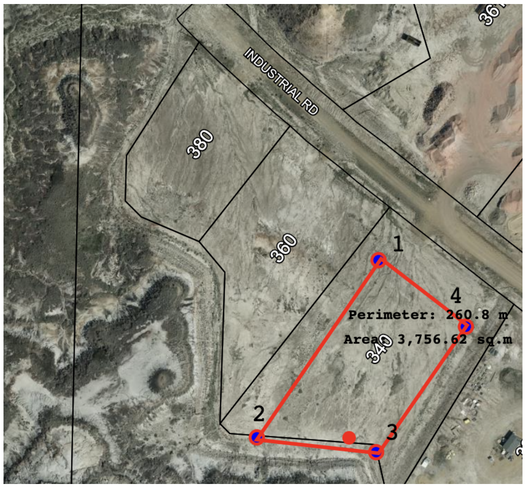

Figure 18: Map of the corners of Site 3, including a red dot indicating where the scoop of soil and panorama were taken.

The panorama photograph for Site 3 can be seen in Figure 19. The site was approached from the west, the direction indicated by a star in the figure.

Figure 19: Panorama for Site 3.

The site is extremely large and flat. There were also dried riverbeds, indicating previous existence of water. The site was in between hills, which made it geographically safe. The rover was south of the starting point but still close, which made it suitable for expansion. As can be seen in Figure 20, there were many flowers and brushes here.

Due to its many benefits and fertile soil (indicated by plants), the rover took a sample from here. The sample included visible roots and seeds.

Figure 20: Picture of area where sample was collected at Site 3.

As the rover headed back to the starting point, another hazard was detected! The route to this white man-made object is shown in Figure 21.

Figure 21: Route where white hazard was detected.

This hazard was found at the GPS coordinates of 51.421575, -112.639373. A camera shot of this hazard can be found in Figure 22.

Figure 22: Camera image of white man-made hazard.

The rover successfully avoided the hazard and returned to the start.

3 Tests Performed

After the rover made it back from the mission, the soil samples were carefully collected from the rover's soil containment storage by scientists. The methodology and results performed on the samples are detailed in this section.

3.1 Methods

MOISTURE TEST. Water content of the soil was evaluated through a soil moisture sensor, which gave a result from 1-10. Adequate moisture is not only essential to plant growth, but also soil structure, temperature, and resistance to weathering [2]. The moisture level also indicated whether the soil was near optimum moisture content.

MAGNET TEST. A neodymium magnet was used to determine magnetic properties of the soil. Around 5g of the sample was placed in a plastic container and magnetic particles were drawn out. Iron oxides are the predominant ferromagnetic substance in soil [3]. The presence of iron oxides can increase structural stability of soil and weaken swelling-shrinkage capacity, minimizing the risk of damage to settlements [4]. Iron oxide also enhances seed germination and metabolic processes of plants, increasing crop yield [5]. Finally, iron oxide has a strong binding capacity with heavy metals, thus reducing them in soils. Bio-accumulation of heavy metals in the food chain can cause health problems [6]. Though too much iron in soil can lead to to toxicity, this is common in wet environments with low pH. Our pH test can indicate whether this is occurring [7].

STRIP TESTS. Ammonia, nitrates, and pH test strips were dipped into a mixture of 5g of the sample and 15 mL of distilled water. Ammonia is primarily produced by various biological metabolic processes [8]. Detecting ammonia is likely indicative of extant life undergoing metabolic processes. The ammonia strip is sensitive to 5 ppm. Nitrates and nitrites could be a source of bioavailable nitrogen for soil organisms including plants and microbes, supporting habitability claims [9]. The nitrate test strips are sensitive to 10 ppm. Our pH test operates primarily as counter-evidence of conditions for life. In general, pH below 6 or above 8 is unfriendly to most forms of soil life [10].

CHLOROPHYLL TEST. Chlorophyll is produced by photosynthetic organisms. Since chlorophyll is not known to be produced abiotically and has a half-life on the order of days [11], its detection indicates the presence of extant life [12]. An autofluorescence test evaluated the presence of chlorophyll in a sample. Soil was delivered to a beaker with 20 mL of 75% acetone solution, which broke down cell walls and released chlorophyll if it existed within a sample [13]. UV light at 385 nm was shone, and a positive result was indicated if the mixture fluoresced at 668 nm (which visually looks red), a signature of chlorophyll [14].

AMINO ACID TEST. Amino acids are complex biomolecules that make up all known forms of life [15]. The ninhydrin test indicated the presence of amino acids in the soil samples. A beaker with 15 mL of water and 0.06 g of ninhydrin powder was heated on a hot plate to boiling, and 5g of soil was delivered to the beaker. The appearance of a color change to Ruhemann's purple indicated the presence of primary amines or amino acids. Evidence of amino acids would indicate the presence of life [16]. Our testing has determined that we cannot consistently identify the presence of amino acids in samples with concentrations much lower than 3 mg per milliliter of soil.

MICROSCOPE TEST. A compound microscope was used to observe a small sample of the soil. Microorganisms and particles greater than one micrometer could be seen. Overall soil texture was analyzed by estimating particle size using the Wentworth scale [17]. Additionally, other microorganisms were analyzed by estimating size [18]. Bacteria, protozoa, and microscopic animals could be discerned through their movement.[19].

3.2 First Site

About 5g of soil were collected. This meant there were some tests we could not conduct. From the naked eye, plant seeds were visible in the sample. First, we evaluated the soil composition.

SOIL TEXTURE. The soil texture was determined to be predominately clay through the microscope. Though it had visible sand particles of around 100 micrometers, most of the sample had particles of less than one micrometer. Additionally, the mixture of the soil with water did not settle and the water remained muddy, indicative of the clay particles in suspension above the sample.

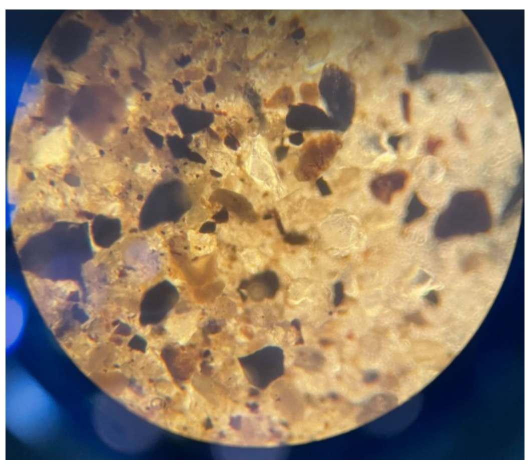

Figure 23: Sample 1 under the microscope at 40x.

The evaluation of the soil texture using the microscope indicated the soil was generally composed of clay. Clay is not a good soil for crops but is a good foundation if it remains dry, but otherwise can shift or swell, affecting settlements.

SOIL MOISTURE. The soil moisture was determined to be 1 out of 10, below the optimum moisture content, meaning that more moisture is needed before compaction and construction on a site can be initialized. Plants will struggle to grow.

Next, the resources of the soil were investigated.

MAGNET. Using a magnet, it was found that iron oxides were present. These oxides may increase the stability and structural integrity of the soil as well as increasing crop yield and keeping heavy metals out of the food chain [4][5][6].

STRIPS. Ammonia was not present in the sample. There was no nitrate or nitrite detected. The pH was 6.5. The lack of ammonia and nitrates/nitrites means that the soil is not very healthy. However, the pH is around neutral which can support crops.

Additionally, the scientific potential was investigated.

CHLOROPHYLL. There was no chlorophyll detected in the sample.

PROTEIN. The ninhydrin test was slightly positive, indicating the presence of amino acids, meaning that the molecules that make up life were found in the sample. This can be seen in the beaker labelled "1" in Figure 24 below.

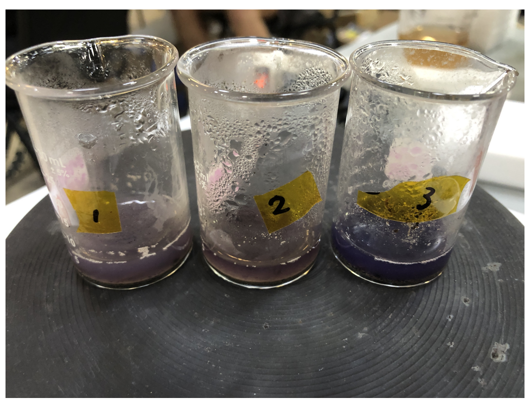

Figure 24: Ninhydrin test results for all three sites, labeled 1, 2, and 3.

MICROSCOPE. The samples did not have any microscopic organisms.

The implications of these findings for the first site's development will be further discussed in the Analysis section.

3.3 Second Site

About 5g of soil were collected. This meant there were some tests that could not be conducted. From the naked eye, plant seeds were visible in the sample.

First, we evaluated the soil composition.

SOIL TEXTURE. The soil texture was determined to be predominately clay, identical to site 1.

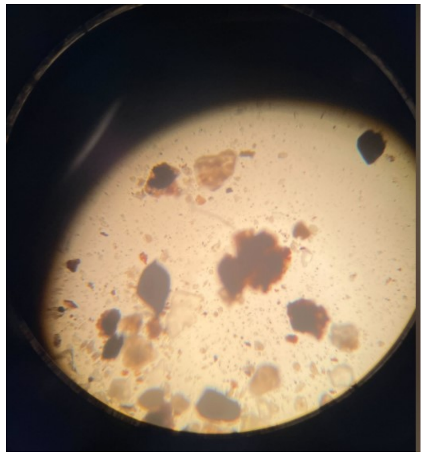

Figure 25: Sample 2 under the microscope at 40x.

SOIL MOISTURE. The soil moisture was the same as site 1: 1 out of 10.

Next, the resources of the soil were investigated.

MAGNET. Iron oxides were also present, similar to site 1.

STRIPS. Ammonia was not present in the sample. There was no nitrate or nitrite detected. The soil pH was 5.5, indicating an inhabitable condition for life. The lack of ammonia and nitrates/nitrites means that the soil is not very healthy.

Additionally, the scientific potential was investigated.

CHLOROPHYLL. There was no chlorophyll detected in the sample.

PROTEIN. The ninhydrin test was medium positive, indicating the presence of amino acids, meaning that the molecules that make up life were found in the sample. This can be seen in Figure 24.

MICROSCOPE. The samples revealed hyphae. This is the filamentous part of a fungus, indicating that life exists in the sample.

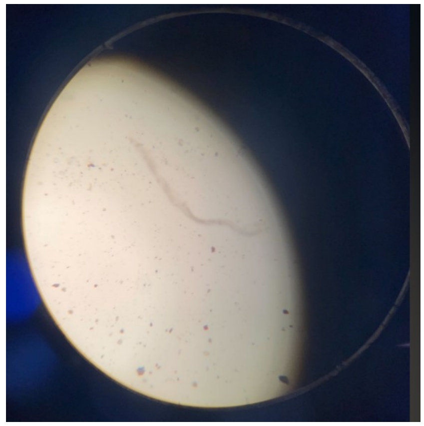

Figure 26: Hyphae from site 2, a kind of fungus, visible at 100x.

The implications of these findings for the second site's development will be further discussed in the Analysis section.

3.4 Third Site

About 10g of soil were collected. From the naked eye, plant seeds and roots were visible in the sample. First, we evaluated the soil composition.

SOIL TEXTURE. The soil texture was determined to be clay loam through the microscope. There were more silt particles (at about 10 micrometers) than previous samples, and the sample settled in water indicating there was less clay.

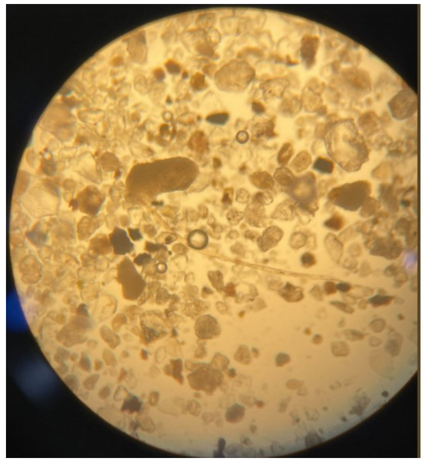

Figure 27: Sample 3 under the microscope at 40x.

SOIL MOISTURE. The soil moisture was the same as site 1: 1 out of 10.

Next, the resources of the soil were investigated.

MAGNET. Iron oxides were also present, similar to site 1.

STRIPS. Ammonia was not present in the sample. There was no nitrate, however nitrates at 10 ppm were detected. The soil pH was 6. The site is slightly more habitable due to the pH being around neutral and the nitrate nutrients being present.

PROTEIN. The ninhydrin test was strongly positive, indicating the presence of amino acids, meaning that the molecules that make up life were found in the sample. This can be seen in Figure 24.

MICROSCOPE. The samples revealed hyphae. This is the filamentous part of a fungus, indicating that life exists in the sample.

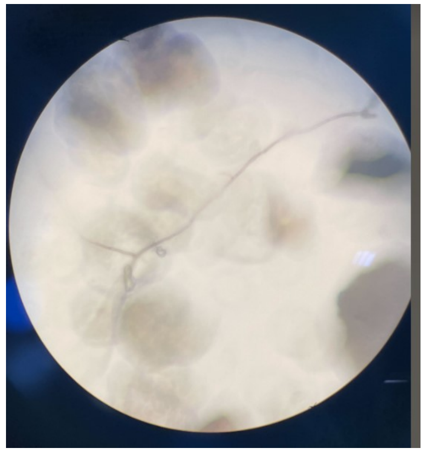

Figure 28: Hyphae, a kind of fungus, visible at 100x.

The implications of these findings for the first site's development will be further discussed in the Analysis section.

4 Analysis

4.1 First Site

After investigating the first site, it is our recommendation to develop this area into an outpost. Cracked soil was visible near the site, which along with our tests confirms that the soil is clay, but also reveals that there was water that caused the clay to expand then a drought that caused it to shrink. The presence of water should be investigated by scientists since it is an essential nutrient to life. Additionally, trees were spotted nearby the site. The trees should be investigated for potential logging since wood would be a helpful resource to have. The growth of the trees indicates that there must be some nutrients in the ground to sustain them, so this should also be investigated.

Location-wise, the first sight if very close to the entrance of the sight, making it restockable with new supplies.

The sample tested slightly positive for protein, which could be another point of interest. We recommend looking into life in the area.

Iron oxide pieces (mostly magnetite) were present in the soil. This should be investigated for its nutritional benefit to the soil and its ability to reduce the concentration of heavy metals. Additionally, iron oxide may reduce shrinkage-swelling of soil, which may be a large problem in the area due to the high concentration of clay and droughts. This should be investigated.

The area of the site found from the GPS coordinates can be seen in Figure 3, showing an area of about 535 square meters. Therefore, this area will accommodate an outpost.

4.2 Second Site

After investigating the second site, it is our recommendation to develop this area into an emergency shelter.

This site was chosen as an emergency shelter because of its proximity to hills. It can block wind, rain, and storms. However, it should be examined first for any dangerous loose rocks that could fall down.

Additionally, the site 2 is close to site 3. Since site 3 was chosen to be the habitation complex, site 2 would be an ideal setup emergency shelter for the workers to stay while working on the permanent settlement. Site 2 is also close to the start, which makes restocking possible.

Riverbeds were also identified nearby, which can be investigated for the future.

Key test results included the pH result at 5.5 and a lack of nitrites/nitrates, and ammonia. This is too basic for actual habitation and growing crops, and the site lacks nutrients. Thus it serves best only as a temporary residence.

The area of the site found from the GPS coordinates can be seen in Figure 12, showing an area of about 1461 square meters. Therefore, this area will accommodate an emergency shelter.

4.3 Third Site

After investigating the third site, it is our recommendation to develop this area into a habitation complex.

This is the only site with adequate soil for growing crops (clay loam), making it closer to the ideal soil texture of loam. However, ground improvement should be considered for the foundation, and more sand should be added to create more fertile soil.

The presence of mycellium fungus (apparent under the microscope) indicates that the soil is fertile. Additionally, pH was around 6 (habitable) and nitrates were present at 10 ppm. Thus, nutrients are present in the soil.

The extreme positive ninhydrin test indicates that there is life and amino acids present. This is extremely beneficial for long-term habitation and growing crops.

Next, the soil is better for construction. Clay will shift and swell with changes in moisture, however clay loam is slightly better. It has a more balanced water retention rate.

For future crop growth and construction, more water should be added to the soil via irrigation or other watering methods. The moisture level was 1 out of 10 (much lower than optimum moisture content), which would not sustain crops nor compress well enough to create a stable foundation for settlement.

Finally, the location is ideal since it is a large flat area. This allows for the possibility of expansion once the original habitation complex is built.

The area of the site found from the GPS coordinates can be seen in Figure 18, showing an area of about 3757 square meters. Therefore, this area will accommodate a habitation complex and significant expansion.

5 Conclusion

From the three sites the rover investigated, we were able to find a site to accommodate an outpost, habitation complex, and emergency shelter. The first site we went to was chosen as an outpost due to its scientific interest (trees, cracked soil), the second site was chosen as the emergency shelter due to its protection from a hill, and the third site was chosen to be the habitation complex due to good soil texture and its size.

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