Survey and Analysis of Arctic Fans in Svalbard, Norway as an Analog for Mars

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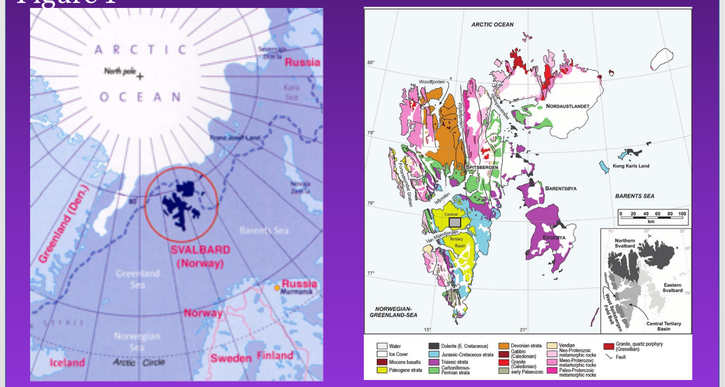
Overview

The islands of Svalbard, Norway are located between Scandinavia and the North Pole (78°50'50.36"N 18°19'00.95"E). This region is known for its glacier-filled frozen tundra environment. Figure 1 shows the location of Svalbard and a geologic map with the different islands labeled.

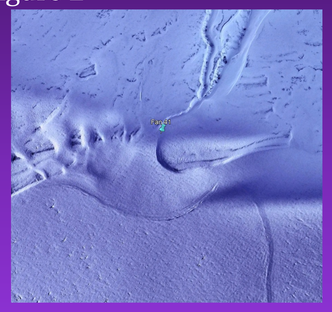
Figure 1



Along the coastline of Svalbard are fan shaped deposits of unconsolidated sediment that are frozen during winter months (mean low temperature -17°C in January) and fluidized during summer months (mean high temperature 5°C in July). In Figure 2, image 2a shows Fan 41 during the arctic conditions on Svalbard in the month of March. Image 2b shows the same Fan 41 during the summer weather of July.

These varying conditions of freezing and thawing make Svalbard a good terrestrial analog for Mars, where fan-shaped features suggest evidence of liquid water on the ancient surface. Comparing alluvial fans and fan-deltas on Earth to those on Mars, we can draw conclusions about the paleoclimate and geologic history of each planet.

Figure 2



a) Fan 41 in March

b) Fan 41 in July

Method

In starting the process of identifying the arctic fans of Svalbard, Google Earth Pro was needed to access high resolution satellite imaging data (< 5 m/ pixel). The images used were acquired by NASA Landsat satellites and Digital Globe commercial satellites.

Next, the coastlines of the islands were scanned for the fan shaped deposits of sediments. Using the historical imaging provided through the application, some remote sections of the islands only had older images available. Additionally, there were regions of imaging where the only available data was for the winter months when the fan deposits are completely covered in snow coverage. Due to these inconsistencies in imaging data, there were areas of the islands where any analyzation of features would've been inaccurate.

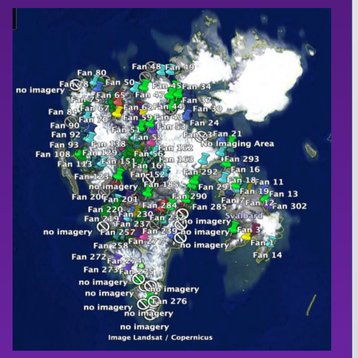
Once a fan was identified, the feature was measured at its widest diameter and marked with a colored pin corresponding to its size range. The overall size range for the recorded fans ranged from less than a kilometer in diameter to over 5 kilometers in diameter. Although all prominent fan shapes were marked, many ≤0.5 km fans could have been overlooked due to their smaller and younger nature.

After a fan has been marked and recorded, any varying qualities about the features or nearby structures were noted and documented for reference. Along with any unique qualities, the specific historical imaging date for optimal observation of the fan was also recorded.

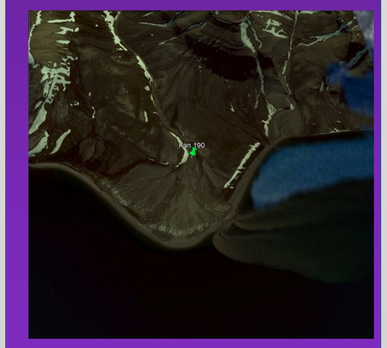
Finally, after the islands Spitsbergen, Barentsøya, and Edgeøya were mapped for arctic fans, the data and coordinates for each fan were recorded into an Excel spreadsheet.

Data

Figure 3



a) Extent of mapping



b) Fan 190- 1.07km diameter.

c) Fan 184- 2.44km diameter

A total of 302 arctic fans were identified and marked on the islands of Svalbard. Figure 3a shows the location and concentration of fans in the different regions of the islands. The positioning of the areas with no available imaging is also depicted.

Table 1

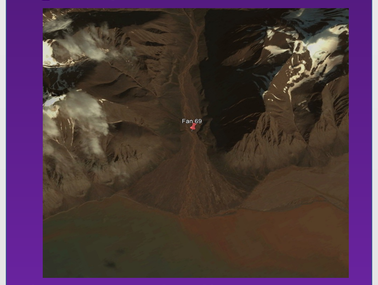
Diameter (km)	# of Fans
≤0.5	64
≥0.5	88
≥1.0	93
≥2.0	33
≥3.0	11
≥4.0	5
≥5.0	6

Table 1 shows the amount of fans that were marked for each diameter size range. From this data, it can be determined that alluvial fans over 1 kilometer were most abundant along the coastline of Svalbard. Overall, the majority of the fans that were observed were of the smaller size ranges at 1 kilometer or less. 0.11 km was the smallest diameter recorded and 5.65 km was the largest.

Figure 3b shows an example of a ≥1.0 km alluvial fan. Its positioning on the edge of the coastline suggests that the shape and size has changed over time. In this picture there is also evidence of sediment transport to the west of the coast.

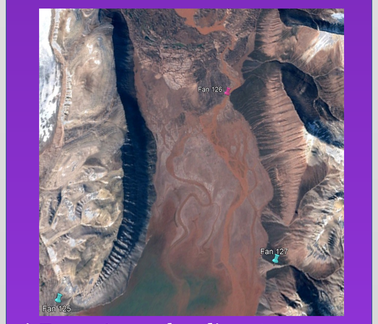
The image for Figure 3c is an example of a ≥2.0 km fan. But this fan in particular has a pristine asymmetrical shape that hugs the coastline of the island. This more uniform shape could have formed due to the location of the outlet for the deposited sediment. The main source point appears to be connected to the valley of the nearby mountains. The gravity from the mountains could facilitate the flow of particles to the one outlet at the end of the valley.

Figure 4



a) Fan 69- 3.03km diameter

b) Fan 221- 5.65 km diameter



c) Fan 126- 4.00km diameter

Featured in Figure 4a is an alluvial fan that seems to have developed from a glacial valley or trough. In this image you can also clearly see the stream of sediment that is drifting away from the fan along the coastline. Also pictured in the figure is an example of the much smaller fan shapes that were found all along the coasts of the islands. To the right and left of Fan 69, the slope of the coast is perfect for ≤0.5 km fans that form most likely from smaller discharges of groundwater.

Figure 4b shows the largest fan documented, at 5.65 km in diameter. In the image you can see that there are several outlets leading to the one alluvial fan area. This could be evidence of an area with more active deposition due to a constant, nearby source of groundwater flow or streams. Another factor influencing the movement of sediments to this fan could be a greater difference in relief of the slope of the area increasing the flow of particles to this location. Fan 221 and its surroundings also indicate long term development and fan movement along the coastline.

Fan 126, shown in Figure 4c, like Fan 69, appears to have formed in the U-shaped valley that a glacier had previously carved. This large, confined area allows for substantial amounts of sediment to build up. This process in turn creates wide, elongated fan shapes that are tucked farther into the island. These glacial valleys were also more likely to have several other alluvial fans along the steep sides. At the bottom of Figure 4c, Fan 125 and 127 are also pictured. Fan 126 that had formed in the middle of the valley had a diameter of 4.00 km, while the fans on the edges had a measured diameter of less than 0.5 km. In similar fan examples, the inside of the glacial valleys were often filled with smaller alluvial fans throughout the inner sections of these valleys.

Conclusion

The arctic fans of Svalbard each show unique alluvial features that are caused by the freezing and thawing cycles that the region experiences. The alluvial fans in this study ranged in size from less than a kilometer to over five kilometers in diameter. Many of these fans displayed asymmetrical geometries consistent with alongshore transport. Although there were limitations to the satellite imagery used and the identification of some features, the arctic fans documented are useful Earth analogs for the study of other planets and their paleoclimate and geology. From this data, preliminary results show that fans in Svalbard record interactions between snow, ice, and overland water flow, similar to what climate models predict for fan-shaped features formed early in Mars' history.

References

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