Does the Lost Jim lava flow (Alaska) really preserve evidence of interaction with permafrost?

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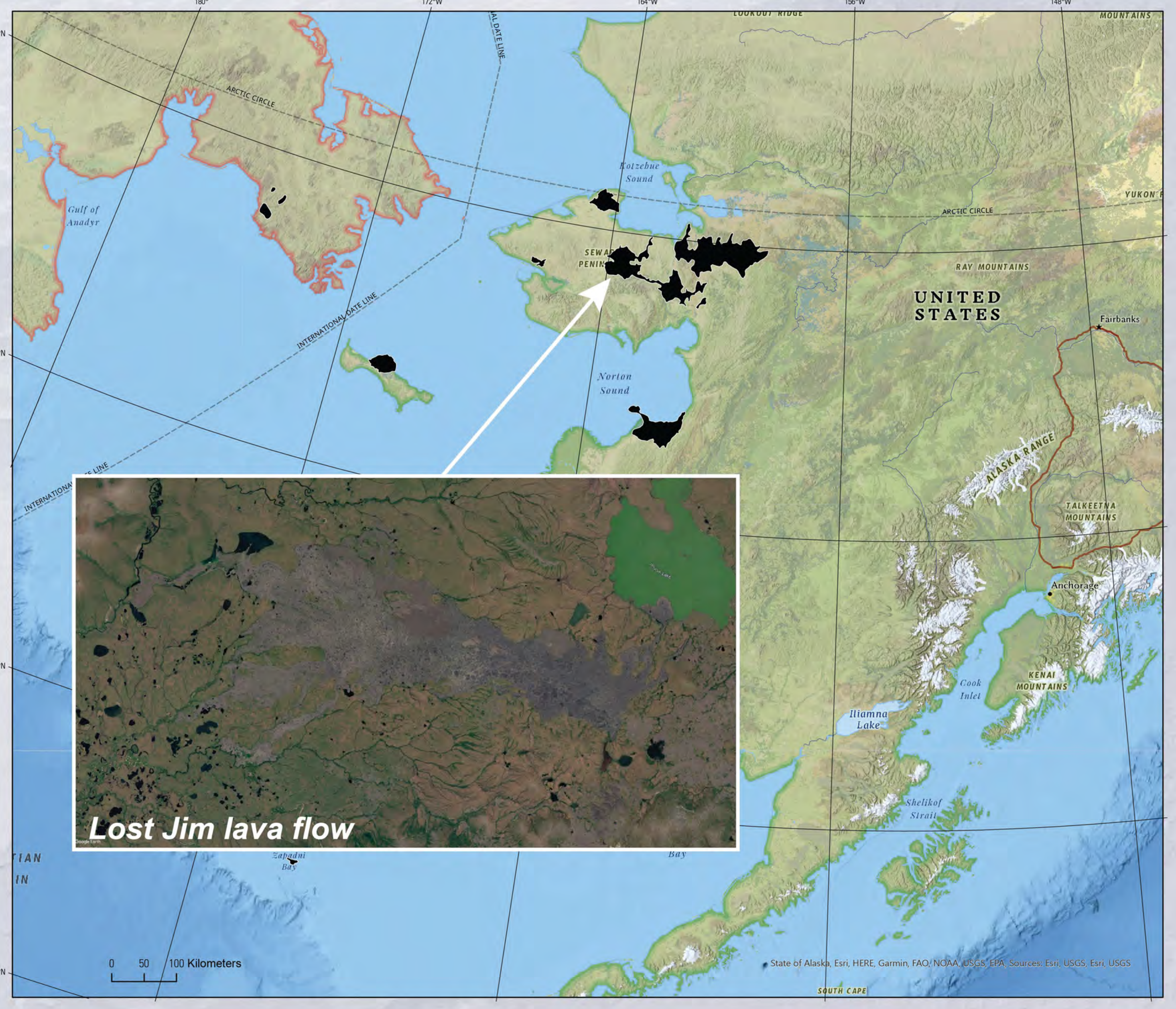
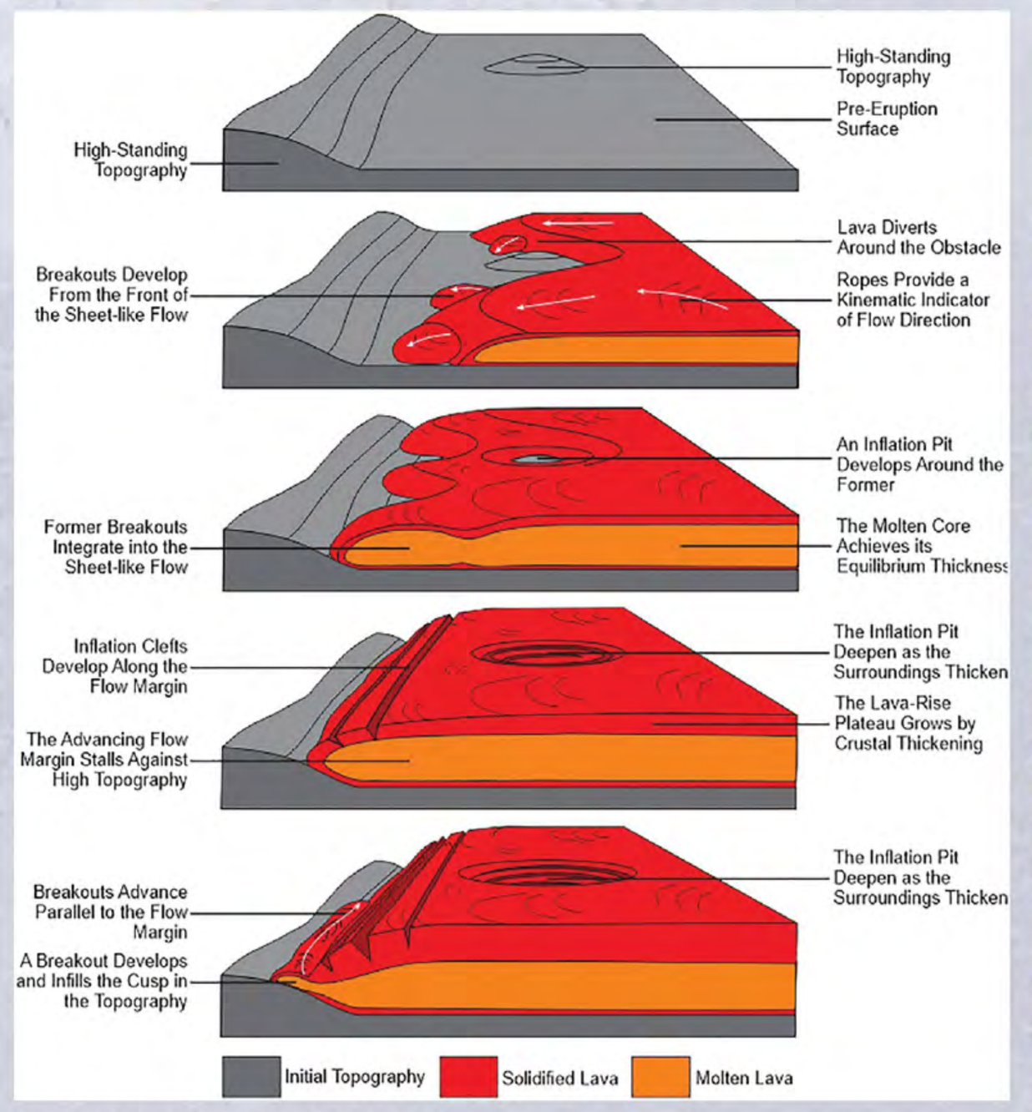
Introduction

The basaltic Lost Jim lava flow is the youngest member of the Imuruk Lake distributed volcanic field. The eruption of the well-preserved, inflated pāhoehoe lava flow is recorded in the oral history of the indigenous Iñupiaq people, and is thought to have occurred in the last few thousand years. The flow is also reported to show evidence of interaction with the underlying permafrost, forming thermokarst pits in the flow as the permafrost melted and formed cavities into which the flow top collapsed (Begét and Kargel, 2008). Our field observations, however, contradict this hypothesis. We propose instead that these are normal inflation pits (lava rise pits) since they preserve inflationary structures around their edges, like rotated surface slabs and flow banding associated with sequential brittle and ductile fracturing, both of which are hallmarks of lava flow inflation. The small diameter of many of the pits (<10 m), compared to flow thickness (at least 5–10 m), also argues against collapse—the relatively high tensile strength of a lava flow would have prevented its collapse into cavities similar in diameter to the flow's thickness. Finally, the pitted surface of the Lost Jim lava flow is similar to satellite views of many other young pāhoehoe lava flows scattered across the globe, showing that the Lost Jim flow is simply a typical inflated lava flow, and permafrost played no significant role in its surface morphology.

Location Map



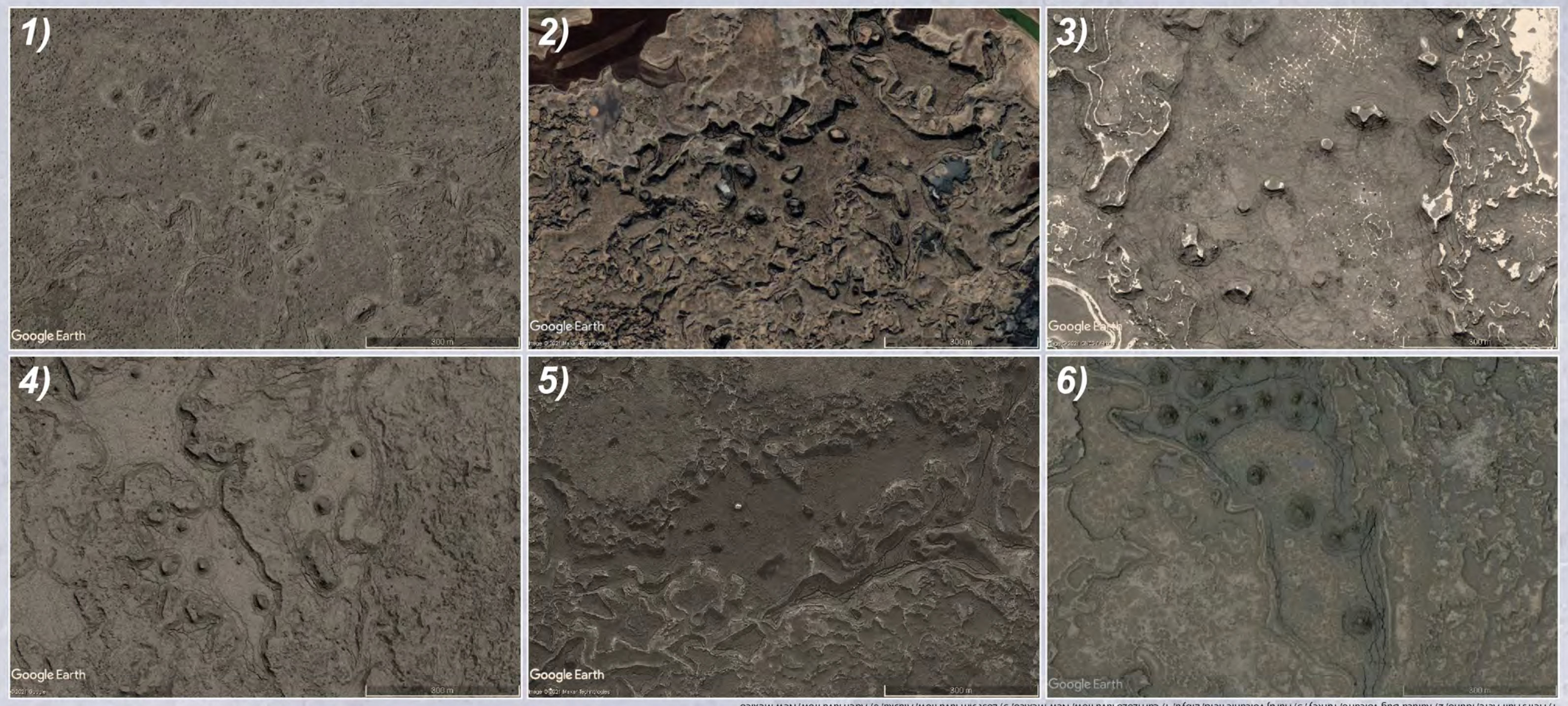
Examples of "pits" in the Lost Jim



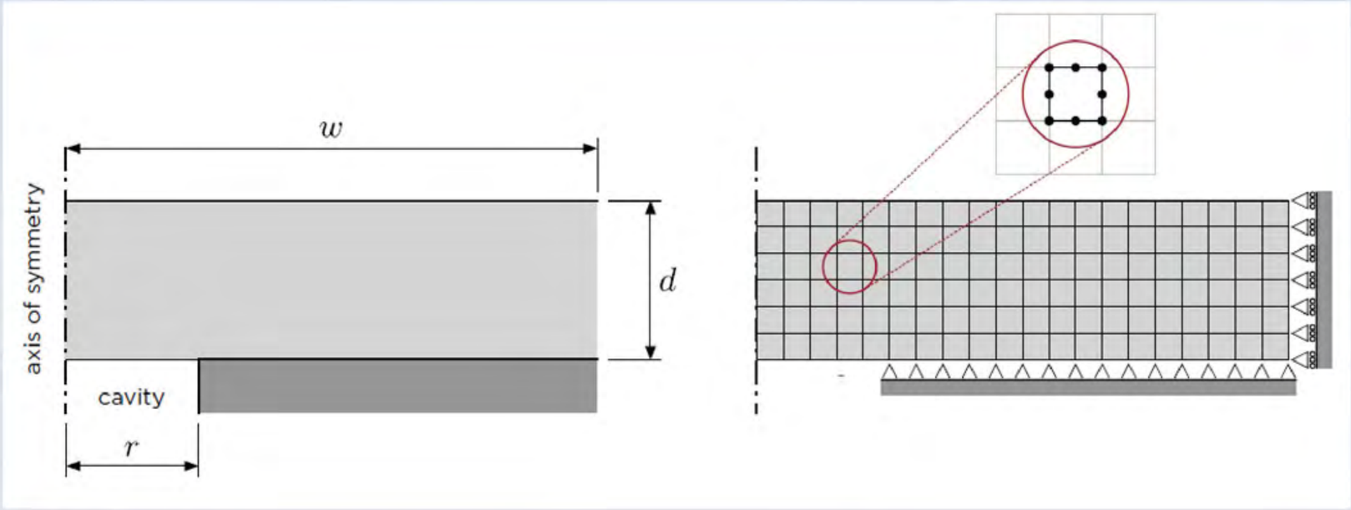
From Hamilton et al. (2020)

The Lost Jim lava flow is clearly an inflated pāhoehoe lava flow, and the "pits" identified on its surface are consistent with lava rise pits (i.e., inflation pits). Pits and depressions like these are common on inflated flow field worldwide.

Which of these is the Lost Jim lava flow?



Finite element analysis on the potential of lava pit formation



Finite element analysis was used to calculate the likelihood that a basalt lava flow like the Lost Jim flow would collapse into an underlying cavity formed by melting permafrost.

The physical problem analyzed is shown above: a basalt layer of thickness *d* is overlaid on an axi-symmetric circular cavity of radius *r*. The overall width of the basalt is *w*, and the basalt is assumed to by fully bonded with the underlying strata.

The domain was modeled using 8-noded 2-D bi-quadratic elements fully integrated using 3×3 (9-point) Gauss Legendre quadrature. The only loading considered was the self-weight of the basalt.

The Geological Strength Index (GSI) was varied from 100 to 10 to represent intact to disintegrated rock masses. The radius to thickness (*r/d*) ratio was varied from 1/2 to 4/3.

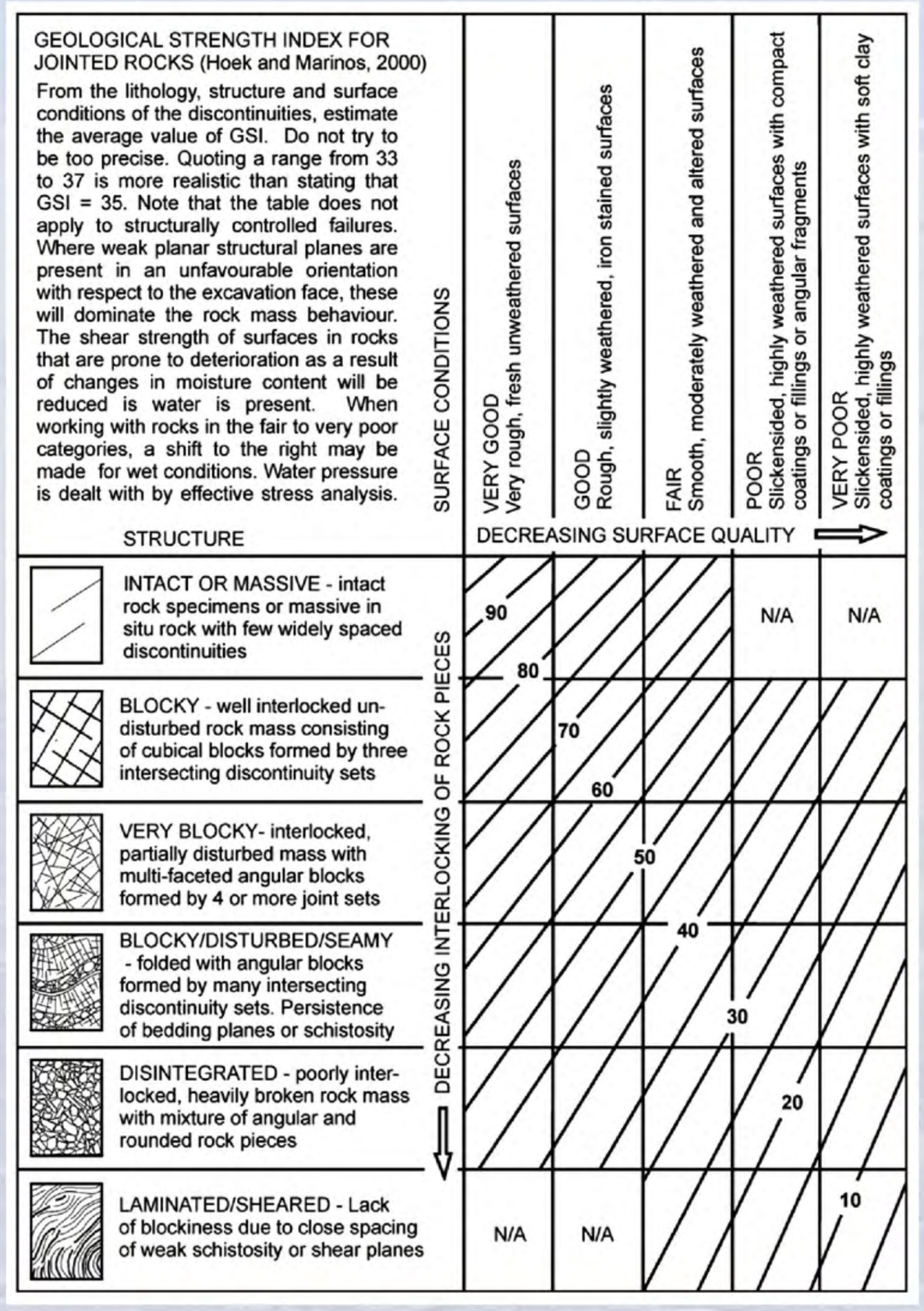


Chart for GSI estimates from geologic observations (from Marinos et al., 2005)

Geological Strength Index, GSI	radius to thickness ratio, *r/d*: 0.500	0.667	0.833	1.000	1.167	1.333
100	-	-	-	-	-	-
90	-	-	-	-	-	-
80	-	-	-	-	-	-
70	-	-	-	-	-	-
60	-	-	-	-	-	1.03×10^{-11}
50	†	2.06×10^{-11}	1.09×10^{-10}	3.49×10^{-10}	9.47×10^{-10}	1.65×10^{-9}
40	8.82×10^{-11}	7.07×10^{-10}	1.89×10^{-9}	3.39×10^{-9}	4.93×10^{-9}	6.33×10^{-9}
30	7.02×10^{-10}	2.06×10^{-9}	3.96×10^{-9}	1.74×10^{-8}	1.05×10^{-7}	3.77×10^{-7}
20	1.33×10^{-9}	1.56×10^{-8}	9.73×10^{-8}	1.35×10^{-6}	6.05×10^{-6}	1.67×10^{-5}
10	2.04×10^{-8}	1.15×10^{-6}	6.60×10^{-6}	2.20×10^{-5}	5.73×10^{-5}	1.31×10^{-4}

Table showing volume integrated plastic strains. Values in red indicate simulations where the bottom portion of the basalt would likely detach. In no instance was there a complete failure of the lava flow.

Take-away observations

It is unlikely that the basalt layer would completely collapse for any of the *r/d* and GSI conditions investigated. Thus, given the prevalence of pits in the 5–20 m diameter range observed across the flow field in areas where the flow thickness is likely at least 10 m (r/d ≤ 1), and given that the flow if fairly fresh and massive (GCI ≥ 80), then the pits observed on the Lost Jim lava flow almost certainly did not form by collapse.

Conclusion

It has been hypothesized that pits on the Lost Jim lava flow formed by collapse of the flow into cavities formed by melting of the underlying permafrost. We contest this view. The Lost Jim flow, and the pits and depressions that adorn its surface, display all the typical hallmarks of flow inflation. Moreover, finite element analysis indicates that it is exceedingly unlikely for the pits for form by collapse—a fresh basalt lava flow is simply too strong to form the relatively small pits that are seen there. Finally, a comparison of the pits on the Lost Jim flow with other inflated flow fields around the world show no significant difference. The Lost Jim lava flow is just a typical inflated flow field and shows no discernable features consistent with the interaction of the flow with the underlying permafrost.