SUPPLEMENTARY MATERIAL FOR:

Subaqueous dune field pattern evolution and interactions: North Loup River, Nebraska, USA

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SUMMARY

This document includes detailed descriptions of bedform interactions captured during the study described in the main text of this work. These interactions are depicted in Figure 2 of the main text. Also in this document are an uninterpreted image of the subaqueous dunes in the study area (Fig. S1) and a series of images similar to panels in Figure 2 of the main text. The latter can be viewed as an animation of the crestline motion if the reader steps forward or backward between pages of this PDF document (i.e., blink between time steps by advancing to the next page). Data used in this work is available at: https://github.com/GALE-Lab/Mason2020_JSR_NorthLoup

DUNE-DUNE INTERACTION DESCRIPTIONS

From time t_0 = 0 min to t_1 = 7 min (Fig. 2A – Fig. 2B)

[1] Two bedforms (light blue and light pink) combined as the faster upstream bedform collided with the downstream one. Because the morphology of the downstream bedform dominated, this interaction is characterized as a **merger** rather than a cannibalization. Four spurs were attached to the downstream (light pink) bedform, and no spurs were visible between the bedforms. This interaction reduced the number of crestlines in the field by one.

[2 & 3] A bedform (burnt orange) in close proximity to two smaller bedforms (fuschia and green) **cannibalized** these smaller bedforms. Spurs were present downstream of one of the smaller bedforms (purple), but not between the bedforms or downstream of the second cannibalized small bedform (green). After the interactions, there were two fewer crestlines.

[4] Two bedforms (dark yellow and blue) **laterally linked** as their fast-moving defects attached. After the interaction, there was one fewer crestline.

[5] An emergent bedform (light green) **split** from the off-white bedform. After the interaction, there was one additional bedform.

[6] An emergent bedform (light purple) **split** from another bedform (peach) and occupied the spur-free area upstream of the original bedform. Spurs were present on the defects of the

parent bedform (peach) but not immediately upstream of the majority of the parent bedform before the interaction, or between the bedforms after the interaction. After the interaction, there was one additional crestline.

From time t_1 = 7 min to t_2 = 15 min (Fig. 2B - Fig. 2C)

[7] The bedform resulting from interaction [2] (dashed orange-fuschia-green) **cannibalized** the defect of another bedform (red) immediately downstream. Only the defects of these bedforms combined, and no spurs were present between, above, or below the interaction lengths. Laterally, where spurs were present between the two bedforms, the cannibalization did not take place. This interaction did not change the overall number of crestlines.

[8] Two bedforms (teal and burnt orange) **laterally linked** as their two defects in close proximity combined. There was one fewer crestline as a result of this interaction.

[9] The nose of the teal crestline intersected the defect of the pink crestline, causing a **defect repulsion**. This is a unique example of this interaction because it was the *upstream* defect that was repulsed. The region in which these interactions occurred was devoid of spurs except one above the attaching bedform (light purple), which was not disrupted by the migrating defects. There was no net change in the number of crestlines as a result of this interaction.

[10] A new bedform (dark red) **split** from the northern-most end of the bedform linked in [4] (blue). One spur was present upstream of the parent bedform (blue) before the interaction and was present but shortened after the new bedform is split off. There was one additional crestline after the interaction.

From time t_2 = 15 min to t_3 = 23 min (Fig. 2C - Fig. 2D)

[11] The crestline split in [6] (light purple) **cannibalized** its parent dune (peach) along half of its length and left behind a small defect from the remaining crestline. Two spurs were present downstream of the parent dune (peach) and no spurs were present between the two interacting bedforms. There is no change in the number of crestlines following the interaction.

[12] The cannibalized bedform from [11] (dashed light purple and peach) and the adjacent bedform (red) **laterally linked**. Spurs were present on the adjacent bedform (red) but not along the length of the interactions. There is one fewer crestline after the interaction.

[13] The defect of a the bedform linked in [4] (dark yellow and blue) **laterally linked** with the defect of a small bedform (light brown). No spurs were present on the small bedform, and the nearest spur on the long bedform was away from the length of bedform over which the interaction occurred. One spur was present just upstream of the interaction and remained after the interaction took place. There was one fewer bedform following the interaction.

[14] An emergent bedform (green) **split** off of the long orange bedform. There were no spurs present near the space involved in the interaction. There was one additional bedform after the interaction.

From time t_3 = 23 min to t_4 = 31 min (Fig. 2D - Fig. 2E)

[15] A new bedform (purple) migrated into the scene from the north and cut across a small bedform (light green) causing a **defect repulsion**. No spurs were present around the impacting bedforms and only two spurs were present on the more upstream part of the dissected bedform after the interaction. There was no change in the number of crestlines as a result of the interaction.

[16] A small bedform (brown) **split** from the concave nose of one of the large bedforms in the field (maroon) and attached to another bedform (yellow) upstream. The new bedform developed in spur-free space upstream of its parent which had no spurs downstream of the interacting region. There was one additional crestline following the interaction.

[17] A small bedform (off-white) **split** from a long bedform (dark yellow). Spurs were absent in the region where the new bedform formed and downstream of the parent bedform over this length, but laterally spurs were present on either side of this interaction. There was one additional crestline after the interaction.

[18] The dark red bedform from [10] (dark red) is obliterated due to **human interference**. There was one fewer bedform following this event.

[19] The defect of a small bedform (green) caught up to a larger bedform (orange), disrupting the bedform and causing a **defect repulsion**. No spurs were present in the vicinity of this interaction. There was one additional crestline following the interaction.

[20] A **defect creation** occurred on the downstream portion of the long orange bedform. There were no spurs immediately upstream or downstream of the interaction, however spurs were present laterally. There was one additional crestline following this interaction.

[21] A small olive green crestline lost definition and became dispersed in place. Images between t_3 and t_4 show the small bedform did not merge or cannibalize, but dissipated along with the attached spurs. The material from this bedform was presumably transported downstream and incorporated into other bedforms, making this an example of **remote transfer**. This was the only example of this interaction type captured. There was one fewer crestline following this interaction.

From time t_4 = 31 min to t_5 = 38 min (Fig. 2E - Fig. 2F)

[22] A bedform (beige) near the edge of the scene cross cut another crestline (maroon) initiating a **defect repulsion**. There were spurs present on the downstream, maroon bedform. There was no change in the number of crestlines as a result of the interaction.

[23] The small bedform created in [16] (brown) **merged** with another bedform immediately upstream (yellow). No spurs were present between the interacting lengths of the two bedforms, but one spur was present immediately adjacent to the two non-attached defects. After the interaction, several spurs were present upstream of the merged length. Following the interaction, there was one fewer crestline.

[24] An upstream bedform (yellow) and downstream bedform (light blue) with overlapping defects **laterally linked** by combining defect arms. The space between and upstream of the interacting defects was devoid of spurs, and two spurs were present downstream of the interaction. There was one fewer crestline after the interaction.

[25] The light gray crestline **split** off of the dashed orange-green-red crestline resulting from [5] and [2] (dashed orange-green-red). In this instance, an upstream spur terminated at the location of the split. There was one additional crestline following this interaction.

[26] The light blue crestline split during [25] impacted the orange-green-purple crestline, causing a **defect repulsion**. This interaction was confirmed using photos at intermediate time steps not shown in Fig. 4. There was no net change in the number of crestlines following this interaction.

[27] Two sections of the orange crestline separated during [20] rejoined via a **lateral link**. There was one fewer crestline as a result of this interaction.

[28] The convex nose of the small bedform created in [17] (off-white) **merged** with the immediately downstream bedform (dark yellow). Spurs were present both upstream and downstream following the interaction. This merger produced one additional crestline since the two defects of the off-white crestline could no longer be considered part of the merged crestline. This merger also formed the initial stage of a bedform repulsion, which occurred over the next ~10 minutes (finishing at time t_7). Throughout these next ~10 minutes, both the convex nose and southernmost defect arm of the upstream bedform (off-white) attached to the downstream bedform (dark yellow), creating two points of dissection and ejecting a coherent small dune which migrated separately downstream. Additional intermediate interactions which constitute the overall bedform repulsion will be documented below.

From time t_5 = 38 min to t_6 = 45 min (Fig. 2F - Fig. 2G)

[29] The bedform resulting from [23] (dashed yellow-brown) **laterally linked** with the defect of another bedform in close proximity (light green). The space closed by the defects of these two bedforms was devoid of spurs, but spurs were present laterally on the upstream side of the merged bedform (dashed yellow-brown), and laterally on the downstream side of the other bedform (green). There was one fewer bedform as a result of this interaction.

[30] The bedform cross cut in [15] (light green) **laterally linked** its two divided parts to reform the crestline. No spurs were present in the space across which the interaction occurs, but four spurs were attached to the more upstream segment. There was one fewer crestline following this interaction.

[31] The lavender crestline **split** off of the downstream teal crestline. Spurs were present both upstream and downstream of the interaction at both time steps. There was one additional crestline as a result of this interaction.

[32] The dark blue crestline **split** from the light blue portion of the crestline that linked in [24]. There were spurs present upstream of the interaction area prior to the interaction, and upstream and downstream following the interaction. There was one additional crestline as a result of this interaction.

[33] The small bedform (light purple) that constituted the unmerged portion of [11] re-attached to its original parent bedform (peach) from [6] in two places, causing a **bedform repulsion**. Spurs were absent in the space between the bedforms during the initial stage of the interaction, but two spurs formed between the impacting bedform (light purple) and the ejected bedform (peach) as the interaction occurred. There was no net change in the number of crestlines as a result of this interaction.

[34] A **defect creation** occurred along the dashed burnt orange-purple crestline. Spurs were attached to the bedform at the beginning of the interaction, and were present both upstream and downstream of the bedform following the defect creation. There was one additional crestline as a result of this interaction.

[35] The defect created in [26] (dashed burnt orange-green) **merged** with the immediately downstream bedform (red). One spur was present lateral to this interaction, and several spurs were present upstream after the merger, but no spurs occurred between the bedforms over the crestline length of the interaction. There was one fewer crestline as a result of this interaction.

[36] A **defect creation** occurred on the yellow crestline at the southern end of the merged crestline from [28]. This interaction did not create any additional crestlines, and is another intermediate interaction constituting the overall bedform repulsion that began in [28].

[37] A **defect creation** occurred in a long crestline (dark yellow). The defect was created just lateral to three spurs on the bedform which are not present in the next frame. This interaction created one additional crestline.

From time t_6 = 45 min to t_7 = 49 min (Fig. 2G - Fig. 2H)

[38] A **defect creation** occurred at the location where the peach and teal crestlines were previously joined in [9]. There were spurs upstream and downstream of the interaction in both time steps. There was one additional crestline as a result of the interaction.

[39] The bedform created in [31] (lavender) **laterally linked** with another bedform (burnt orange) across a spur-free zone in the field. Both time steps had spurs upstream of the interaction. There was one fewer crestline as a result of the interaction.

[40] The defects created in [34] (dashed burnt orange-purple) **laterally linked** to reform the crestline. There were adjacent downstream spurs on both defects prior to the interaction. There was one fewer crestline as a result of the interaction.

[41] A defect of the off-white crestline from [17, 28, 36] impacted the dark yellow crestline causing a **defect repulsion**. This was the final intermediate interaction that completes the bedform repulsion initiated in [28]. There were adjacent spurs present before and after the interaction, and a downstream spur formed off of the ejected bedform. There was no change in the number of crestlines.

[42] The defect created in [37] (dark yellow) **laterally linked** with the merged bedform resulting from [2,3,7] (dashed burnt orange-red-green). Defects of each bedform closed the intervening spur-free space. There were several spurs upstream of the interaction. There was one fewer crestline as a result of the interaction.

[43] A new crestline (white) **split** from the light green bedform. There were adjacent spurs in both time steps, but none in the immediate vicinity of the interaction area. There was one additional crestline as a result of this interaction.

[44] The light gray crestline from [25,26] underwent a **defect creation**, separating it from the dashed orange-purple crestline. There were upstream spurs present before and after the interaction. There was one additional crestline as a result of this interaction.

From time t_7 = 49 min to t_8 = 56 min (Fig. 2H - Fig. 2I)

[45] A new bedform defect migrated into the scene (pink) and impacted a bedform (brown) causing a **defect repulsion**. There were no visible spurs in the vicinity of the interaction. There was no net change in the number of crestlines due to the interaction.

[46] The nose of the recently linked light green-yellow-brown crestline [29] **merged** with the downstream maroon crestline. There were upstream spurs present in both time steps. Similar to [28], the nose-driven merger increased the total number of crestlines by one because the defects to either side of the nose remained unmerged and could no longer be considered one continuous crestline.

[47] The small bedform (peach) ejected in [33] impacted the downstream bedform (blue-yellow) linked in [4] causing a **defect repulsion**. The impacting defect arm migrated across a zone devoid of spurs to reach the downstream crestline, and the two spurs that were present between the small bedform and downstream target were ephemeral. There was no change in the number of crestlines as a result of this interaction.

[48] The defect of the orange crestline partially **cannibalized** the bright green crestline. There were upstream spurs present in both time steps. There was one fewer crestline as a result of this interaction.

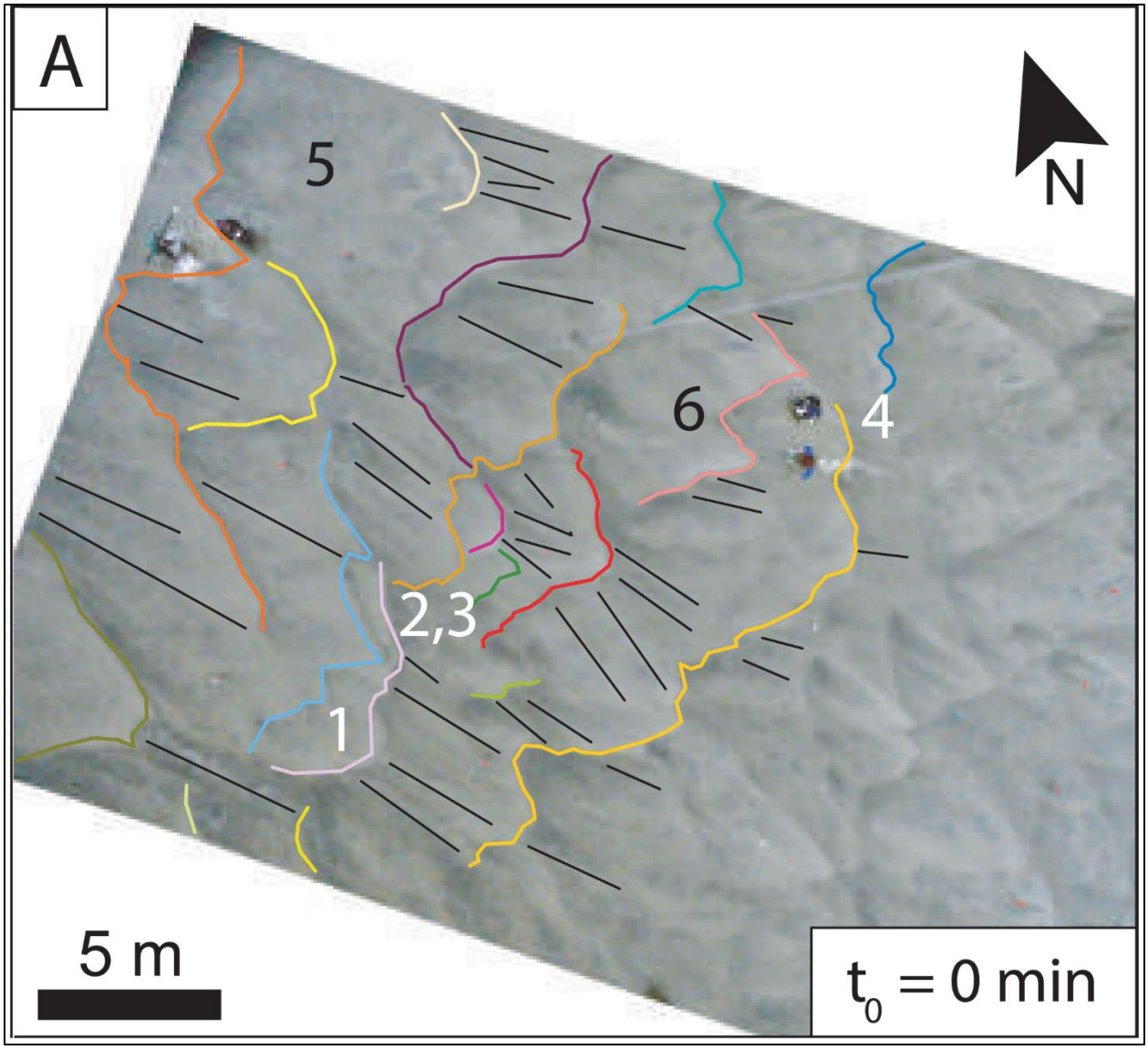
[49] The defect of the light blue-light pink crestline was **cannibalized** by the upstream orange crestline. There were spurs adjacent to the interaction in both time steps. There was one fewer crestline as a result of the interaction.

[50] The light gray crestline from [44] **laterally linked** with the crestline it was previously attached to (dashed orange-purple). Upstream spurs were present both before and after the interaction. There was one fewer crestline as a result of the interaction.

Figure S1: A raw image from t_0 of subaqueous dunes in the study area. Dune crests in the images are visible as dark curves where the water deepens and dark heavy mineral grains are more concentrated. Compare this image with Figure 2A in the main text or Figure S2 below. Researchers in the frame show the scale of the image and red points in the image are static across the study duration and were used as control points to georeferenced images.

DUNE MIGRATION

Each of the following pages shows one time-step in the crestline tracking shown in Figure 2 of the main text. To move between time steps, simply advance the PDF to the next page. All images have been georeferenced to overlap and apparent motion represents the motion of the dunes.


A
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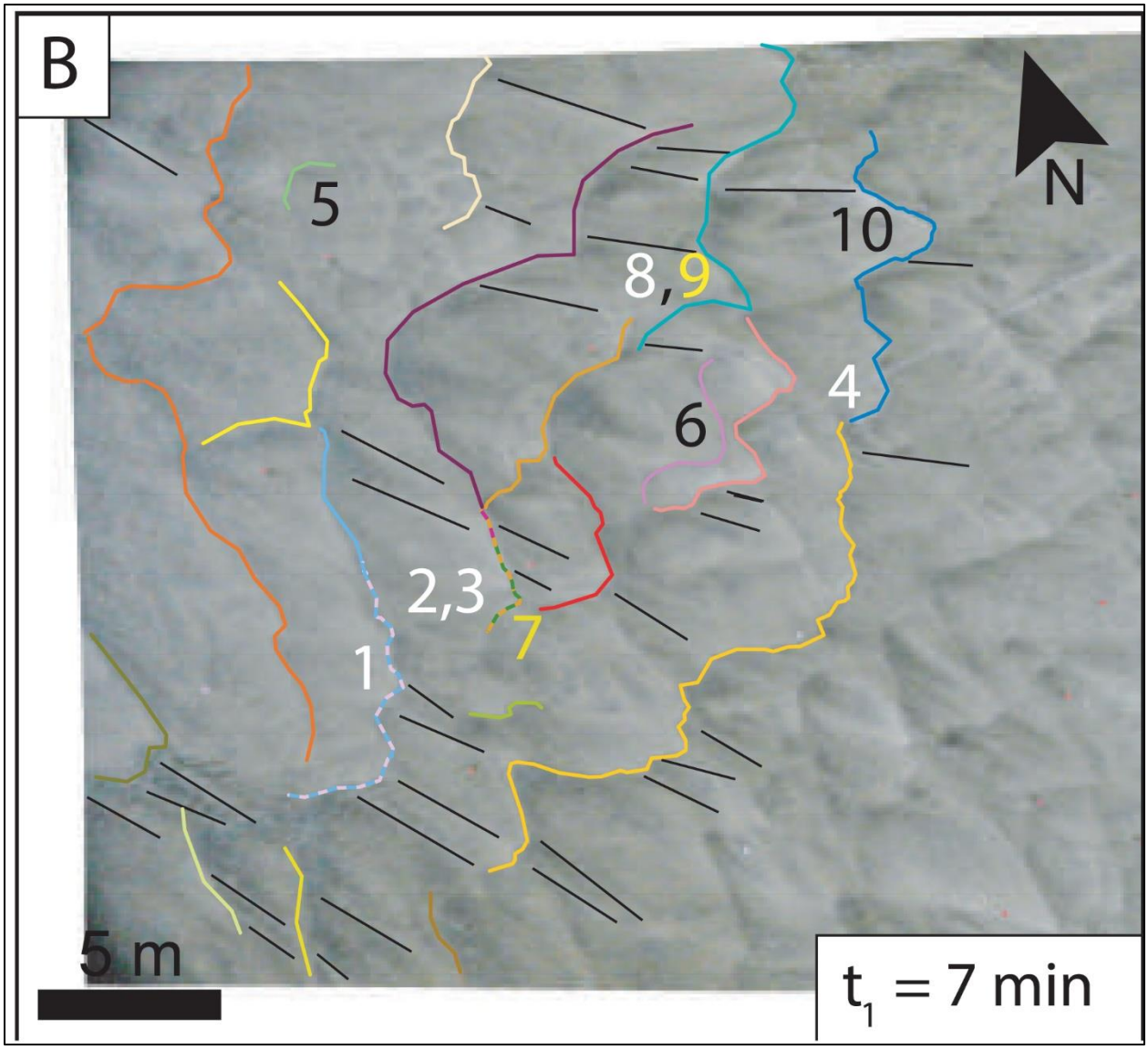
6
4
2,3
1
5 m
t_0 = 0 min


B
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10
8,9
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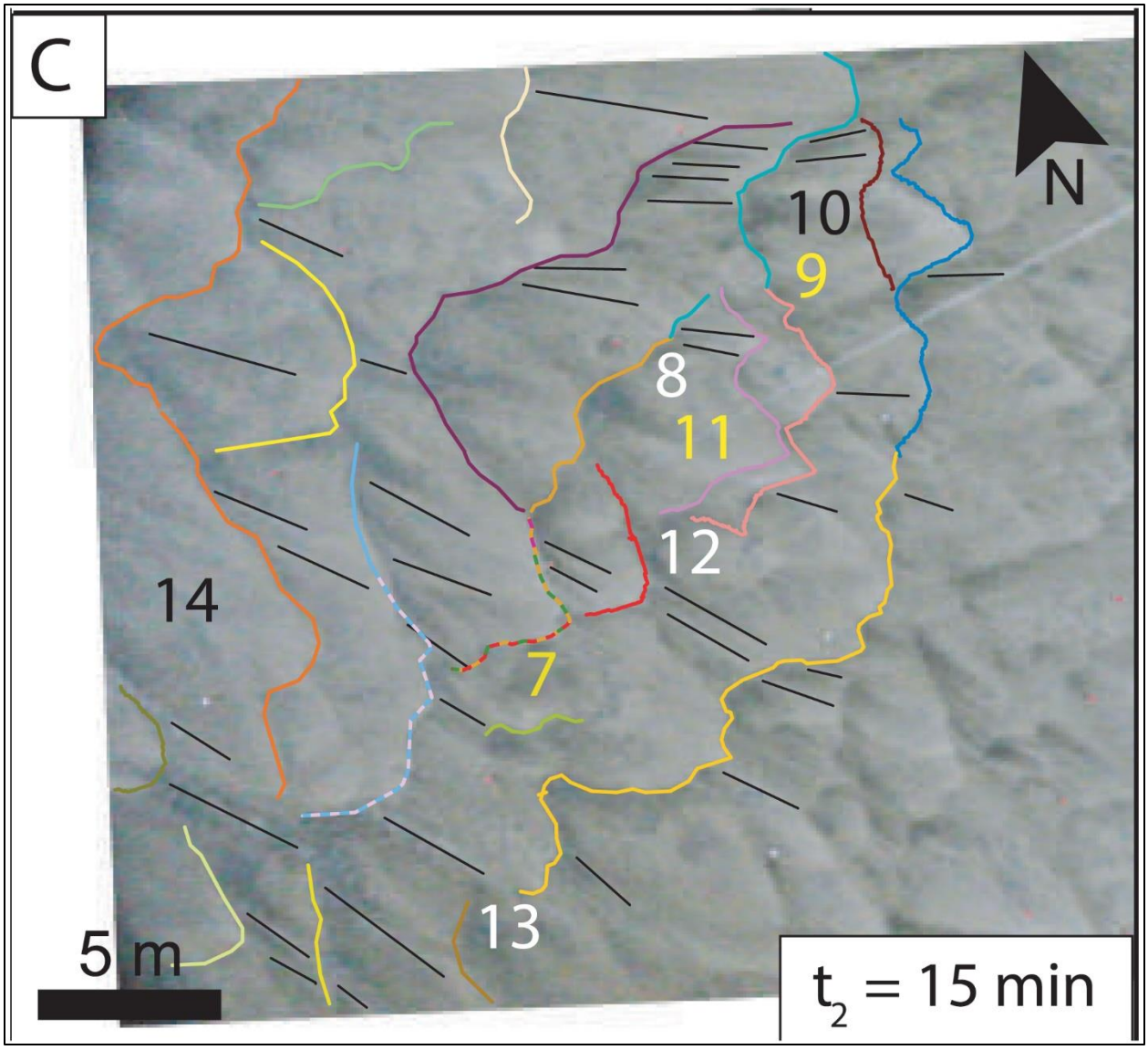
5 m
t1 = 7 min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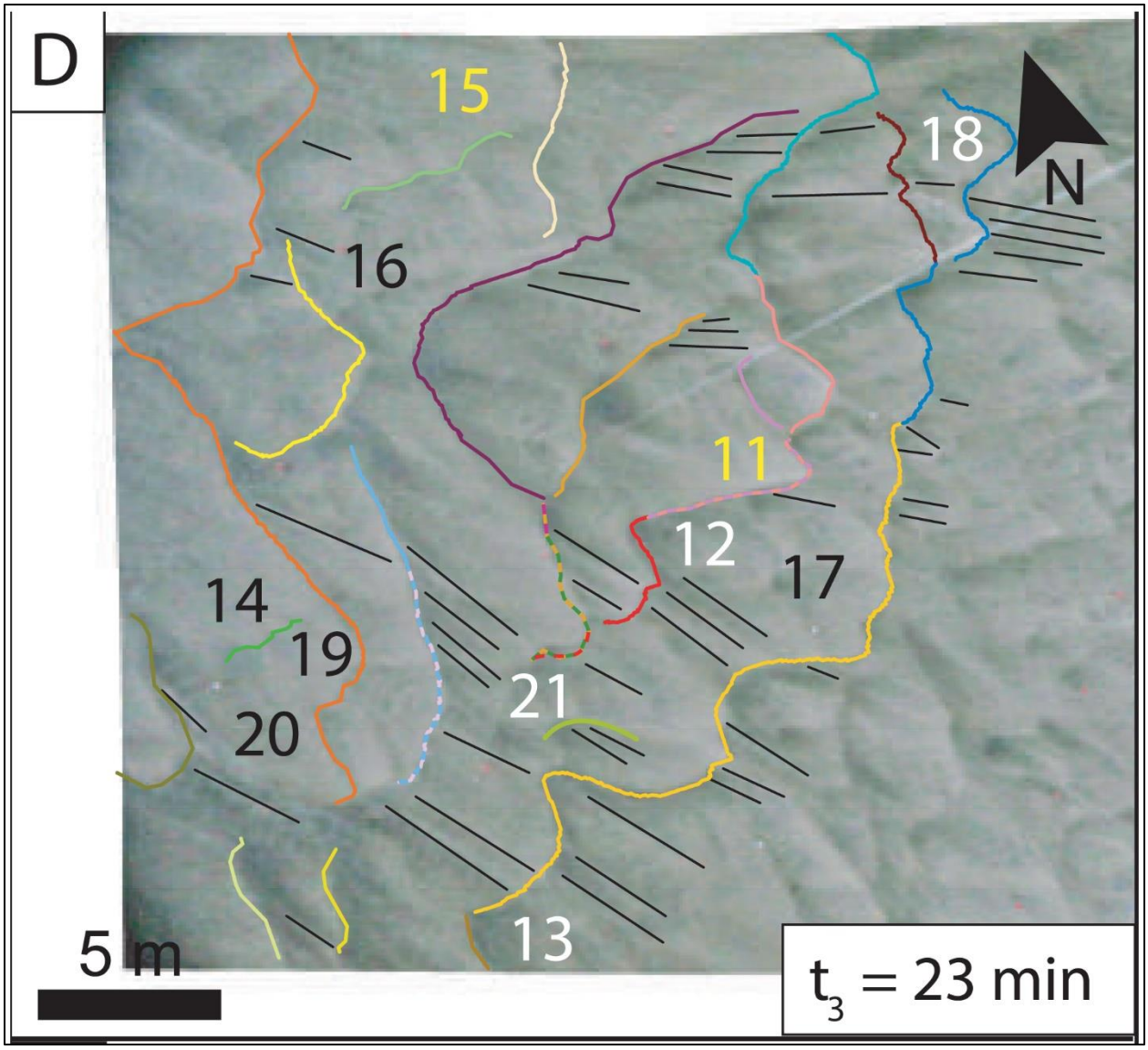
5 m
t_2 = 15 min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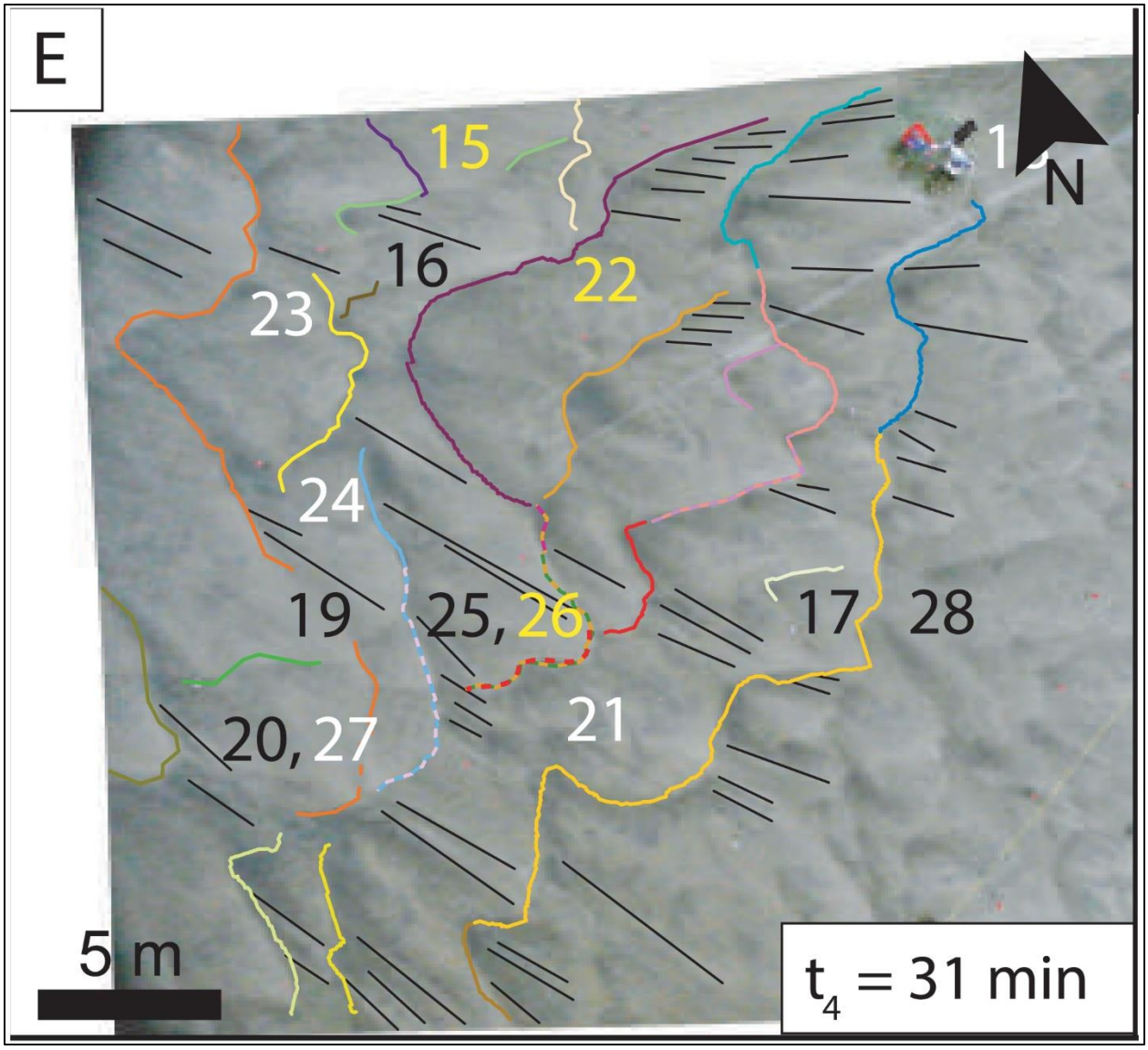
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21
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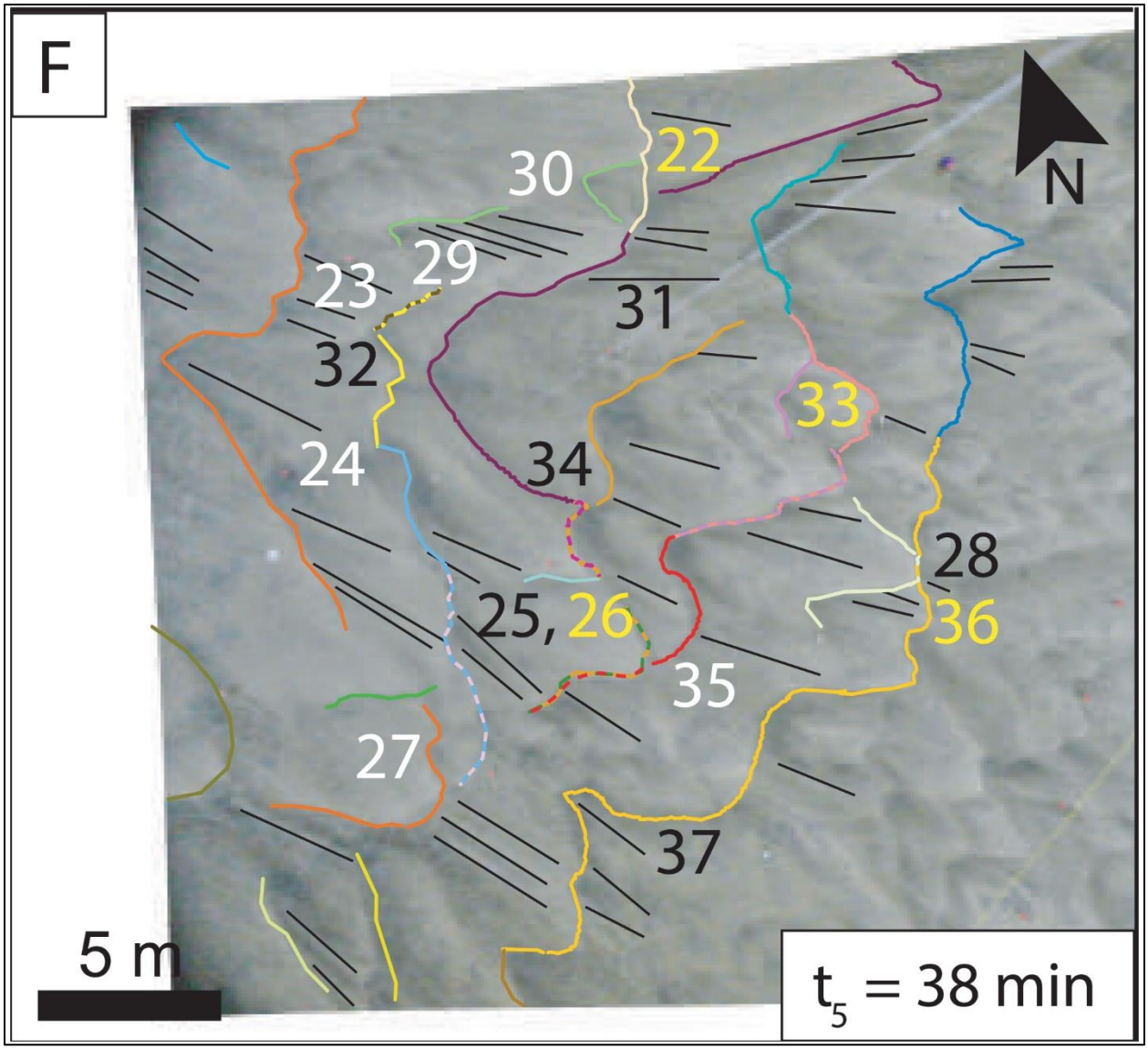
5 m
t_4 = 31 min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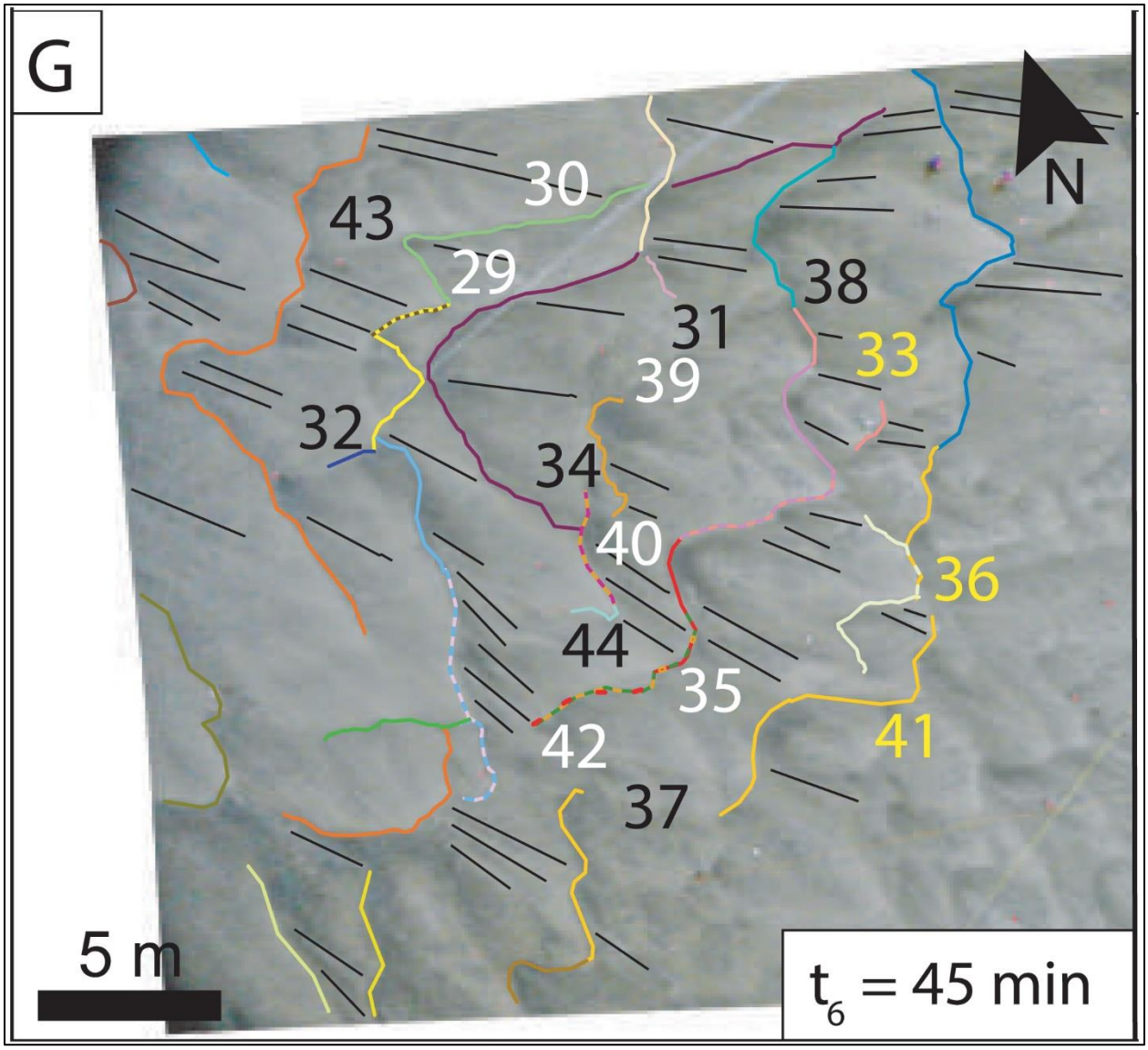
t_5 = 38 min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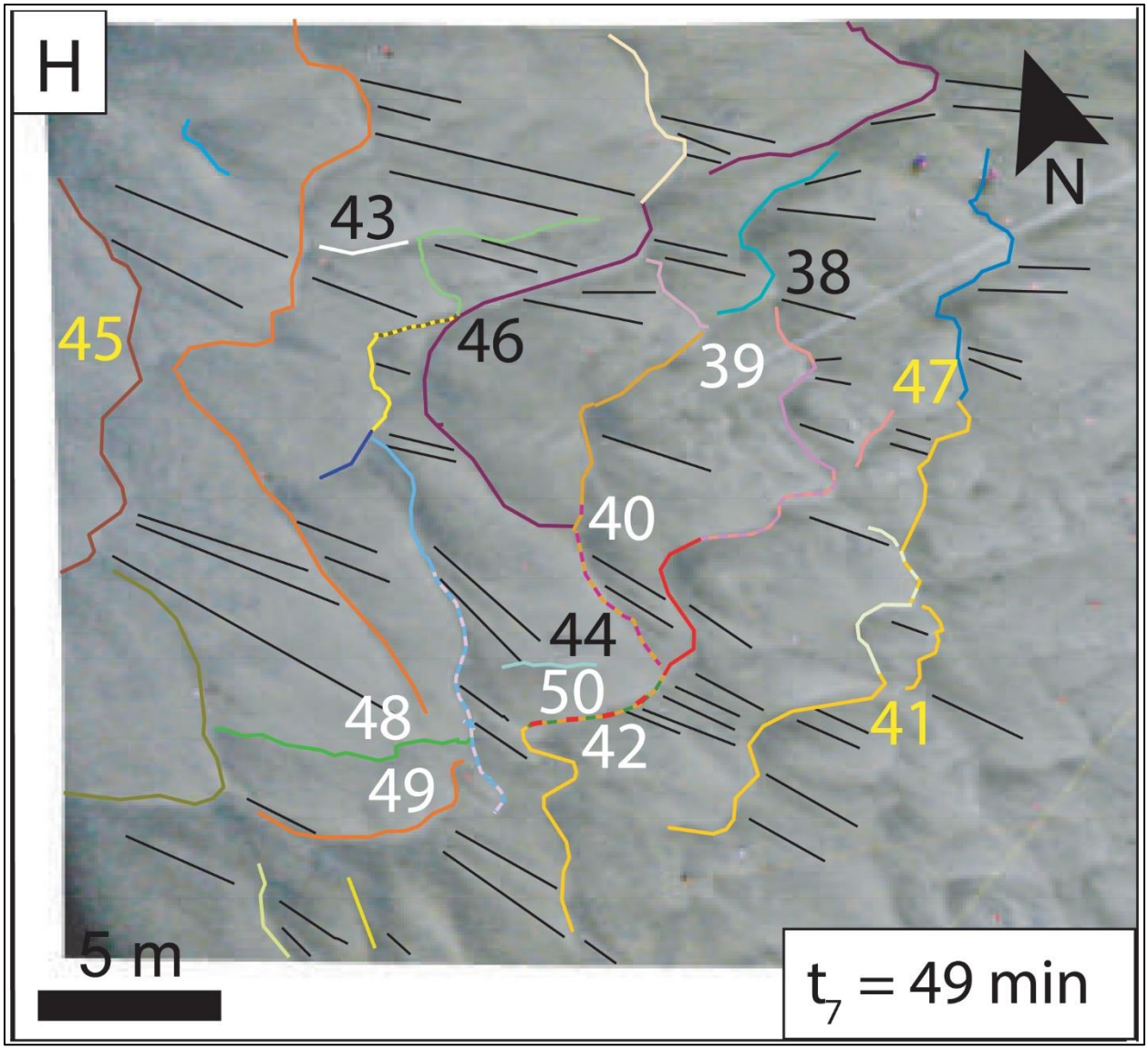
t_6 = 45 min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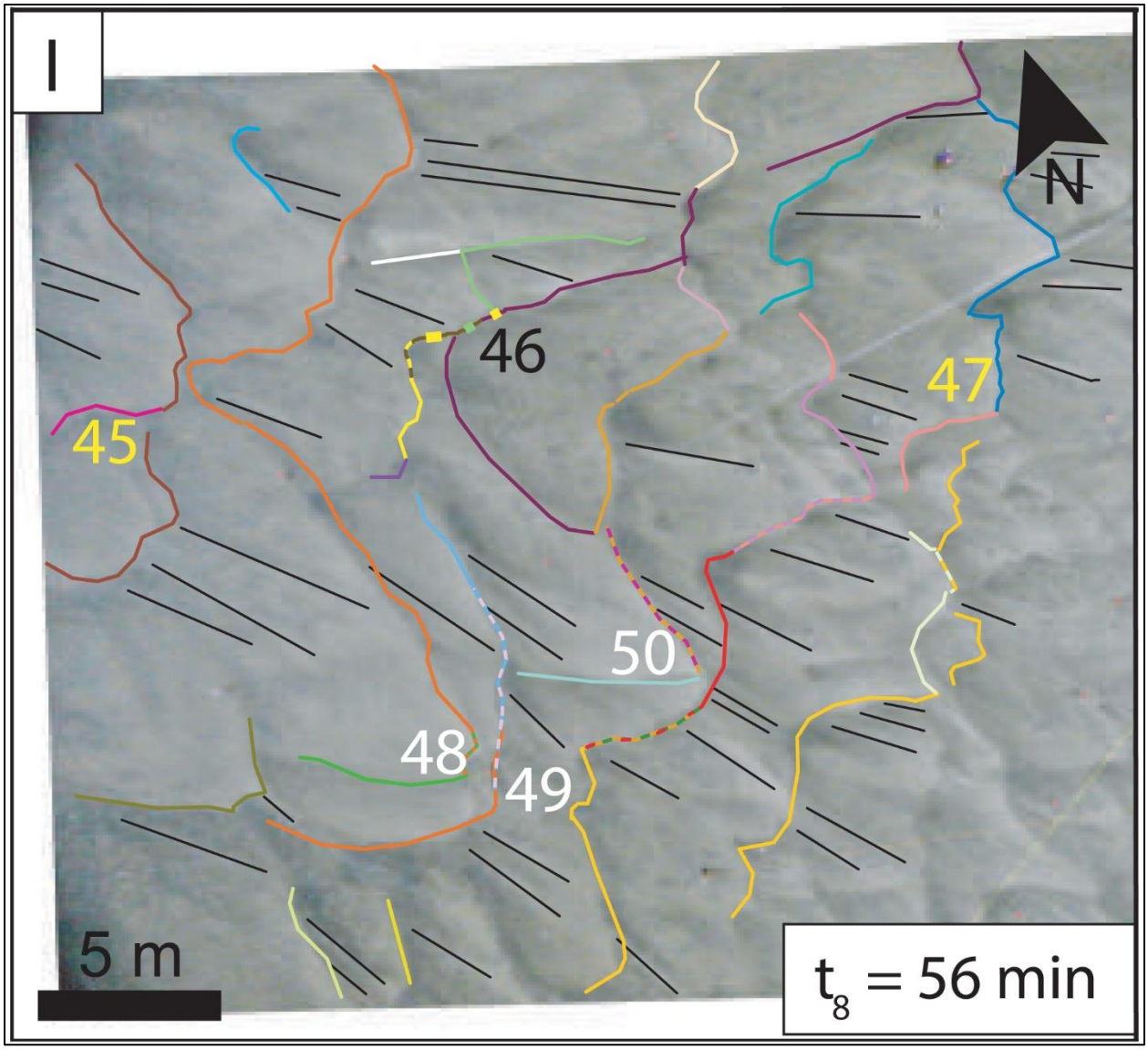
t_7 = 49 min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5 m
t_8 = 56 min