National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594

HWY22MH003

MATERIALS LABORATORY

Factual Report 23-011

March 14, 2023

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A. ACCIDENT INFORMATION

Location: Pittsburgh, Pennsylvania
Date: January 28, 2022
Vehicle: Fern Hollow Bridge
Investigator: Dennis Collins (HS-22)

B. COMPONENTS EXAMINED

Fractures surfaces on the top ends of two bridge legs.

C. EXAMINATION PARTICIPANTS

Specialist Adrienne Lamm
National Transportation Safety Board
Washington, D.C.

D. DETAILS OF THE EXAMINATION

1.0 Introduction and Structure Terminology

On Friday, January 28, 2022, about 6:37 a.m. eastern standard time, the Fern Hollow bridge, which carried Forbes Avenue over the north side of Frick Park, in Pittsburgh, Allegheny County, Pennsylvania, experienced a structural failure. As a result, the 447-foot-long bridge fell approximately 100 feet into the park below.

The bridge superstructure was a frame-floorbeam-stringer system with two parallel lines of rigid "K" frames. Each frame was comprised of three-span, continuous welded I-shaped steel girders, and two inclined, welded steel I-shaped legs. The structure was unique in that the legs were bolted to I-girders. The entire superstructure was made from uncoated weathering steel plates. The ends of the girders rested on reinforced concrete caps on stone masonry abutments, and each leg rested atop reinforced concrete thrust blocks. The bents of the bridge referred to the legs and thrust blocks, taken together with their associated cross bracing.

Figure 1 shows a plan view composite photo of the collapsed structure with the locations of the legs underneath the structure outlined and labeled. The bridge legs were individually labeled according to bent number and bridge side. The first index of the naming convention is “B” for bent. The second index is the numeric “1” or 2”, meant to indicate the first and second bent away from the near abutment. The final index is the letter “L” or “R”, representing left or right when looking east from the near abutment. Thus, B1R refers to the leg in bent 1 on the right side of the bridge.

In Figure 1, the plan view composite photo is compared to schematics in plan view and elevation view orientations, with the components of the bridge labeled consistent with the latest bridge inspection report.[1] Figure 2 shows the plan view composite photo of the collapsed structure relative to the elevation view schematic, with each leg identified.

The bridge legs were a built-up I-shape cross-section configuration of web plate bracketed by flanges. The width of bridges legs tapered slightly from the top down, with a second, sharper taper resulting in a trapezoidal-shaped shoe at the bottom of the leg. The width of the flanges was oriented perpendicular to the direction of the girders, with the web plate perpendicular to the width of the flanges. The "K" frame design results in legs that are non-orthogonal at the intersection with the girders at the top of the structure when viewed in profile. The angles the legs form with the girders are thus identified as an acute angle and an obtuse angle. A schematic showing the outward facing side of a leg mating with a girder is shown in Figure 3.

2.0 Fracture Surface Location and Retrieval

While on-scene, investigators observed fracture surfaces at the end plates on the tops of legs B1R and B2L where they connected to the girders. The fracture surface on leg B1R was visible outside the collapsed structure; the fracture occurred transversely through the span 2 side flange at the weld above a cable connection point on the leg, as shown in Figures 4 and 5. The weld on the span 2 side was at the obtuse angle of leg B1R. The fracture surface on leg B2L was visible underneath the collapse structure, as shown in Figures 9 and 10. The fracture on leg B2L was transverse through the span 3 side flange weld also above a cable connection point on the leg. The weld on the span 3 side was at the acute angle of leg B2L.

Both fracture surfaces had relatively flat sections with a line of heavily oxidized features directly adjacent to the flange faces. Inboard of the relatively flat area, the leg B1R fracture surface curved towards the external face of the span 2 flange, as indicated by the blue dotted arrow in Figure 6. Inboard past the relatively flat area on leg B2L, the fracture surface thrust outward, then changed progression direction again to jut inwards towards the internal flange face. The blue dotted arrow in Figure 10 traces the general z-shape of the profile of the leg B2L fracture surface.

The legs were uncovered and removed to an evidence staging area as documented in NTSB Materials Laboratory Factual Report 23-009. The fracture surfaces were torch cut from the legs along the lines indicated by the white arrows in Figure 6 for leg B1R and Figure 11 for leg B2L. The fracture surfaces were coated in grease to prevent further oxidation and the pieces were wrapped in foam to prevent

[1] "2021 Routine Bridge Safety Inspection Report, City of Pittsburgh, Allegheny County, Forbes Avenue over Fern Hollow and Nine Mile Run" by Gannett Fleming, Inc.

damage during shipment. Both pieces were then transported to the NTSB Materials Laboratory in Washington DC for further examination.

3.0 Fracture Surface Examination

At the NTSB Materials Laboratory, the pieces were further sectioned to remove bulk material and allow for easier handling during examination. The fracture surfaces were soaked in Evapo-Rust® (CRC Industries, Horsham PA) heavy duty rust remover, cleaned with mild liquid detergent and a soft bristle brush, and then rinsed with methanol. This process was repeated several times, until no further change was observed in the appearance of the fracture surfaces.

After cleaning, the fracture surfaces were examined optically and under magnification using stereomicroscopy. The line of heavily oxidized features on the fracture surfaces directly adjacent to the flange faces lightened but were not completely removed by the cleaning. Ridges[2] perpendicular to the flange face were observed between cleavage facets within the line of heavily oxidized features on both fracture surfaces, as indicated by the green arrows in Figures 7 and 8 for leg B1R and Figure 12 for leg B2L.

Multiple crack progression marks consistent with an advancing crack front were visible on the fracture surfaces. The crack progression marks were observed within the line of heavily oxidized features, as well as further inboard from the flange faces. The crack progression marks further inboard of the flange faces had varying levels of oxidation. The crack progression marks on the leg B1R and leg B2L fracture surfaces are indicated by the yellow brackets in Figures 7 and 8; and Figure 12, respectively. Between the crack progression marks, the fracture surface features were rough and consistent with overstress. Such features were particularly visible under side lighting conditions, as demonstrated in Figure 8.

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[2] Dennis McGarry, Mechanisms and Appearances of Ductile and Brittle Fracture in Metals, Failure Analysis and Prevention, Vol 11, 2021 ed., ASM Handbook, Edited By Brett A. Miller, Roch J. Shipley, Ronald J. Parrington, Daniel P. Dennies, ASM International, 2021, p 304–342.

The remaining areas on the transverse fracture surfaces past the crack progression marks (indicated by the orange arrows in Figures 7, 8, and 12) were minimally oxidized, with rough features consistent with overstress. The additional fracture surfaces through the length of the flange and web on leg B2L also had rough features consistent with overstress, as shown in Figure 13.

Submitted by:

Adrienne V. Lamm
Materials Engineer

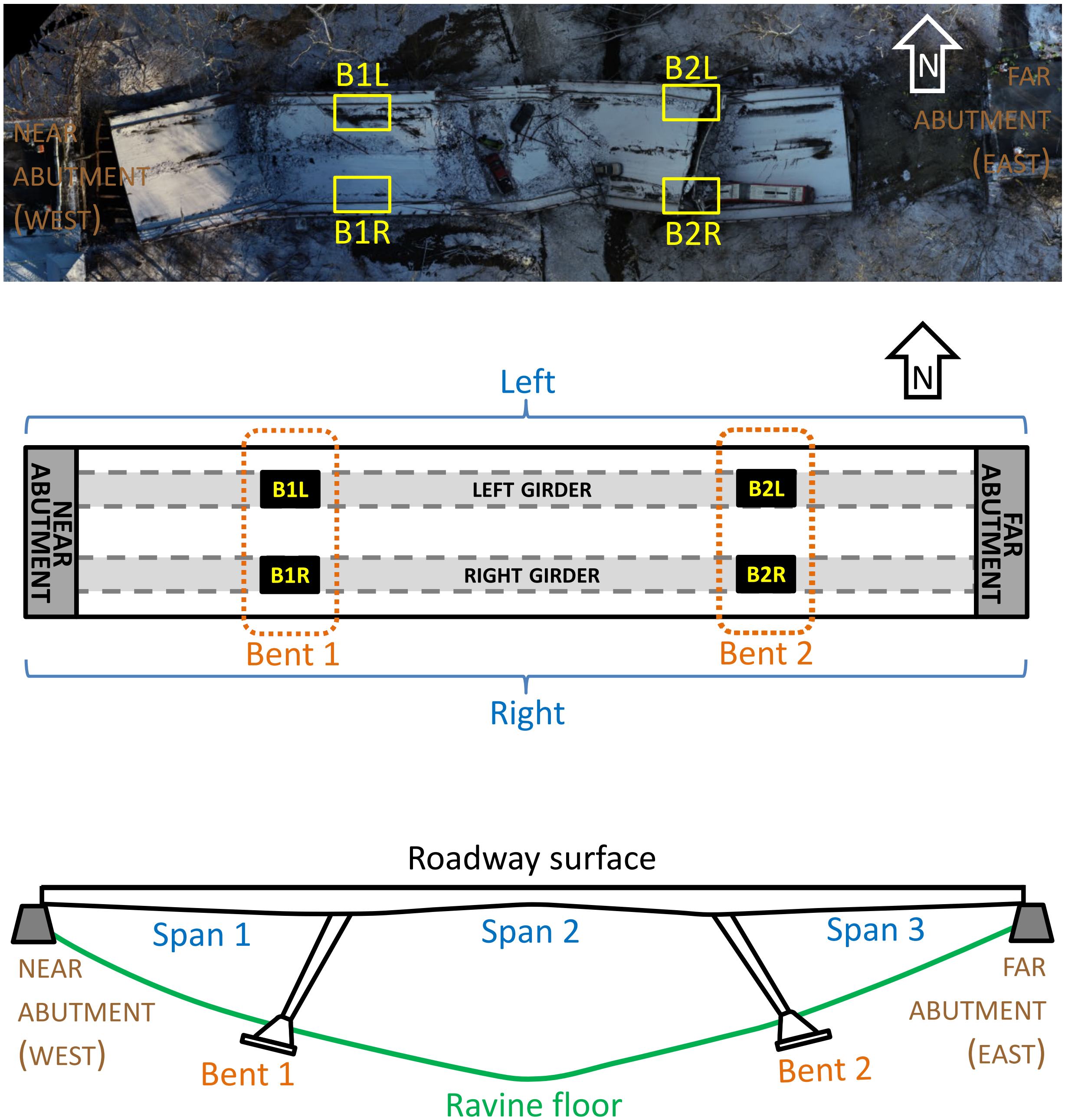

Figure 1. Plan view composite photo of the collapsed structure with the locations of the legs underneath the structure outlined and labeled (top), compared to schematics of the bridge in plan view (middle) and profile view (bottom).

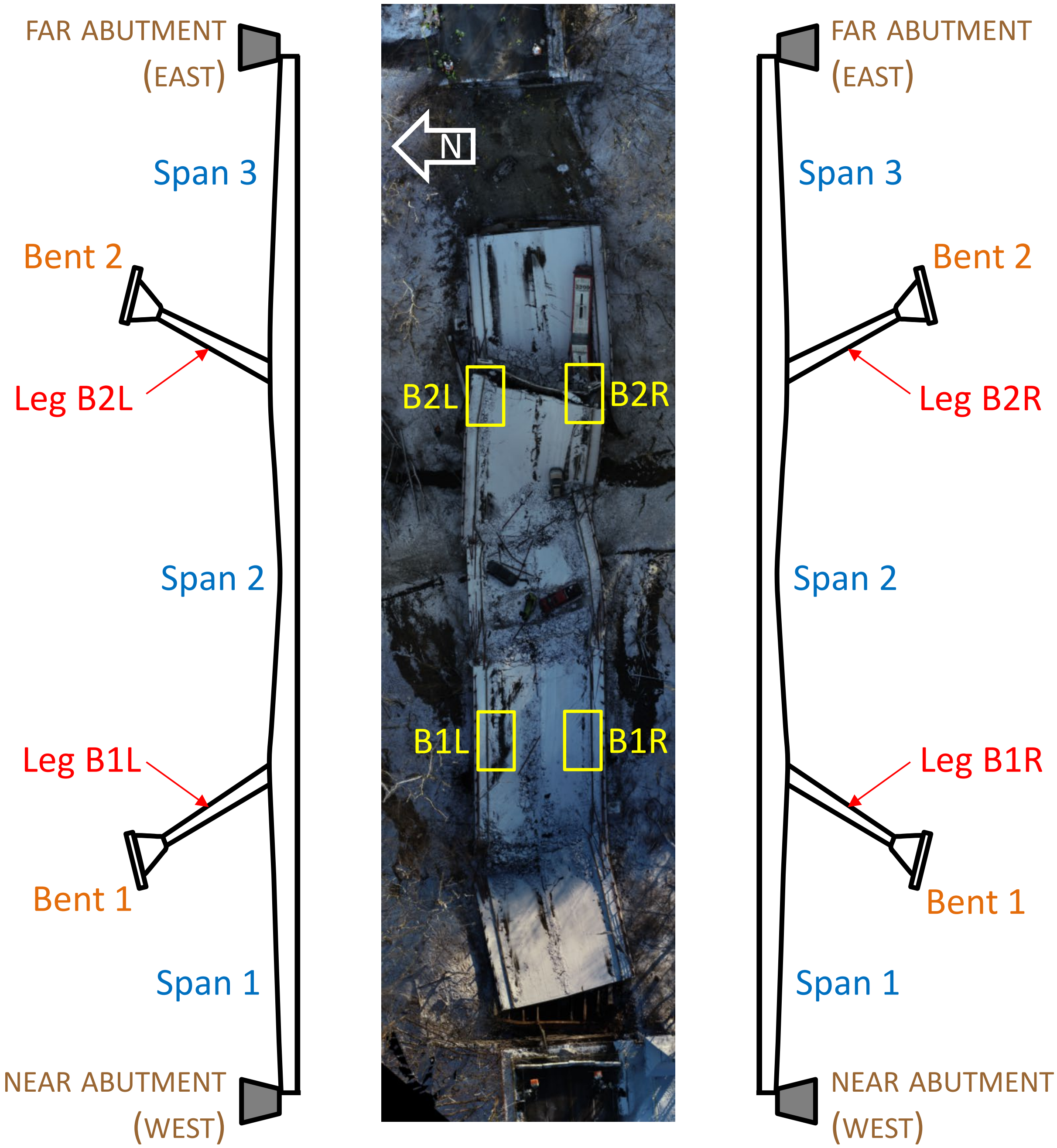

Figure 2. Plan view composite photo of the collapsed structure relative to the elevation view schematic, with each leg identified.

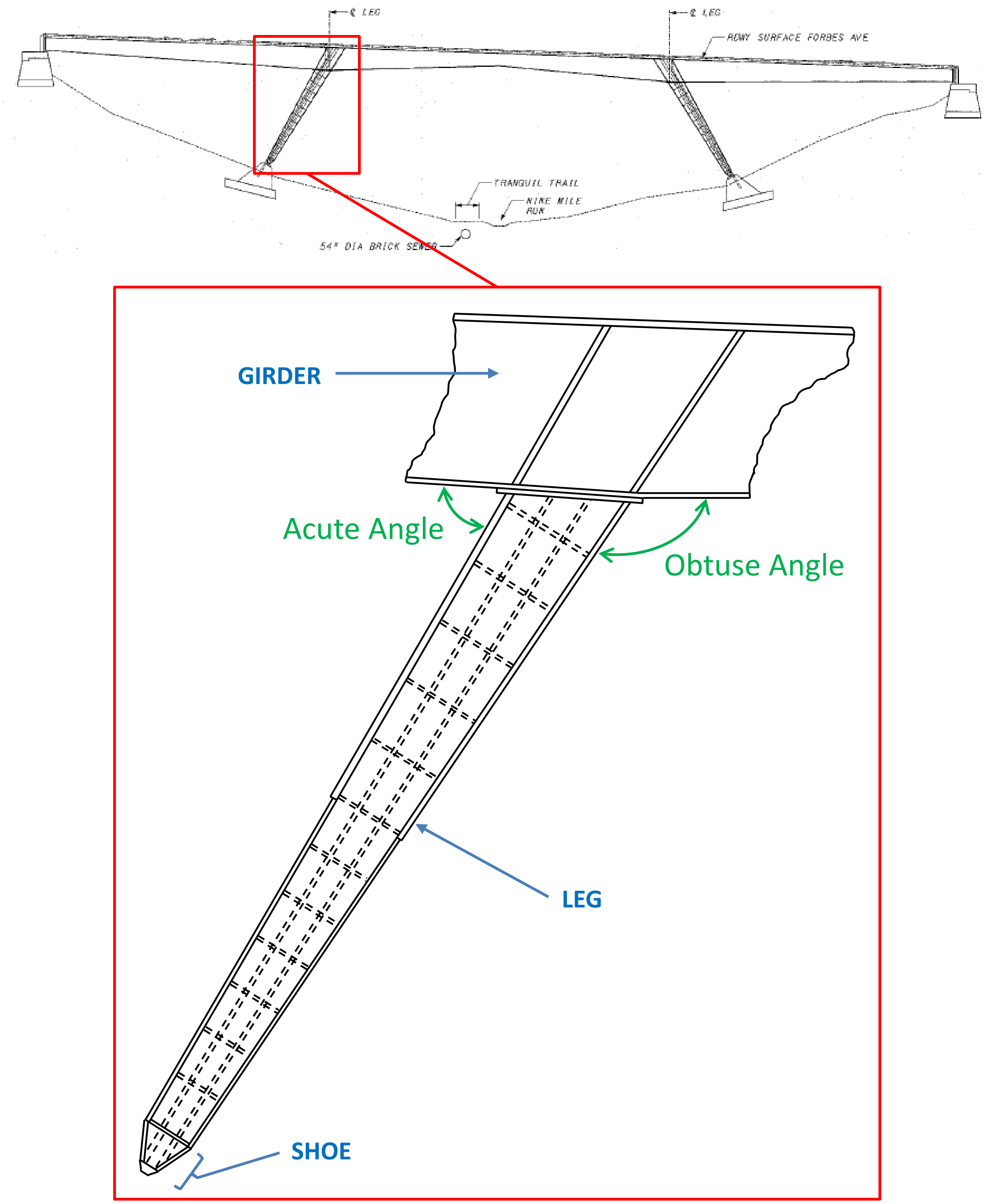

Figure 3. Schematic showing the outward facing side of a leg mating with a girder. (Schematic not to scale)

Figure 4. Photos showing the location of the fracture at the top of leg B1R (yellow dashed line) visible outside the collapsed structure.

Figure 5. Photos showing the fracture surface through the end plate weld at the top of leg B1R visible outside the collapsed structure.

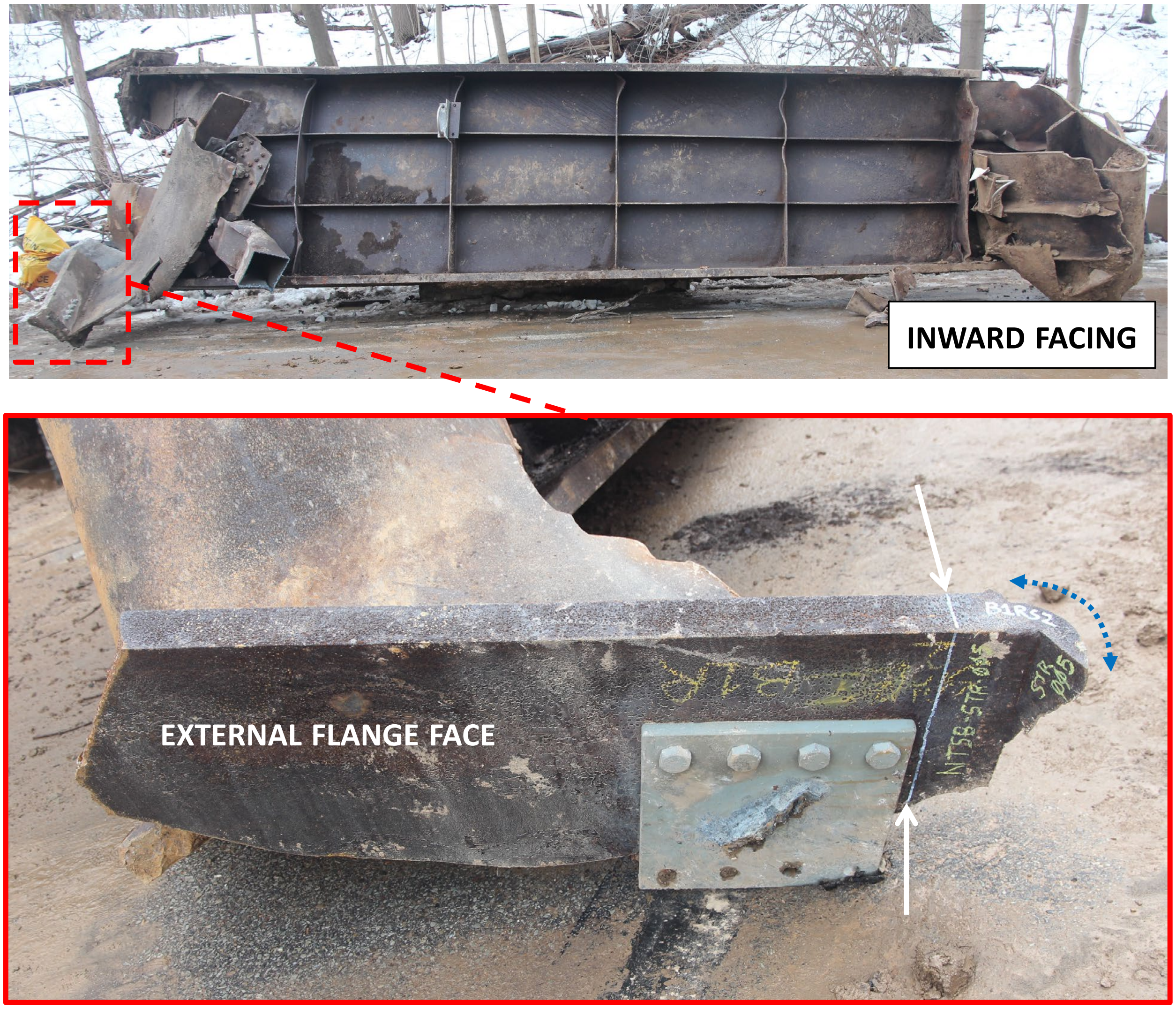

Figure 6. Photos showing the line (white arrows) along which the fracture surface was sectioned for retention after leg B1R was removed from the collapse site to an evidence staging area. The blue dotted line indicates the z-shaped profile of the fracture surface.

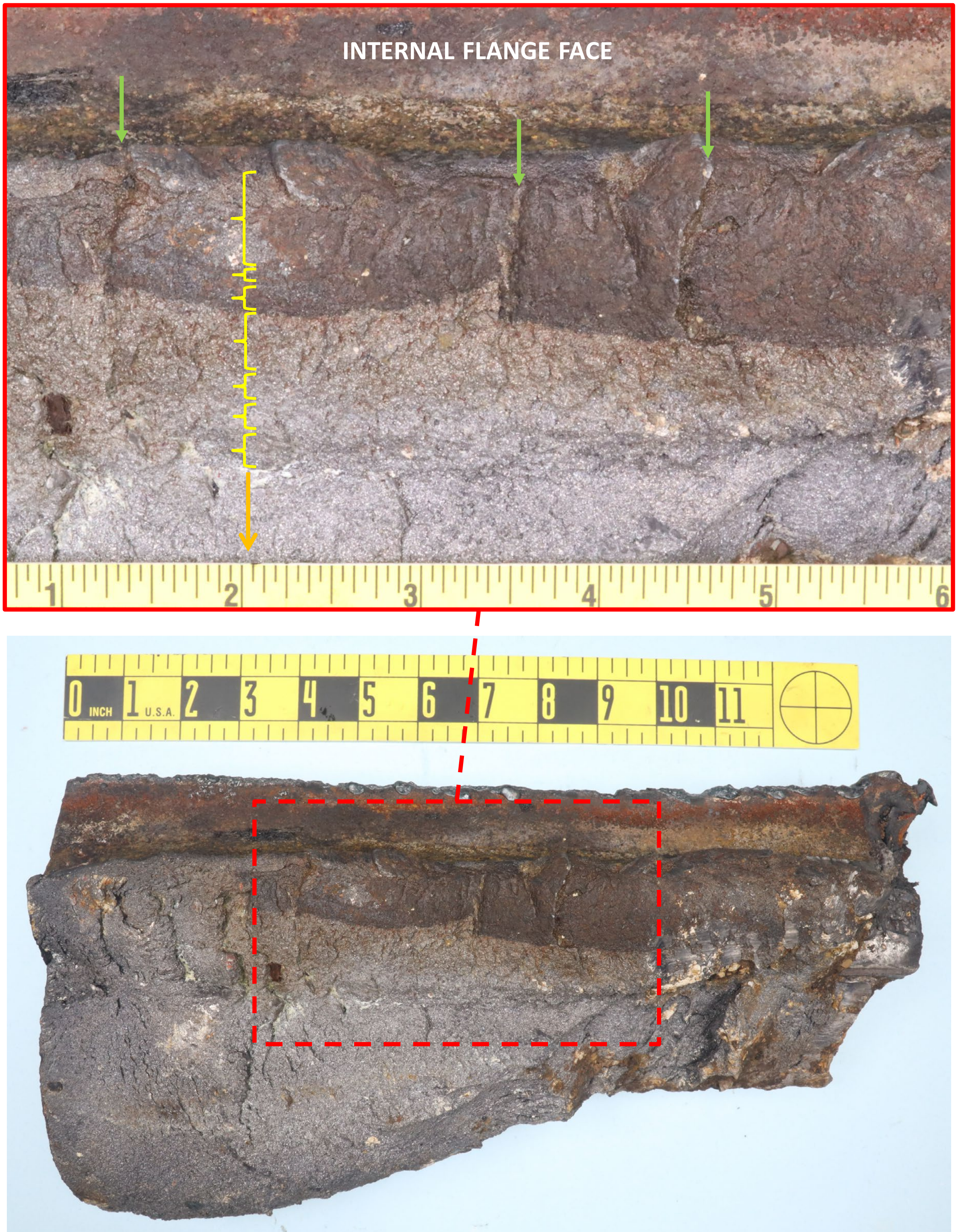

Figure 7. Macro photos of the fracture surface on leg B1R as viewed under direct lighting. The green arrows point to ridges within the line of heavily oxidized features. The yellow brackets indicate crack progression marks. The orange arrow points in the direction of crack propagation on the remaining fracture surface.

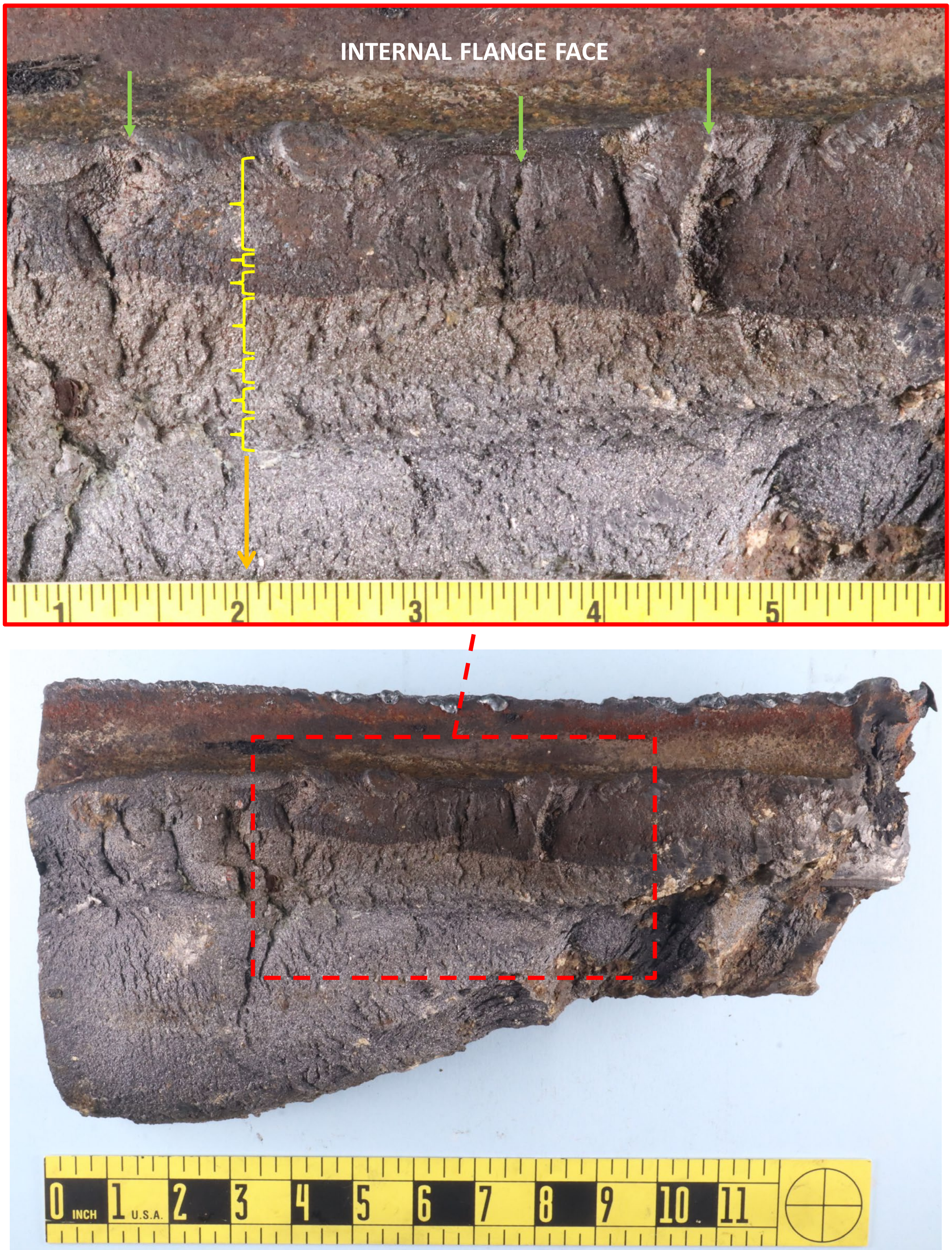

Figure 8. Macro photos of the fracture surface on leg B1R as viewed under side lighting. The green arrows point to ridges within the line of heavily oxidized features. The yellow brackets indicate crack progression marks. The orange arrow points in the direction of crack propagation on the remaining fracture surface.

Figure 9. Photos showing the location of the fracture (yellow arrow) at the top of leg B2L underneath the collapsed structure.

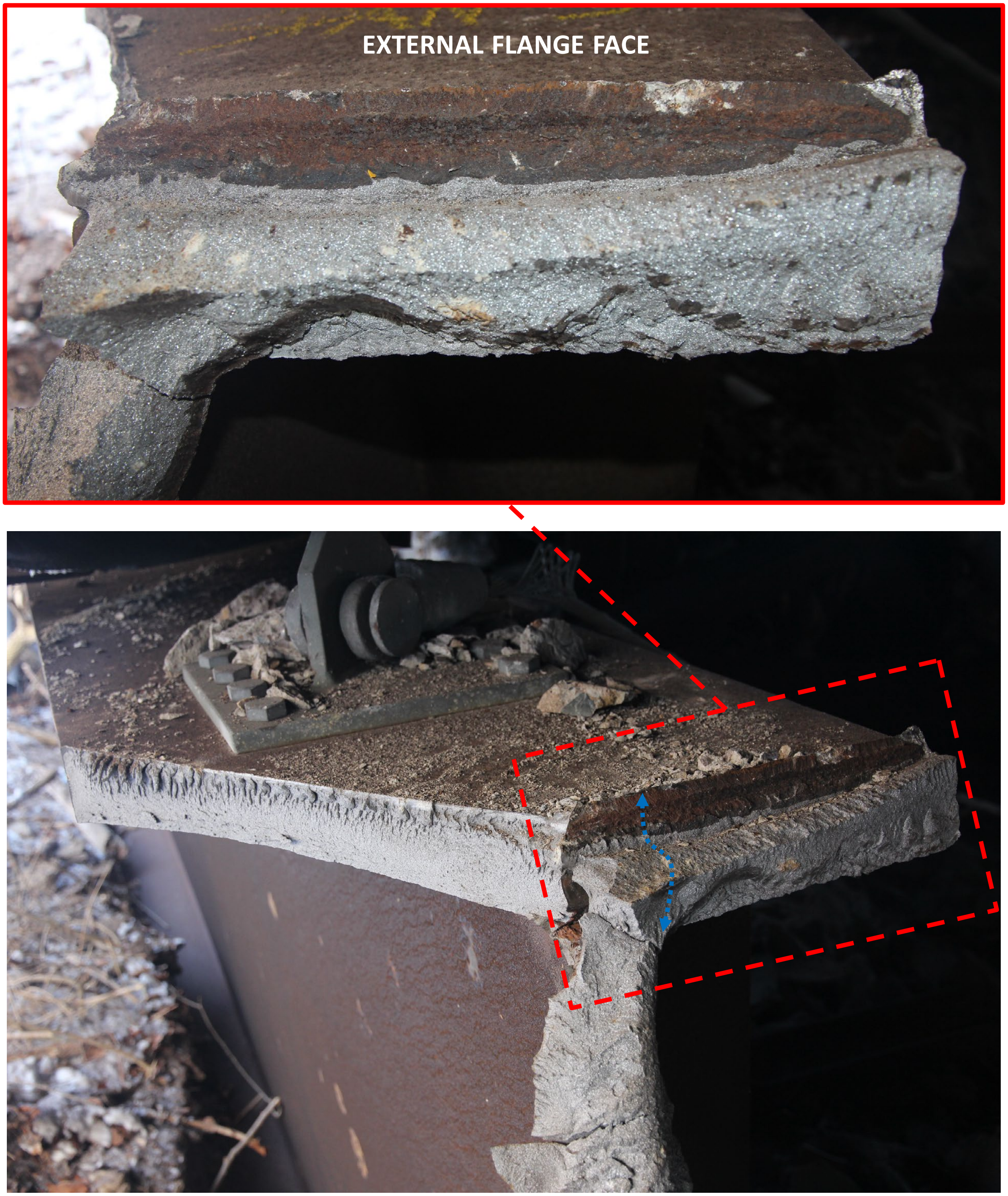

Figure 10. Photos showing the fracture surface through the end plate weld at the top of leg B2L visible underneath the collapsed structure. The blue dotted line indicates the z-shaped profile of the fracture surface.

Figure 11. Photos showing the line (white arrows) along which the fracture surface was sectioned for retention after leg B2L was removed from the collapse site to an evidence staging area.

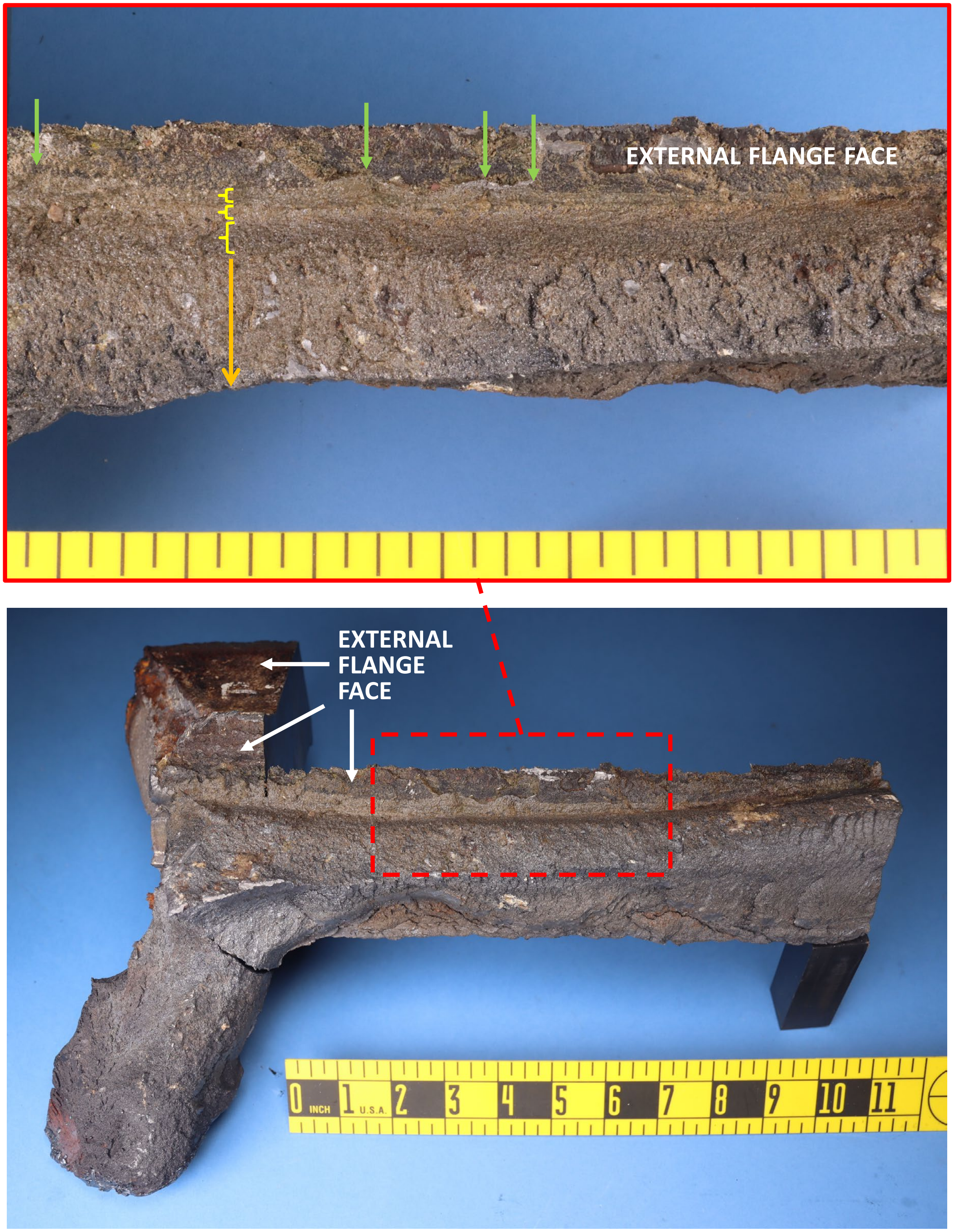

Figure 12. Macro photos of the fracture surface on leg B2L as viewed under direct lighting. The green arrows point to ridges within the line of heavily oxidized features. The yellow brackets indicate crack progression marks. The orange arrow points in the direction of crack propagation on the remaining fracture surface.

Figure 13. Macro photo of the fracture surface on leg B2L as viewed in profile under direct lighting.