TECHNICAL REPORT NO. 7878

300 FOOT RADIO TELESCOPE - FRACTURED MAIN BOX GIRDER PLATE

ASSOCIATED UNIVERSITIES, INC.

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TECHNICAL REPORT

February 27, 1989

Report No. ME-1115

Technical Report No. 7878

Your P.O. No. 44521-130

Associated Universities, Inc.
Suite 603
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Attention: Mr. Thomas J. Davin, Jr.

Subject: 300 FOOT RADIO TELESCOPE - FRACTURED MAIN BOX GIRDER PLATE

INTRODUCTION:

A failed plate from the main box girder of the 300 ft. radio telescope at Greenbank, West Virginia, was submitted to Lucius Pitkin, Inc. for metallurgical examination. We were advised that the telescope had been in-service approximately 26 years. In addition, we were advised that at the time of failure, temperatures were moderate and there were no severe winds or other inclement weather conditions.

OBJECT:

The purpose of this examination was to determine the nature and, if possible, the probable cause of failure of the submitted box girder plate.

PROCEDURE AND OBSERVATIONS:

A. Visual Examination

The submitted section of 1/2-in. thick fractured main box girder plate is shown in the as-received condition in Fig. 1. Examination of the subject plate revealed the fracture to be approximately 37 inches long and passed through two bolt holes apparently used to fasten an adjacent gusset plate.

Visual examination revealed the majority of the fracture to be slanted and lightly oxidized (rusted), as is characteristic of a recent fast ductile fracture. Closer examination of the slanted fracture surfaces revealed faint chevron-like markings, the convergence of which indicated the bolt holes to be the fracture origins. The fracture surfaces adjacent to the bolt holes were relatively flat in appearance, exhibiting little or no plastic deformation, and were covered with a heavy black oxide. These heavily oxidized regions extended approximately 1-in.to 2-in. to each side of the bolt holes. The relatively flat and heavily oxidized appearance of the fracture surface adjacent to the bolt holes is characteristic of progressive long-term cracking in the nature of fatigue. Fig. 2 is a photograph showing the appearance of the plate fracture surfaces in the vicinity of the bolt holes.

In addition, approximately midway between the failed bolt holes and short edge of the plate, a 1/2-in. wide discontinuity intersected the fracture plane, as shown in Fig. 3. The appearance of this plate discontinuity was characteristic of weld metal deposit/splatter or an arc gouge. The fracture surface adjacent to this region was relatively flat and heavily oxidized indicating this damage may have been present for some time. It should be noted, however, that the fracture surface chevron-like ridges (which generally converge toward fracture origins) did not converge in the vicinity of the weld deposit/splatter and, as such, this discontinuity was not considered to be the primary fracture origin.

Close examination of the fracture surface adjacent to the bolt holes revealed the presence of ratchet marks at the bolt hole surfaces, as shown in Figs. 4 and 5, as is characteristic of fatigue crack initiation. In addition, as shown in Figs. 6 and 7, secondary cracks parallel to and below the primary fracture were also observed at the bolt holes. The presence of secondary cracks is also characteristic of fatigue crack growth and these cracks generally occur under moderate to high cyclic stresses.

B. <u>Composition</u>

Drillings from the failed plate were submitted for qualitative emission spectrographic analysis. The results of the analysis indicated the box girder plate to be a plain carbon steel. Complete results of this analysis are given in Table I, appended.

C. Mechanical Properties

1. Hardness

A hardness survey was performed on a ground surface of the box girder plate material. Results of this survey indicated the plate material to have a relatively uniform hardness of Rockwell B 71.0. Based upon standard conversion charts for steel, this hardness corresponds to an ultimate tensile strength of approximately 62,000 psi

2. Tensile

One 1/2-in. wide flat tensile specimen was prepared from the plate material (perpendicular to the fracture plane) and tested at room temperature in accordance with ASTM: E8.

Results of the tensile test were as follows:

Yield strength, psi (0.2% offset)	46,300
Ultimate tensile strength, psi	62,400
Elongation, % (2-in. gage)	34.0

The tensile test results are typical of a plain carbon steel, i.e., ASTM: A36 structural steel.

D. Metallographic Examination

Longitudinal and transverse cross-section microspecimens were prepared so as to pass through the fatigue crack origins and fast ductile fracture regions. The specimens were mounted in Bakelite, carefully ground and polished for metallographic examination.

In the as-polished, unetched condition the plate material exhibited a normal quantity of non-metallic inclusions and no laminations or seams at the fracture origin. The plate material was considered satisfactorily clean in this respect.

Etching the microspecimens revealed the general microstructure of the plate material to be comprised of fine grained ferrite (iron phase) and pearlite (iron iron-carbide phase), as is characteristic of a plain carbon structural steel. Fig. 8 is a photomicrograph showing the general microstructure of the plate material.

Examination of the fracture regions adjacent to the bolt holes revealed fracture profiles which were relatively flat and transgranular (propagating through the grains rather than along grain boundaries), as is typical of progressive or fatigue failure under cyclic loading. Fig. 9 is a photomicrograph showing the transgranular fracture profile adjacent to a bolt hole. Further, as shown in Fig. 10, small secondary transgranular cracks parallel to the primary fracture were also observed at the bolt hole surfaces. The presence of secondary cracks are characteristics of fatigue fracture at moderate to high cyclic stresses.

Remote from the fracture origin, the final fracture profile was slanted, transgranular and the grains adjacent to the surface were plastically deformed, as is characteristic of fast ductile fracture. Fig. 11 is a photomicrograph showing fracture profile through the final fracture region.

E. Scanning Electron Microscopy

The large secondary crack at one of the bolt holes was carefully back-cut and opened so as to expose the fracture surface for examination in a JEOL T330A scanning electron microscope. The fracture surface was heavily oxidized and therefore cleaned by immersion in Alconox and again in 3% EDTA prior to examination. However, these cleaning procedures removed very little of the oxide coating. The fracture surface was examined at an accelerating potential of 20 keV.

As shown in Fig. 12, the fracture surface was covered with an oxide scale and no significant fractographic information was obtained.

DISCUSSION AND CONCLUSIONS:

Results of our investigation revealed failure of the submitted main box girder plate to have occurred as a result of progressive cracking in the nature of fatigue. Propagation of these fatigue cracks under cyclic loading from both bolt holes eventually resulted in a fast ductile fracture when the combination of cyclic stress range and crack size exceeded the fracture toughness of the plate material.

Further, the results of the fractographic examination revealed secondary fatigue cracks also had originated at the bolt hole surfaces. The presence of the secondary fatigue cracks at the bolt holes indicates the presence of intermediate to high cyclic stresses.

The bolt material was a plain carbon steel and exhibited yield and tensile strengths typical of ASTM: A36 structural steel. No metallurgical or fabrication defects were found in way of the bolt hole fracture origins.

Respectfully submitted,

LUCIUS PITKIN, INC.

Robert S. Vecchio, Ph.D.
Engineer

Approved: A. J. Vecchio, P.E.
Vice President

RSV/pm/2

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SPECTROGRAPHIC ESTIMATES

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The following is our analysis of 1 sample(s) of drillings from main box girder plate.

TABLE I

BY QUALITATIVE SPECTROGRAPHIC ANALYSIS

Iron	Major
Manganese	0.X
Silicon	0.X low
Aluminum	0.0X low
Vanadium	0.0X low
Molybdenum	0.0X low
Nickel	0.0X low
Chromium	0.0X low
Copper	0.00X
Magnesium	0.00X low

Elements checked for but not found: Titanium, Zinc, Zirconium, Bismuth, Lead, Tin, Antimony, Beryllium, Gallium, Germanium, Phosphorous, Boron, Cobalt, Columbium, Tungsten.

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By

NOTE: Major = above 5% estimated. Minor = 1.5% estimated. .X, .OX, .OOX, etc. = concentration of the elements estimated to the nearest decimal place – e.g. .OX = .01-.09% estimated. *= less than. NF = not found. The numbers in parenthesis indicate the estimated relative concentration of the element among the various samples. Detectability varies considerably among the elements and also depends upon the amount and nature of the sample, therefore, "Not Found" or NF means not detected in the particular sample by the technique employed.

FORM 104-7/81

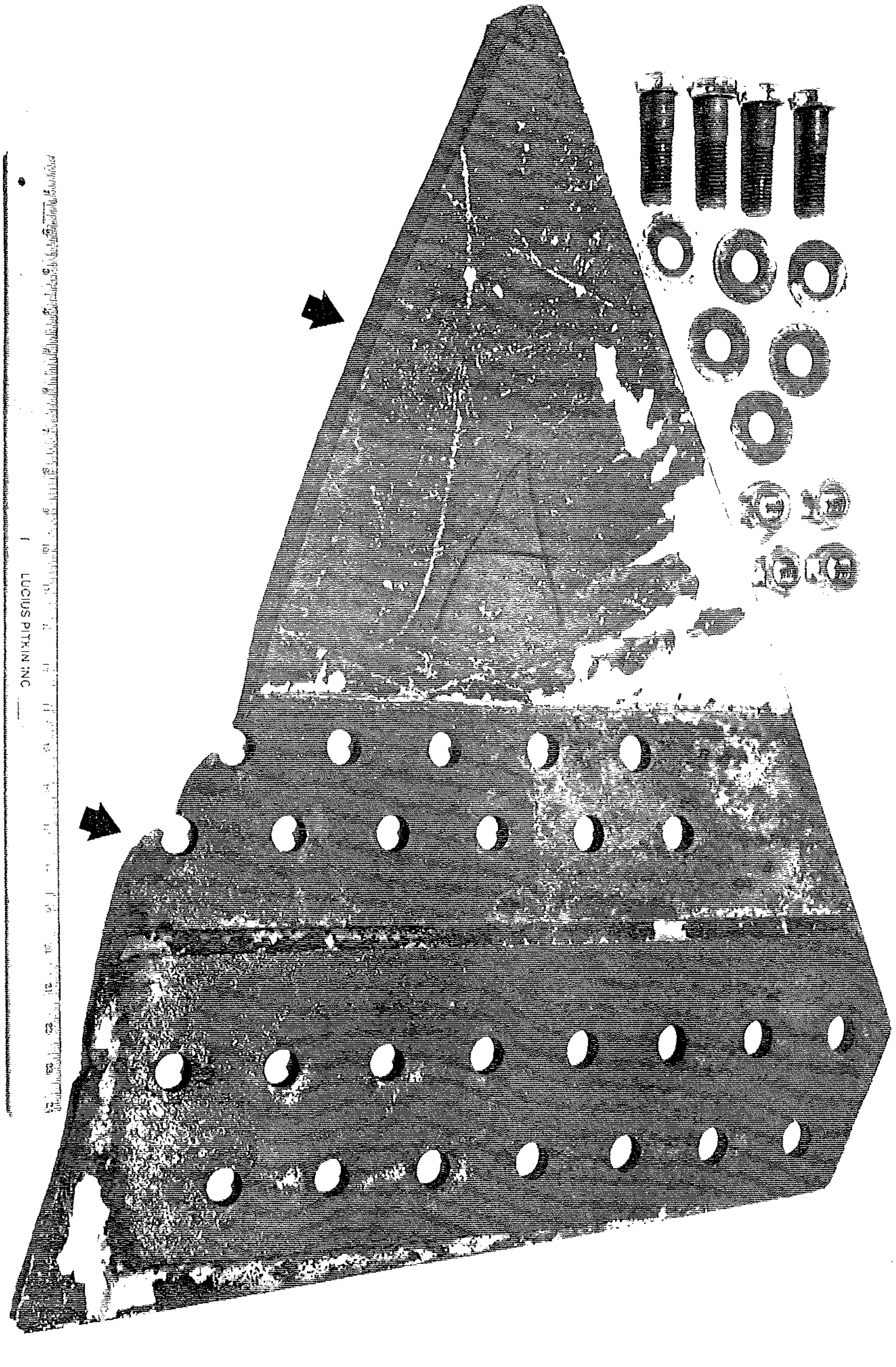
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Fig. 1 FAILED MAIN BOX GIRDER PLATE, AS-RECEIVED

Photograph showing the submitted 1/2-in. thick main box girder plate from the 300 ft. radio telescope at Greenbank, West Virginia, in the as-received condition. The plate fracture was approximately 37 in. long (arrows) and intersected two bolt holes.

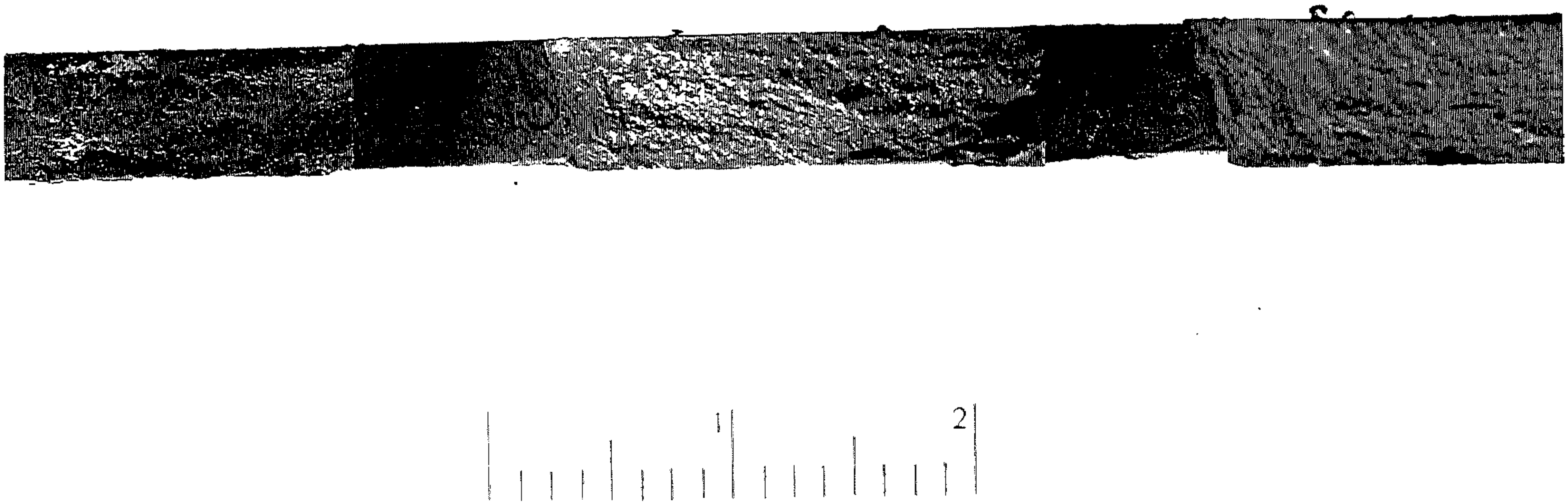

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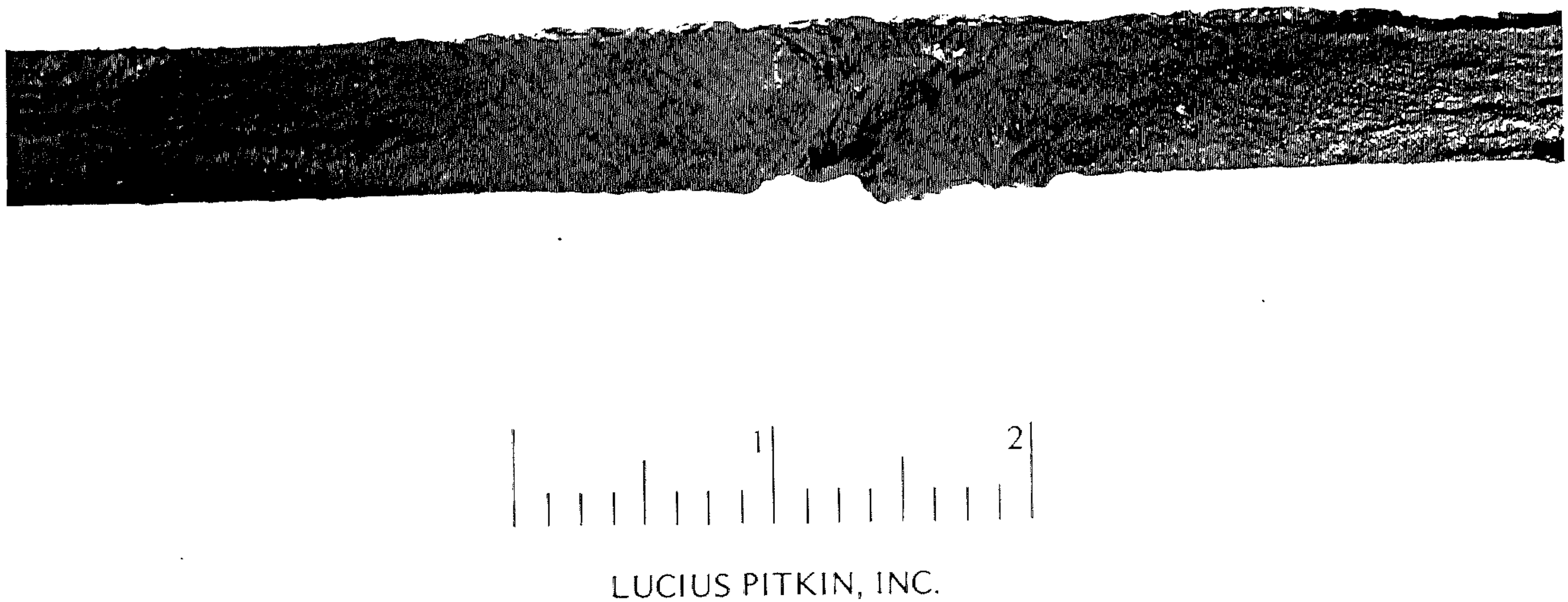
Fig. 2 PLATE FRACTURE SURFACE

Photograph showing the flat and heavily oxidized appearance of the plate fracture surfaces adjacent to the bolt holes. This flat and heavily oxidized fracture appearance is the characteristic of long-term progressive or fatigue cracking. The convergence of chevron-like marks indicates the bolt holes to be the fracture origins.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2
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Fig. 3 PLATE FRACTURE SURFACE DISCONTINUITY

Photograph showing a weld deposit/splatter or arc gouge discontinuity in the fracture plane approximately midway between the bolt holes and the short edge of the plate. The lack of converging chevron-like marks near this discontinuity indicated it was not a primary fracture origin.

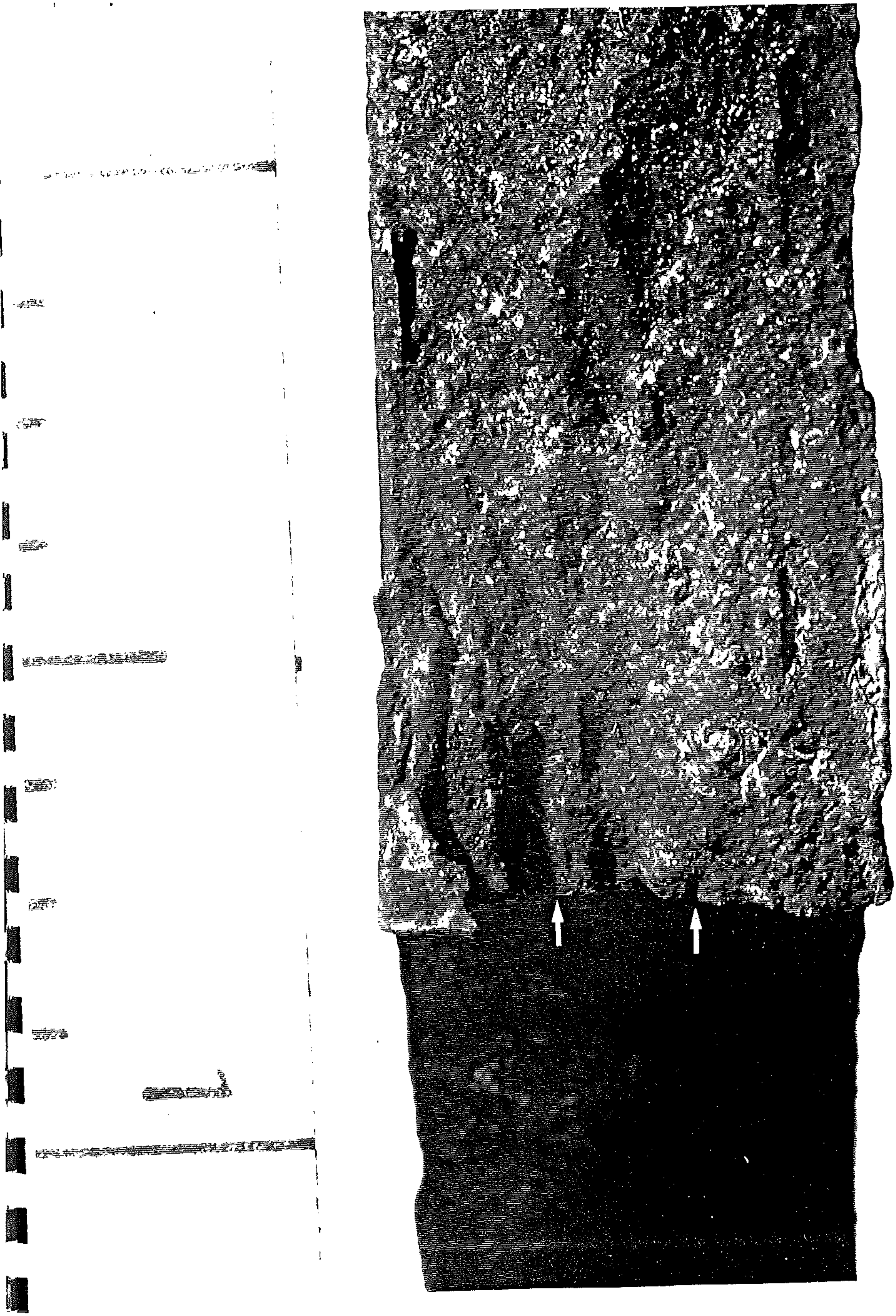

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Fig. 4 FRACTURE ORIGIN

Close-up photograph showing the presence of fracture surface ratchet marks (arrows)at the bolt hole surfaces, as is characteristic of progressive crack initiation in the nature of fatigue.

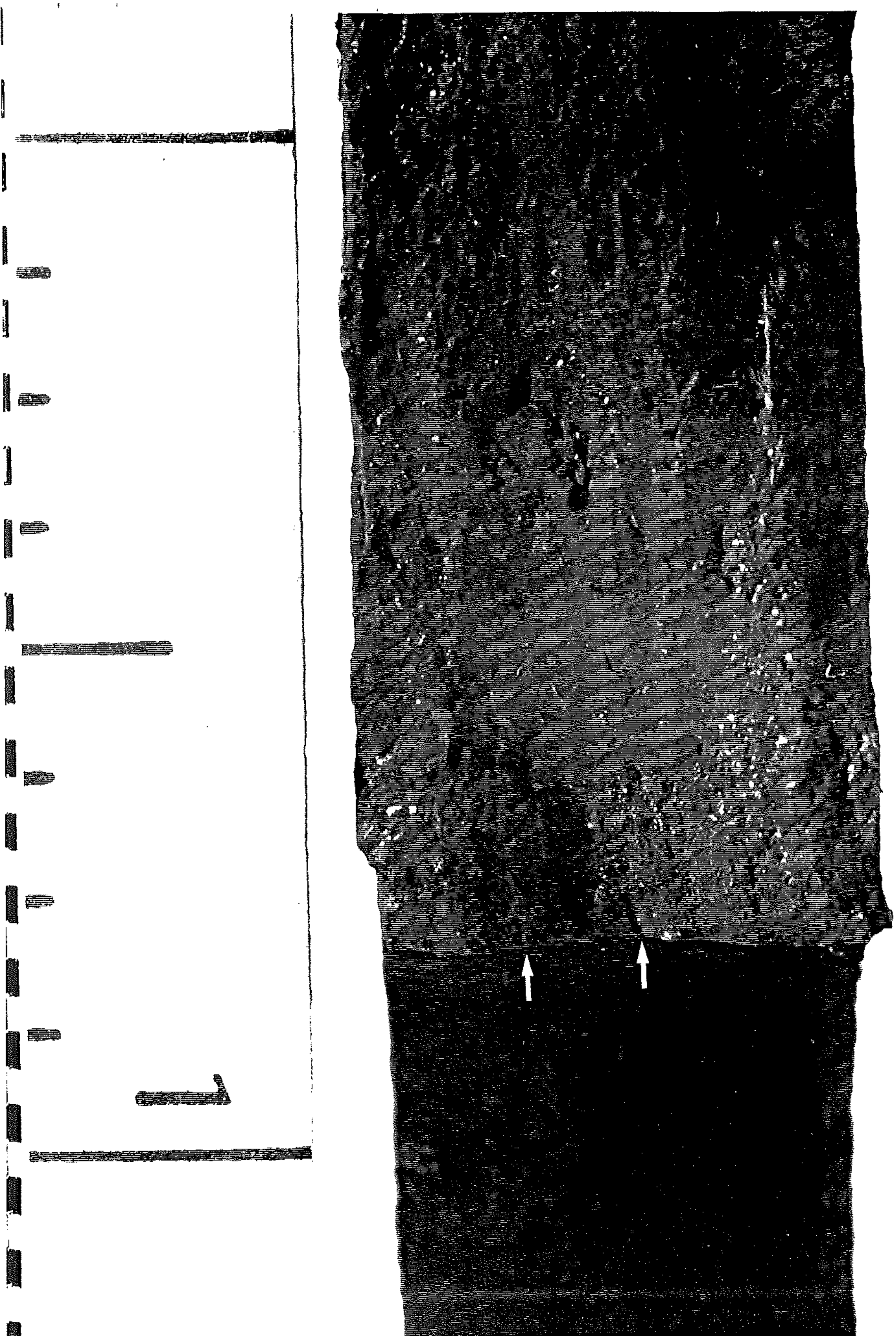

Fig. 5 FRACTURE ORIGIN

Close-up photograph showing the presence of fracture surface ratchet marks (arrows) at the bolt hole surfaces, as is characteristic of progressive crack initiation in the nature of fatigue.

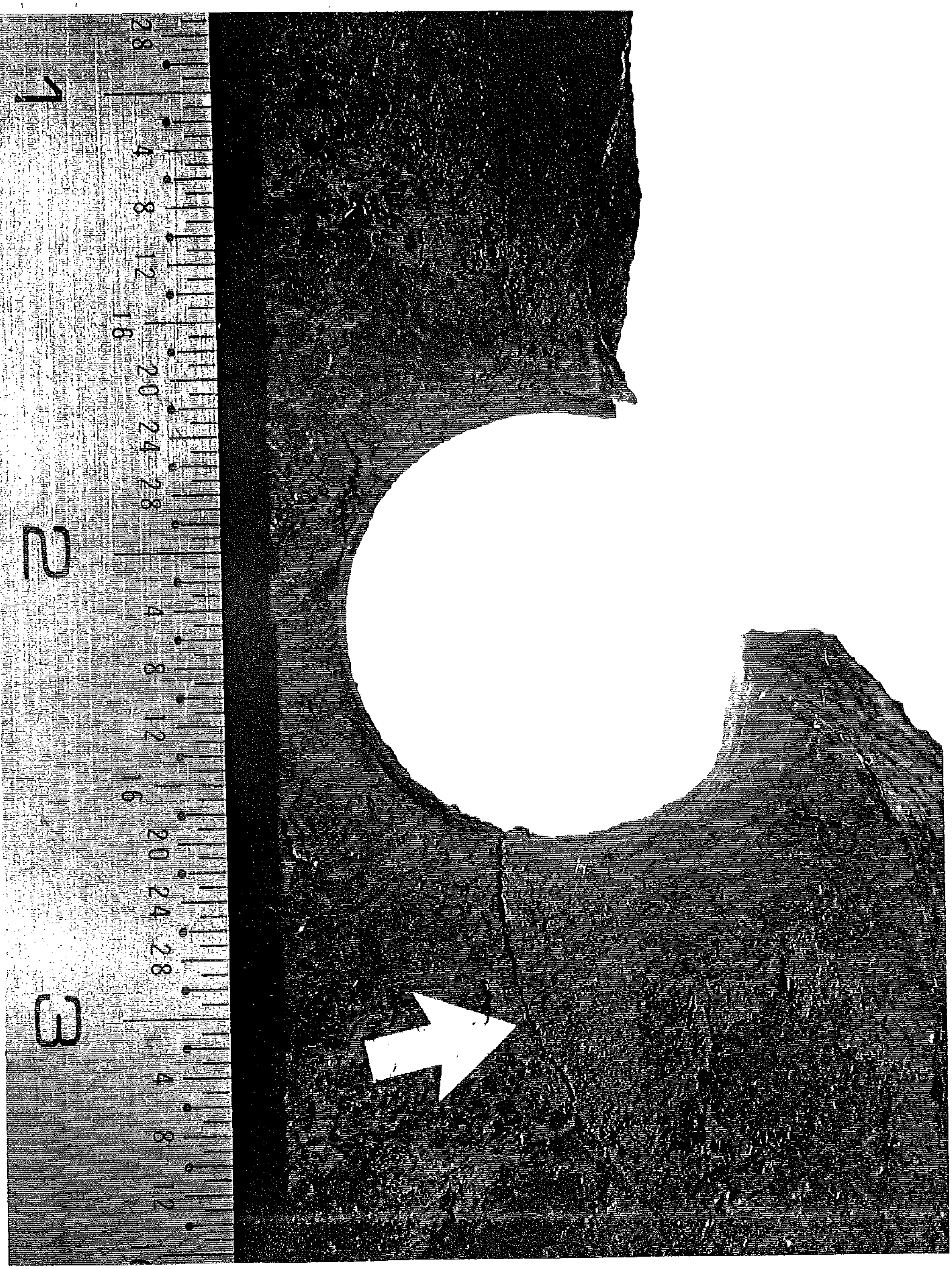

Fig. 6 SECONDARY FATIGUE CRACK

Close-up photograph showing a secondary fatigue crack (arrow) parallel and adjacent to the primary fracture, as is characteristic of fatigue cracking under intermediate to high cyclic stresses.

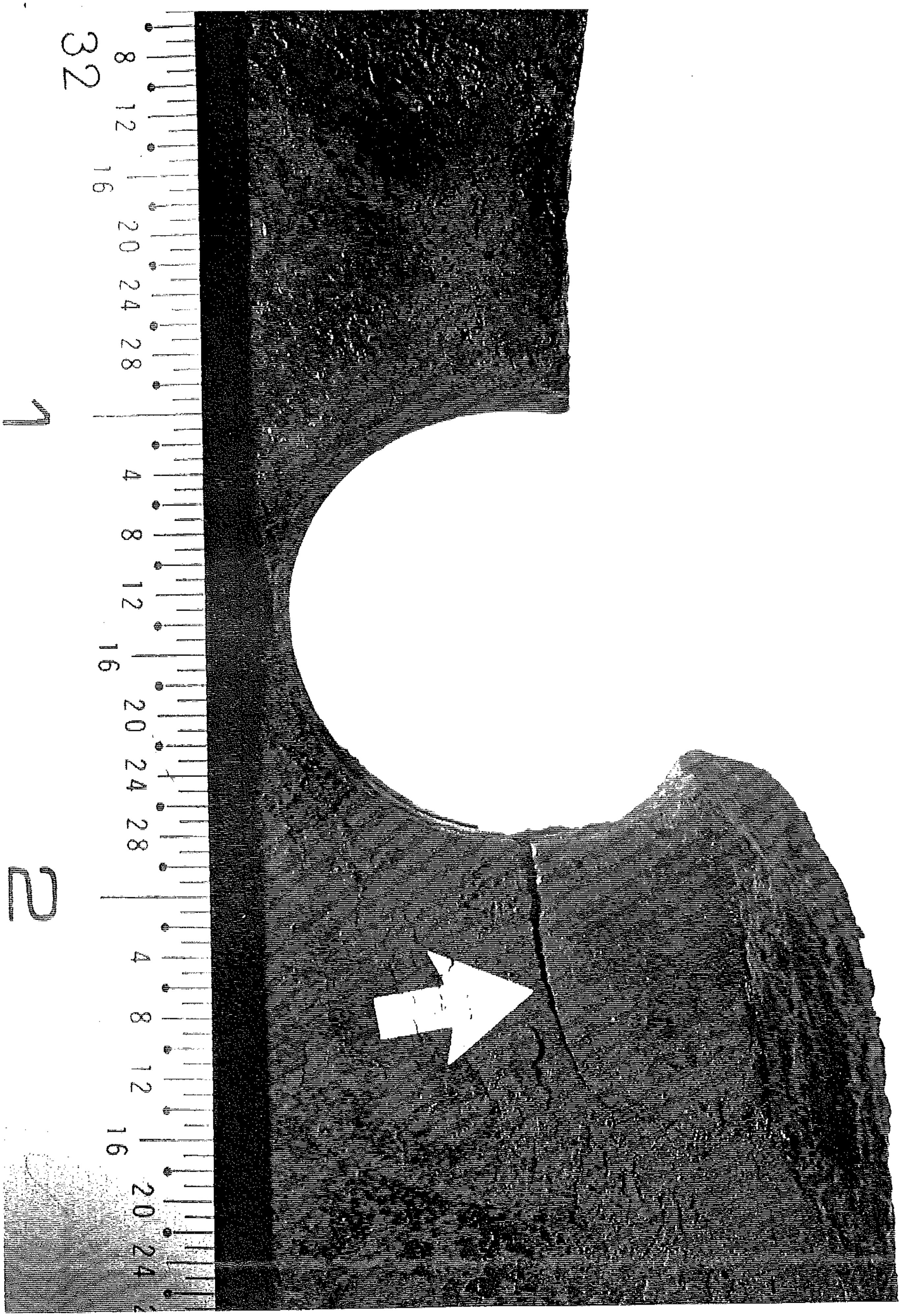

Fig. 7 SECONDARY FATIGUE CRACK

Close-up photograph showing a secondary fatigue crack (arrow) parallel and adjacent to the primary fracture, as is characteristic of fatigue cracking under intermediate to high cyclic stresses.

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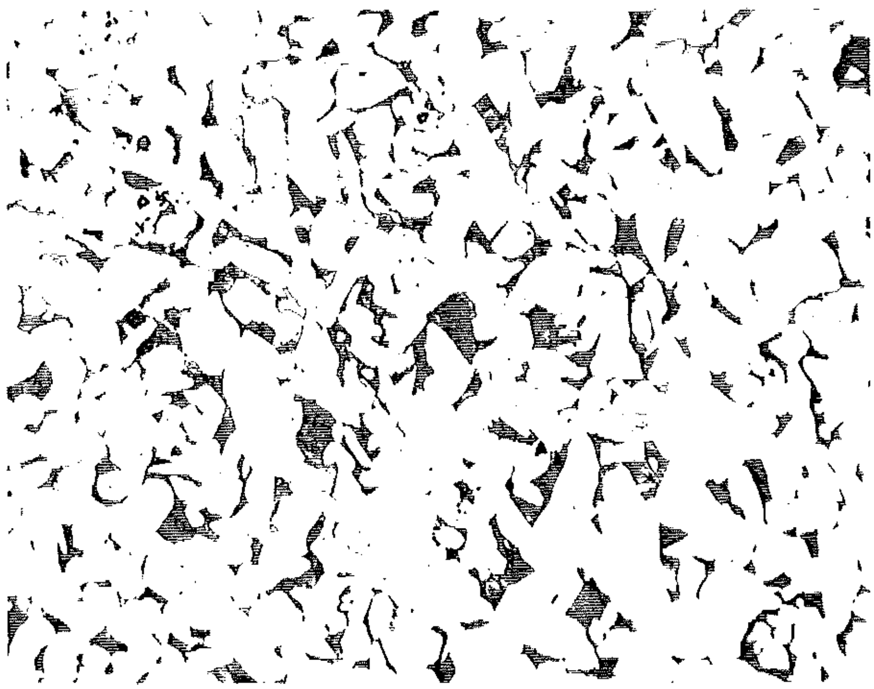

Fig. 8 GENERAL MICROSTRUCTURE 200 X

Photomicrograph showing the general microstructure of the main box girder plate material to be comprised of fine grained ferrite (iron phase) and pearlite (iron iron-carbide phase), as is typical of a plain carbon steel.

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Fig. 9 FRACTURE PROFILE AT ORIGIN 200 X

Photomicrograph showing the box girder plate fracture profile (top) at the fracture origin (bolt hole surface - right side) to be relatively flat and transgranular, as is characteristic of progressive cracking in the nature of fatigue.

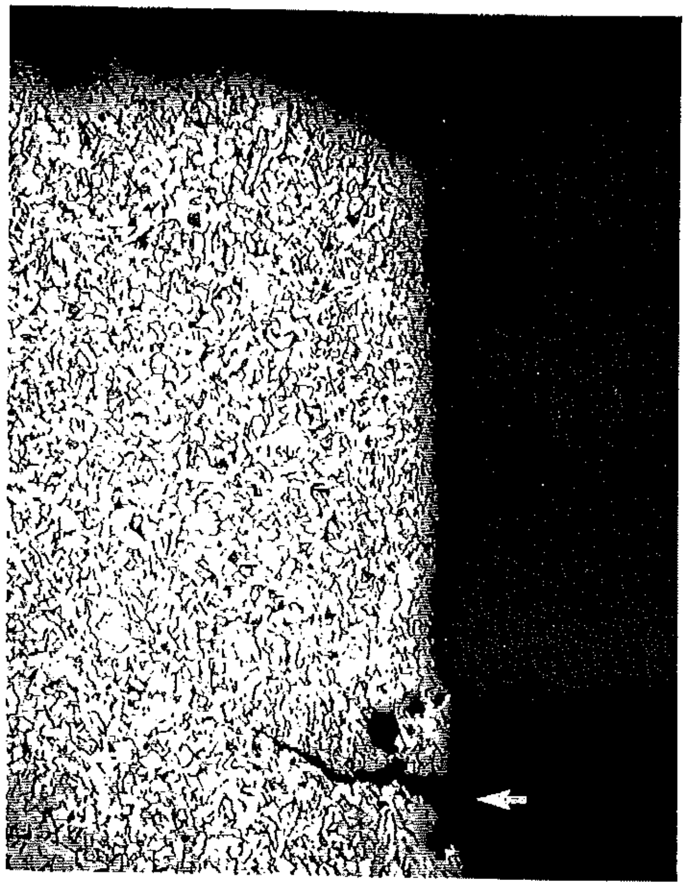

Fig. 10 SECONDARY FATIGUE CRACK 50 X

Photomicrograph showing a secondary fatigue crack (arrow) parallel to and just below the primary fracture (top) at the bolt hole surface (right side). The presence of secondary cracks is characteristic of fatigue fracture at moderate to high cyclic stresses.

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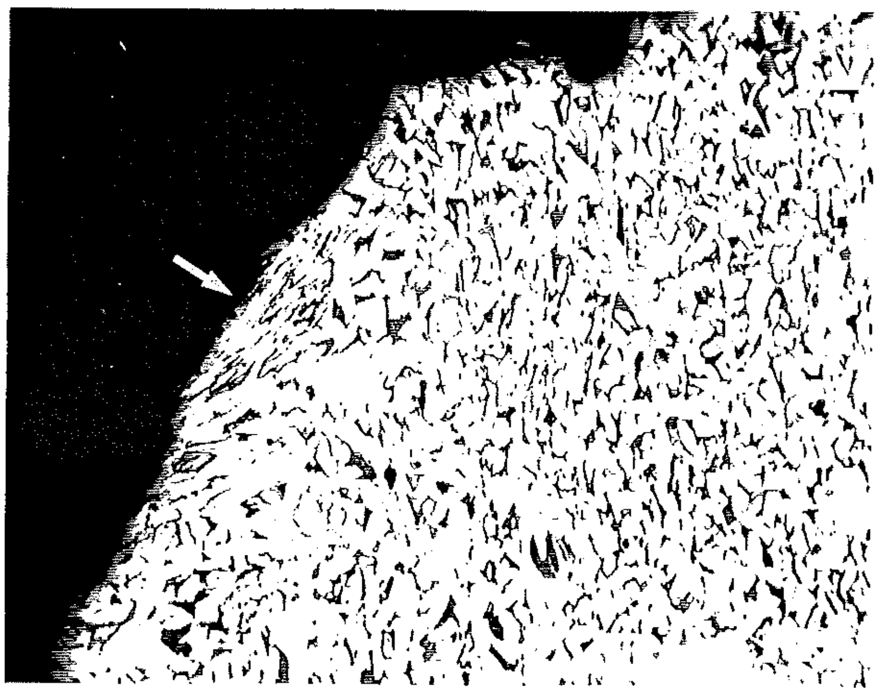

Fig. 11 FRACTURE PROFILE REMOTE FROM BOLT HOLE ORIGIN 100 X

Photomicrograph showing the slanted and transgranular fracture profile of the plate fracture remote from the bolt hole origin. In addition, the grains adjacent to the fracture surface (arrow) are plastically deformed, as is characteristic of fast ductile fracture.

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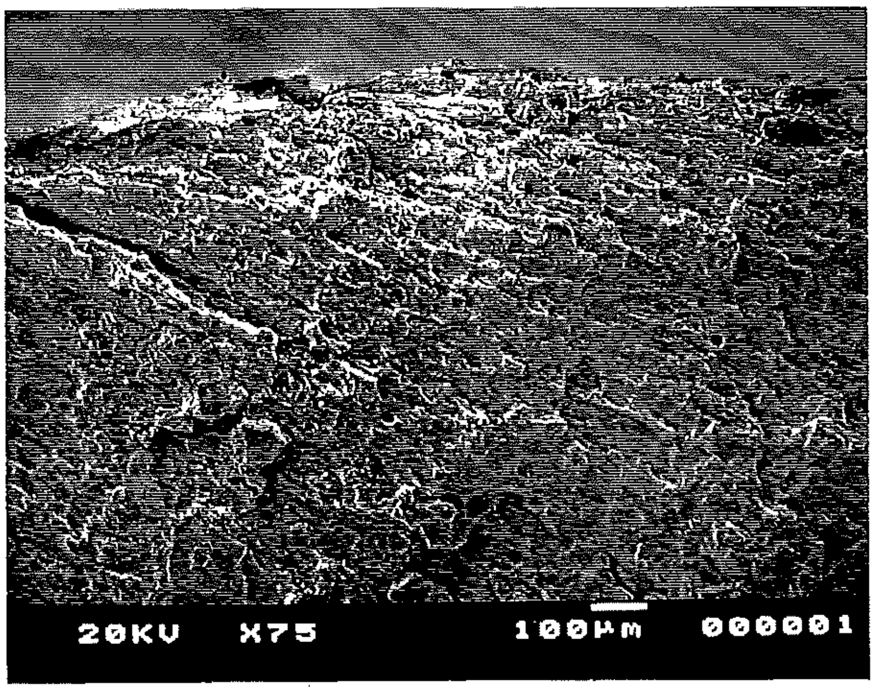

Fig. 12 FRACTURE ORIGIN AT ORIGIN 75 X

Scanning electron micrograph showing the box girder plate fracture surface at a bolt hole fracture origin. Even after extensive cleaning procedures the fracture surface exhibited a tenacious oxide, thus, no significant fractographic information was obtained.