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**Metallurgical Services**

Title

**EXAMINATION OF FATIGUE TEST PLATES**

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Client

**STRUCTURAL MONITORING SYSTEMS**

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**Title :** Examination of Fatigue Test Plates

**Client :** Structural Monitoring Systems

**Date :** 03/10/2002

### 1.0 Introduction

Three test plates reported by the Structural Monitoring Systems crack detection sensors to have crack indications in the rivet holes were examined to determine the size of the cracks. The samples were examined using optical and Scanning Electron Microscopy (SEM).

The following information was provided with the test plates.

Coupon ID	Crack Location	Crack Size
R515-287	Hole #1	1 mm
R515-288	Hole #1	2 mm
R515-288	Hole #2	1 mm
R515-289	Hole #2	2 mm

### 2.0 Results of Metallurgical Examination

#### 2.1 Visual Examination

The cracked holes were examined using a stereomicroscope. The crack in 288 hole #1 was just visible, and appeared to be 1 mm long. The crack in 287 hole #1 was also just visible, and appeared to be 0.5 mm long. See fig 1.

The samples were then subjected to SEM examination, see below for results. After this examination 288 hole #1 was very lightly abraded to remove just enough material to present a flat surface, about 0.020 mm was removed. The surface was etched in NaOH solution and the cracks became visible. This sample had a 2 mm crack on each side of the hole. The surface of the test plate near the hole was covered with a network of cracks, these cracks did not intersect the hole edge. The depth of these cracks was not investigated. See fig 2.

Sample 288 hole #1 was sectioned through the hole and one side was polished on the plate surface, the other sectioned and ground back to show the crack on the hole internal surface. This allowed the depth of the crack to be measured, it was found to be 2 mm deep. More detailed examination using the metallographic microscope was conducted, see below for details.

The cracks in the other samples were not visible.

## 2.2 SEM Examination

The plates were cut into smaller pieces to allow the holes to be examined on the SEM. The holes and 10 mm of material around each hole was examined. The samples were tilted to allow examination of the hole surface, the raised ridge found on previously examined samples was present on all samples.

It was very difficult to see the cracks on the SEM, but cracks were found in some samples. The cracks could not be seen on the plate surface as they blended into the surface deformation and craze cracking, but could be seen on the hole surface. Some of the cracks had extruded material from the crack, this was cadmium in some cases, and aluminium in others. See fig 11 to 16.

## 2.3 Metallographic Examination

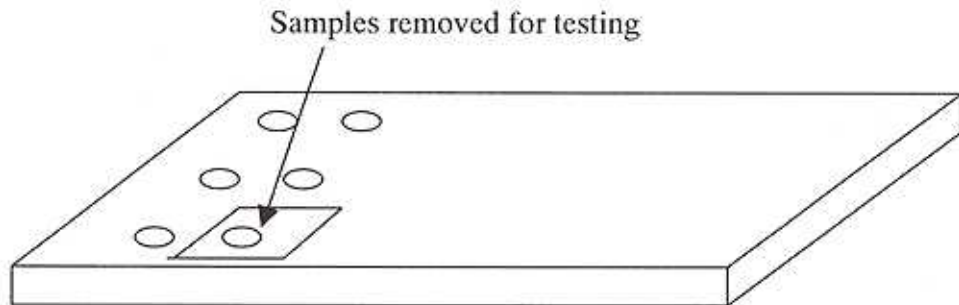
Metallographic examination of the plate surface after removing 0.5 mm of material from the surface proved to be the most effective method for observing the cracks. The samples were mechanically polished and etched in NaOH solution.

The fine craze cracks observed before removing the 0.5 mm of material could not be seen after removal of the material. However, if the material was not removed, the major cracks could not be reliably found.

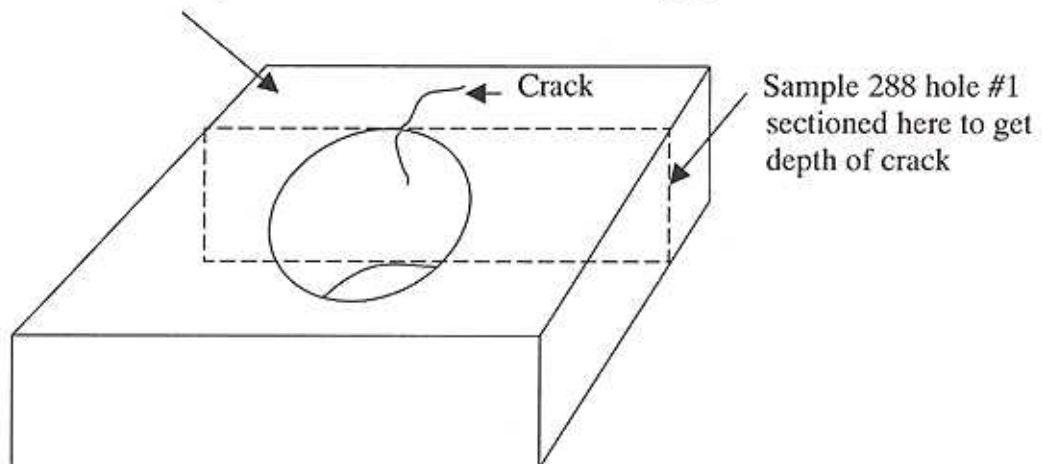
Cracks were found in all the reported locations, sample 289 hole #2 was different in that the major crack did not intersect the hole, this 3 mm crack was 0.5 from the hole.

Sample ID	Crack Length	Comment
287 hole #1	0.85 mm	Single crack at the hole
288 hole #1	2.0, 1.8 mm	Cracked both sides of hole
288 hole #2	0.25 mm	Small crack at hole edge
289 hole #2	3.0 mm, 0.15 mm	Small crack at hole, large crack remote from hole.

See fig 3 to 10.



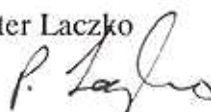
This surface polished down 0.5 mm for metallographic examination



### 3.0 Conclusion

The cracks were found by polishing the plate surface and etching to reveal the cracks. The crack size was in good agreement with the reported crack indication size, except for sample 288 hole 2.

Shallow craze cracking of the plate surface near the holes was observed. These may be the initiators of the crack found in 289 hole #2 which did not reach the hole edge.

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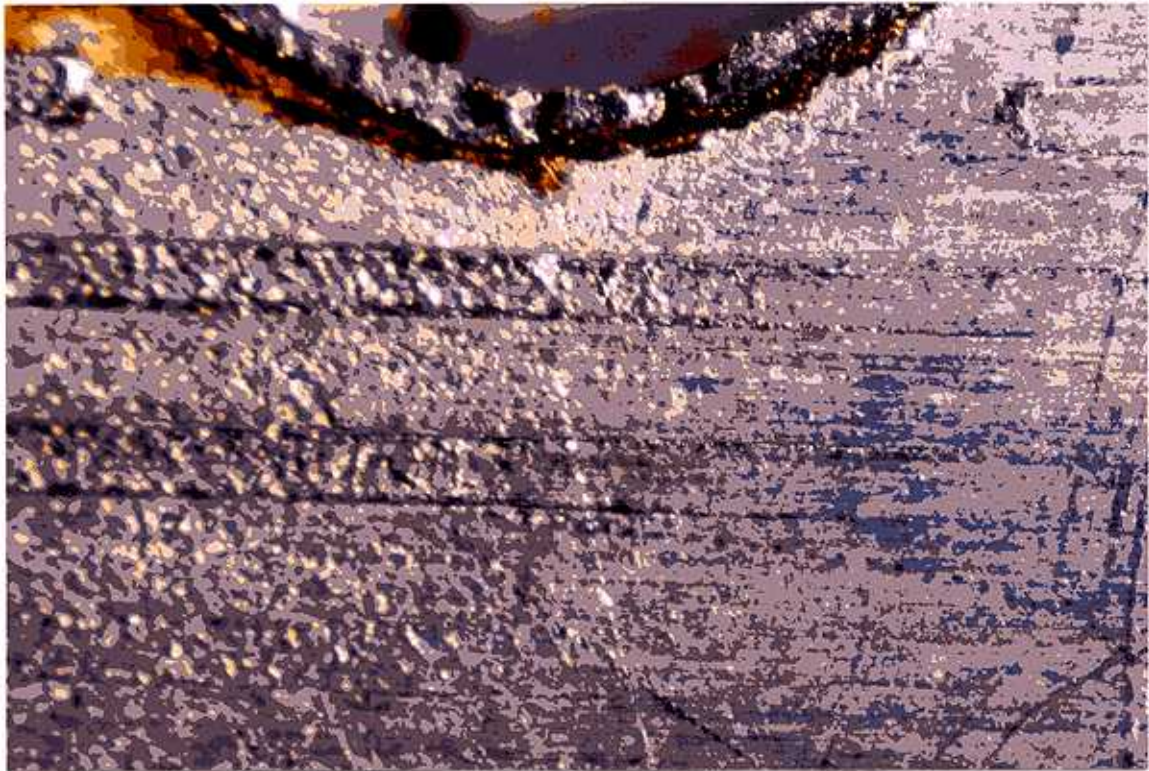


Fig 1 288 Hole #1. Optical stereomicroscope image showing the crack reaching into the mark left by the sensor cavity. The crack is very difficult to see. (X 20)

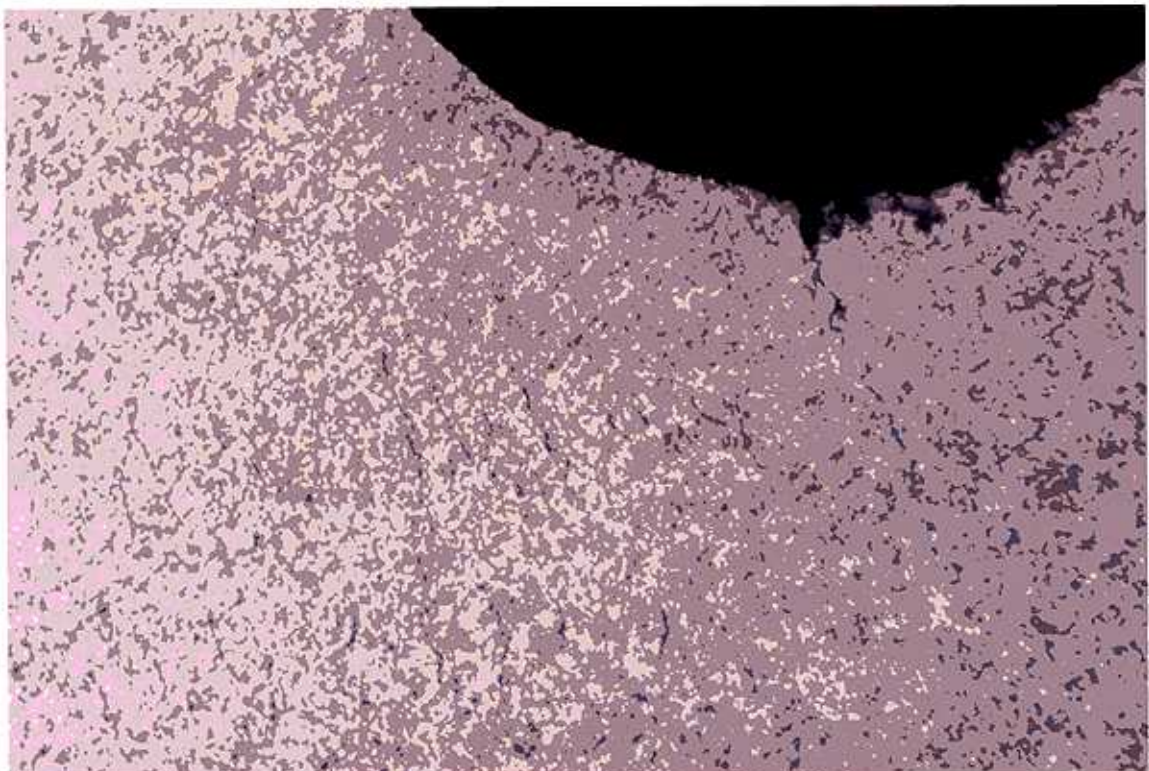


Fig 2 Same sample after very light polish and etching. Note the crack is clear and the craze cracking can be seen. (X 20)

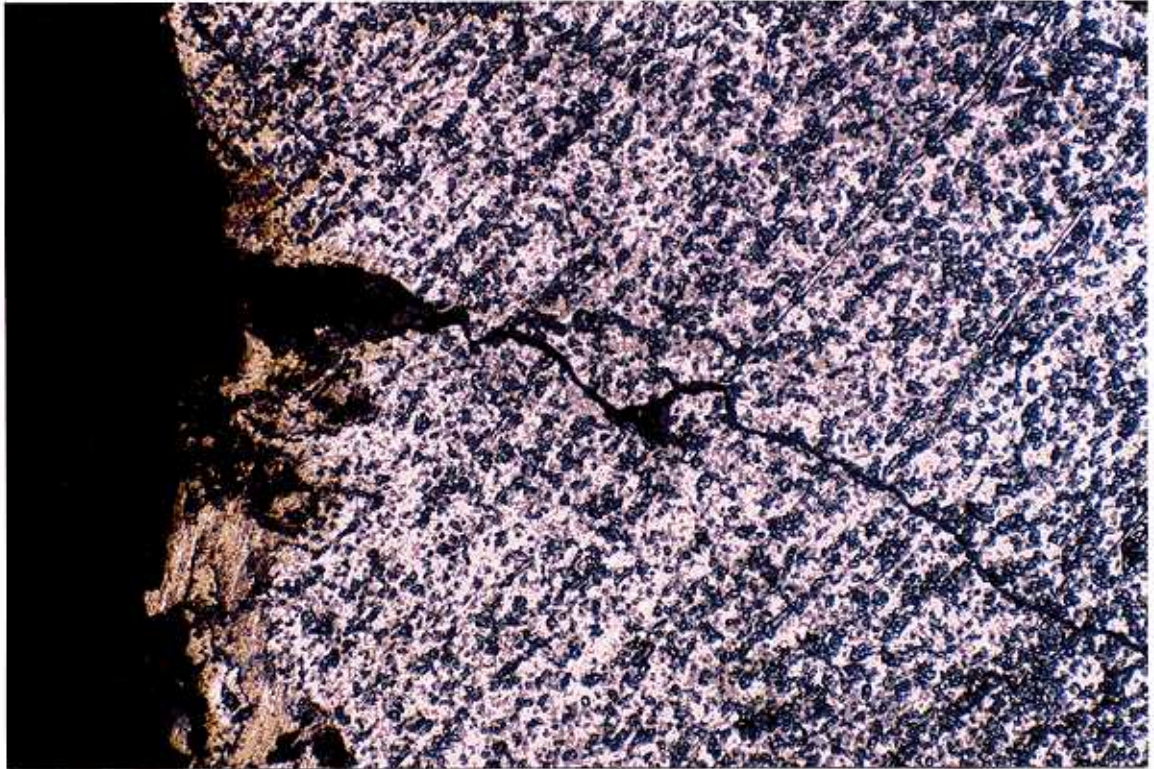


Fig 3 288 Hole #1. Micrograph showing the major crack.

(X 100)



Fig 4 288 Hole #1 Shallow surface craze cracks near the hole after light polishing and etching. Compare with the SEM images of the rippled surface.

(X 100)

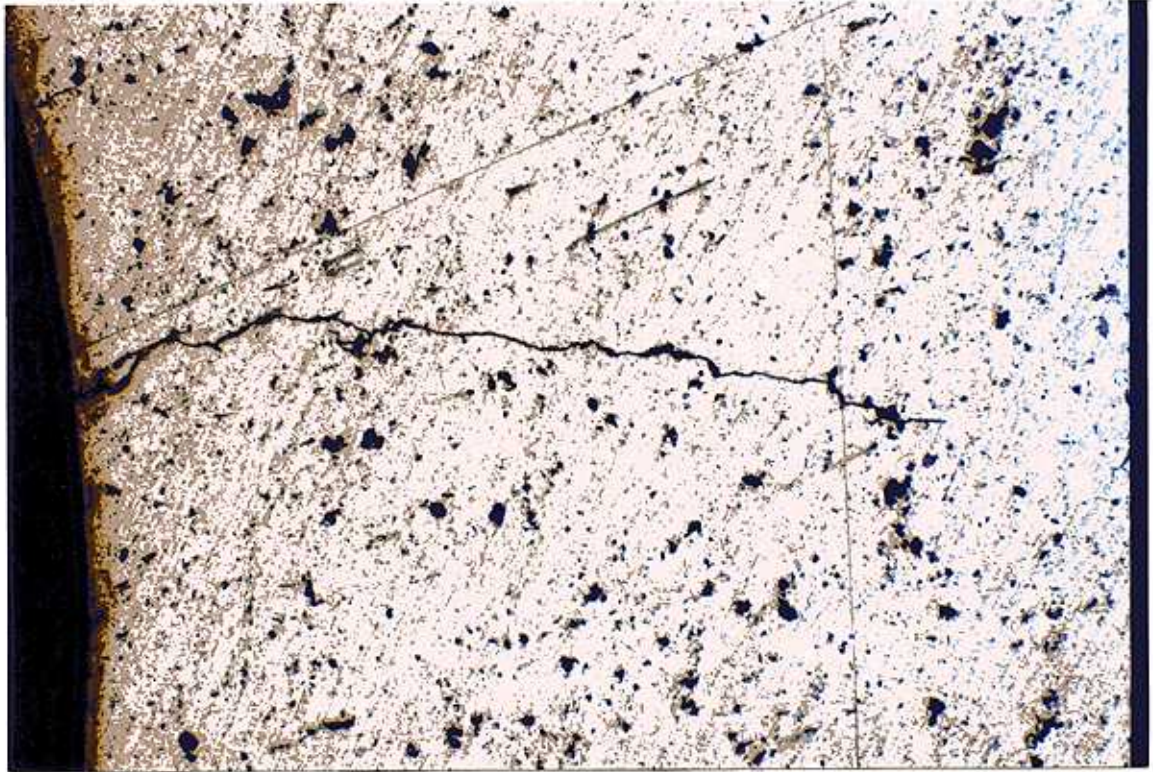


Fig 5 288 Hole #1. Photomicrograph after removing 0.5 mm from the surface of the plate, polishing and etching. Compare with fig 3. (X 100)



Fig 6 288 Hole #1. Polished section along the hole surface, the crack was 2 mm deep. (X 100)



Fig 7 289 Hole #2. Optical stereomicroscope image showing the small crack at the hole edge. (X 100)

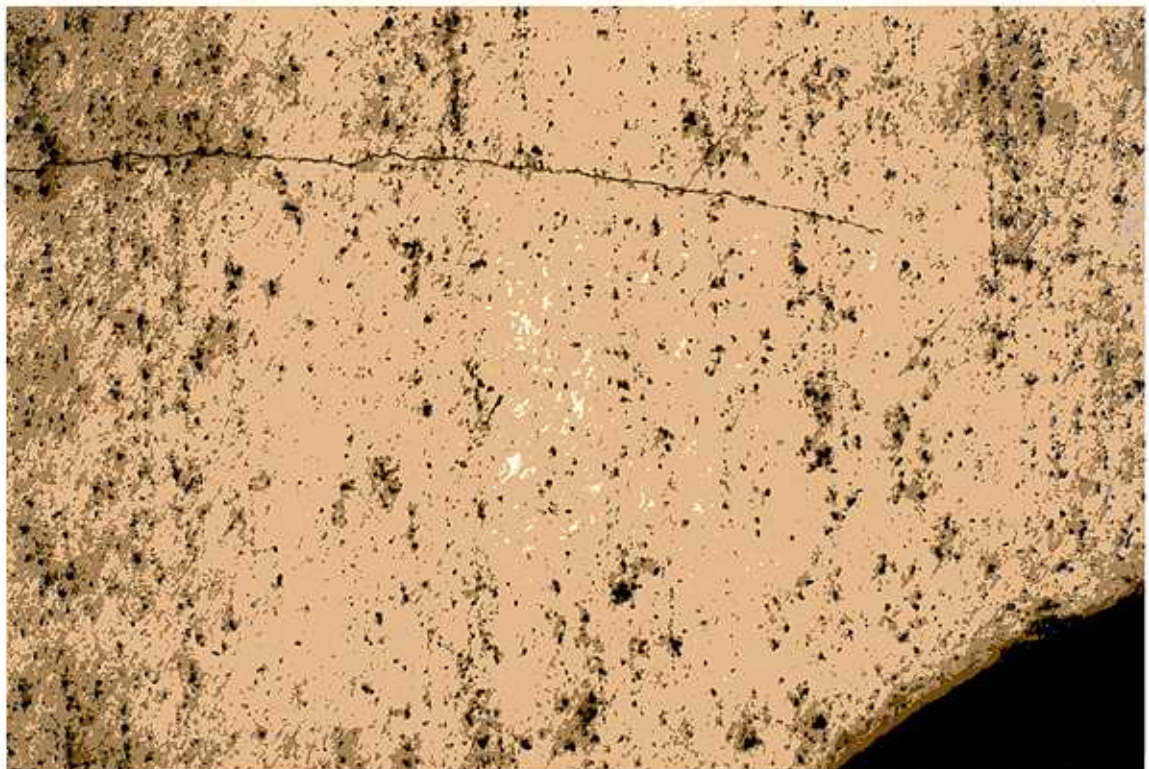


Fig 8 289 Hole #2. 3 mm crack remote from the hole. (X 100)

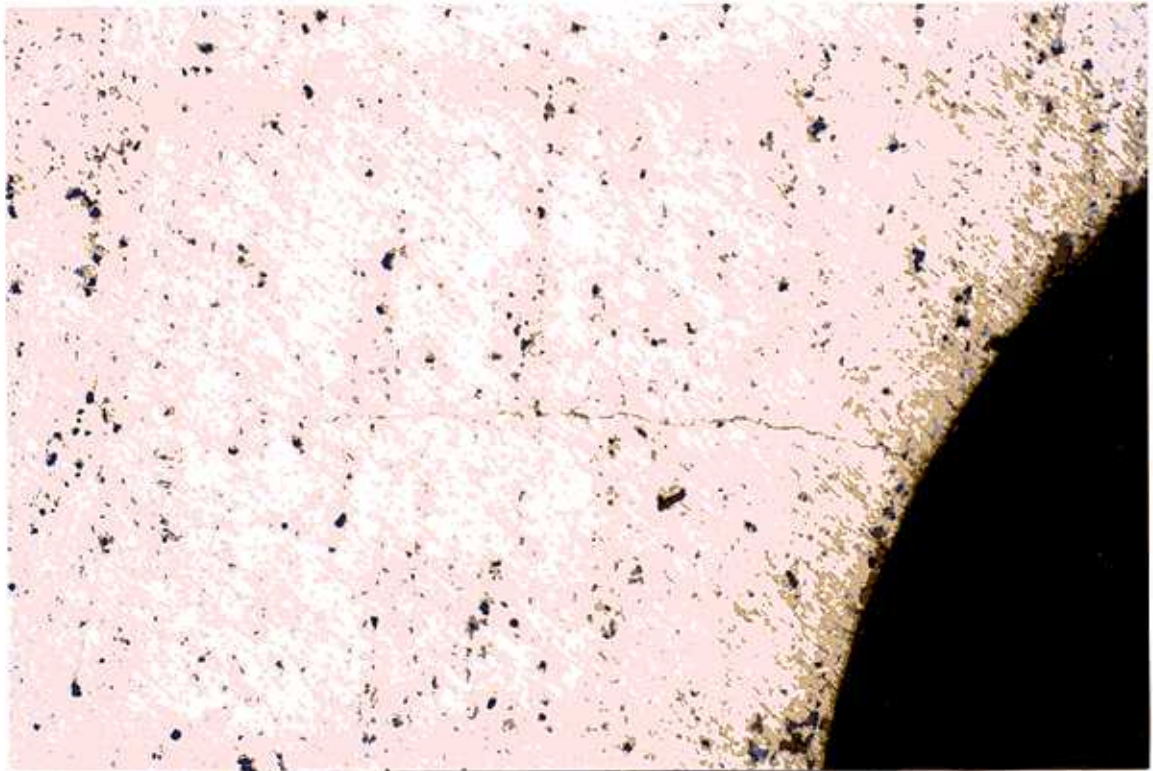


Fig 9 287 Hole #1. Crack extending from the hole edge.

(X 100)

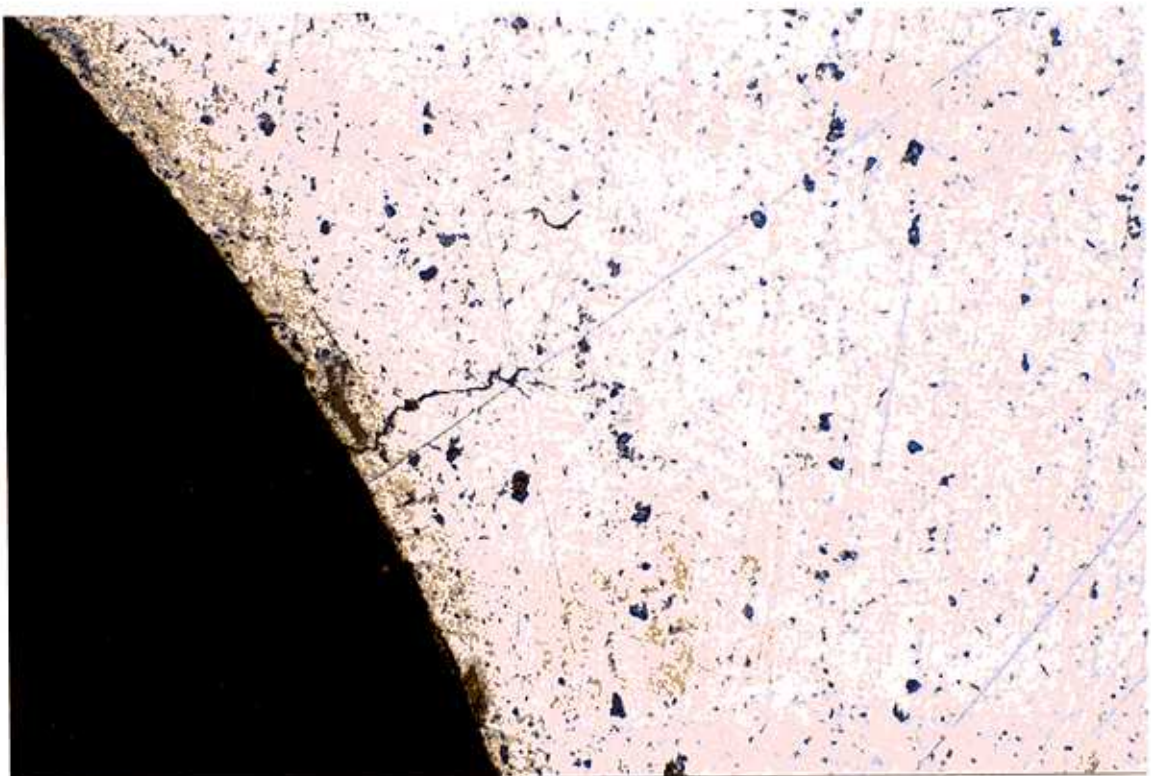


Fig 10 288 Hole #2. Small crack extending from the hole edge.

(X 100)

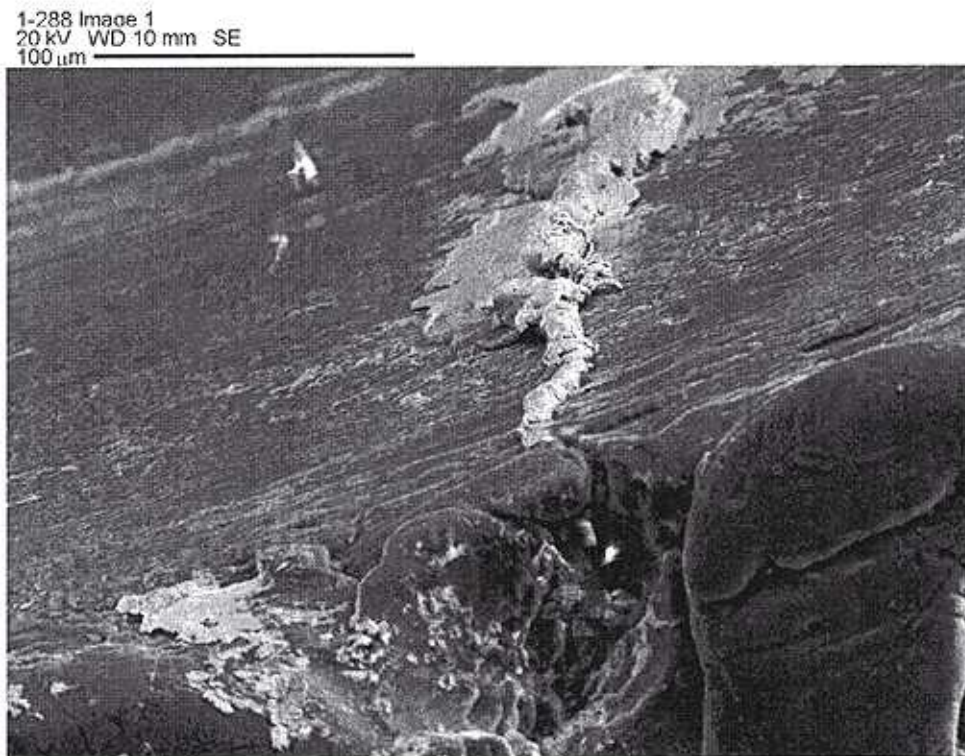


Fig 11 288 Hole 1 SEM image of the hole surface with material extruded from the crack

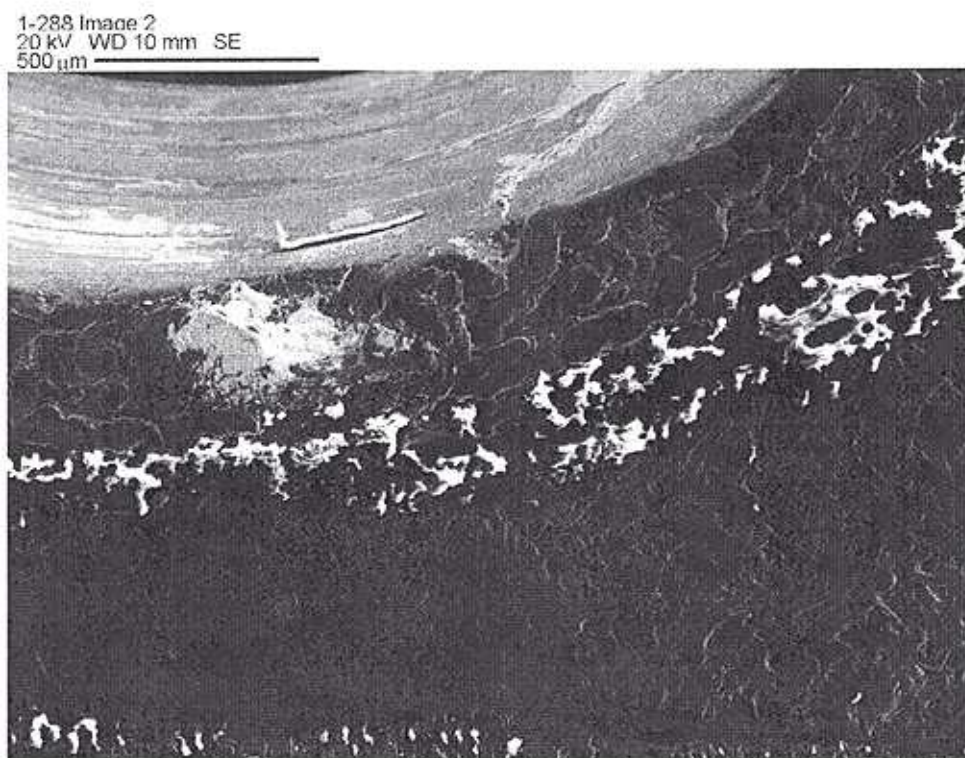


Fig 12 288 Hole 1 Lower magnification image of fig 11.

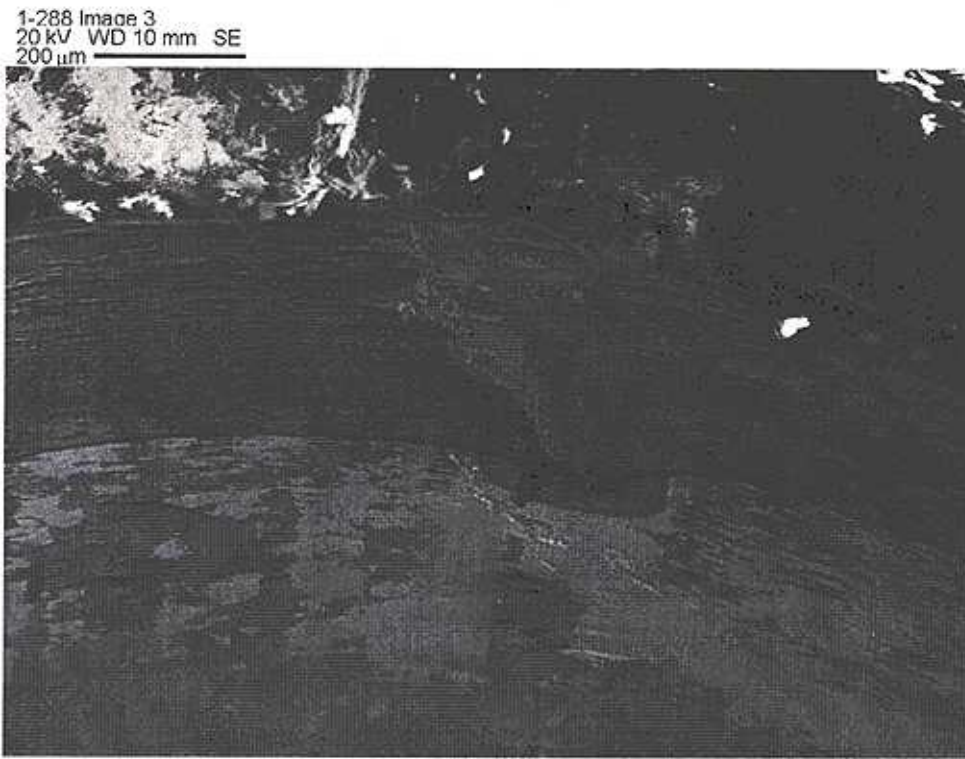


Fig 13 288 Hole 1 Crack on the other side of the hole.

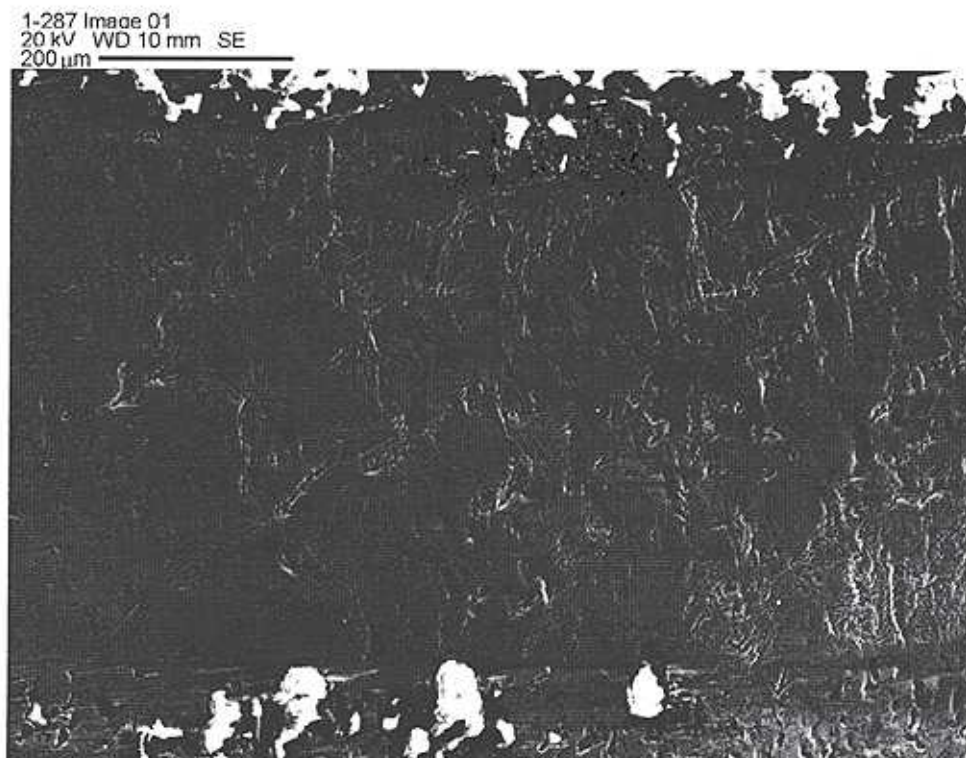


Fig 14 287 Hole 1 Surface ripples on the plate surface near the hole.

1-287 Image 02  
20 kV WD 10 mm SE  
100  $\mu$ m



Fig 15 287 Hole 1 Surface ripples likely to be the main crack.

1-287 Inside Hole Image 1  
20 kV WD 10 mm SE  
50  $\mu$ m

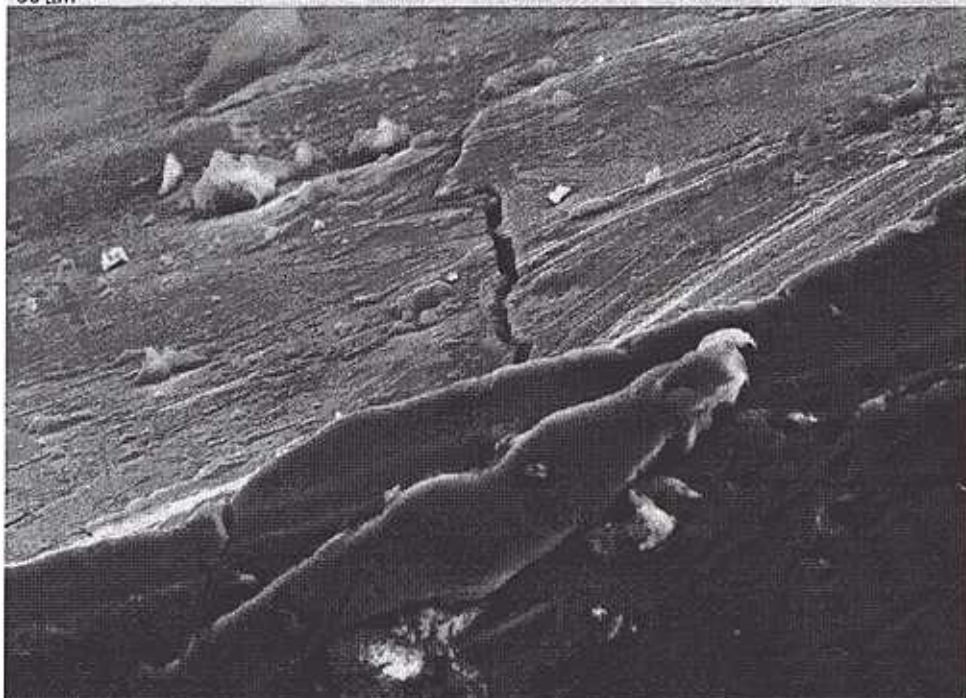


Fig 16 287 Hole 1 The crack has opened up on the hole surface.