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JPL PUBLICATION 84-42 CODE Report No. 27

Coastal Zone Color Scanner (CZCS) Imagery of Near-Surface Phytoplankton Pigment Concentrations From the First Coastal Ocean Dynamics Experiment (CODE-1), March–July 1981

Mark R. Abbott
Philip M. Zion

(NASA-CR-174169) COASTAL ZONE COLOR SCANNER (CZCS): IMAGERY OF NEAR-SURFACE PHYTOPLANKTON PIGMENT CONCENTRATIONS FROM THE FIRST COASTAL OCEAN DYNAMICS EXPERIMENT (CODE-1), MARCH - JULY 1981 (Jet Propulsion G3/48
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Coastal Zone Color Scanner (CZCS) Imagery of Near-Surface Phytoplankton Pigment Concentrations From the First Coastal Ocean Dynamics Experiment (CODE-1), March-July 1981

Overleaf: Phytoplankton pigment distribution on 15 June 1981.

This color image shows the near-surface phytoplankton pigment concentration as measured by the Coastal Zone Color Scanner (CZCS) aboard the polar-orbiting satellite NIMBUS-7. In this scene off Northern California, different colors correspond to the pigment concentration (see color scale in the image). The procedures for creating such images are discussed in detail in the text.

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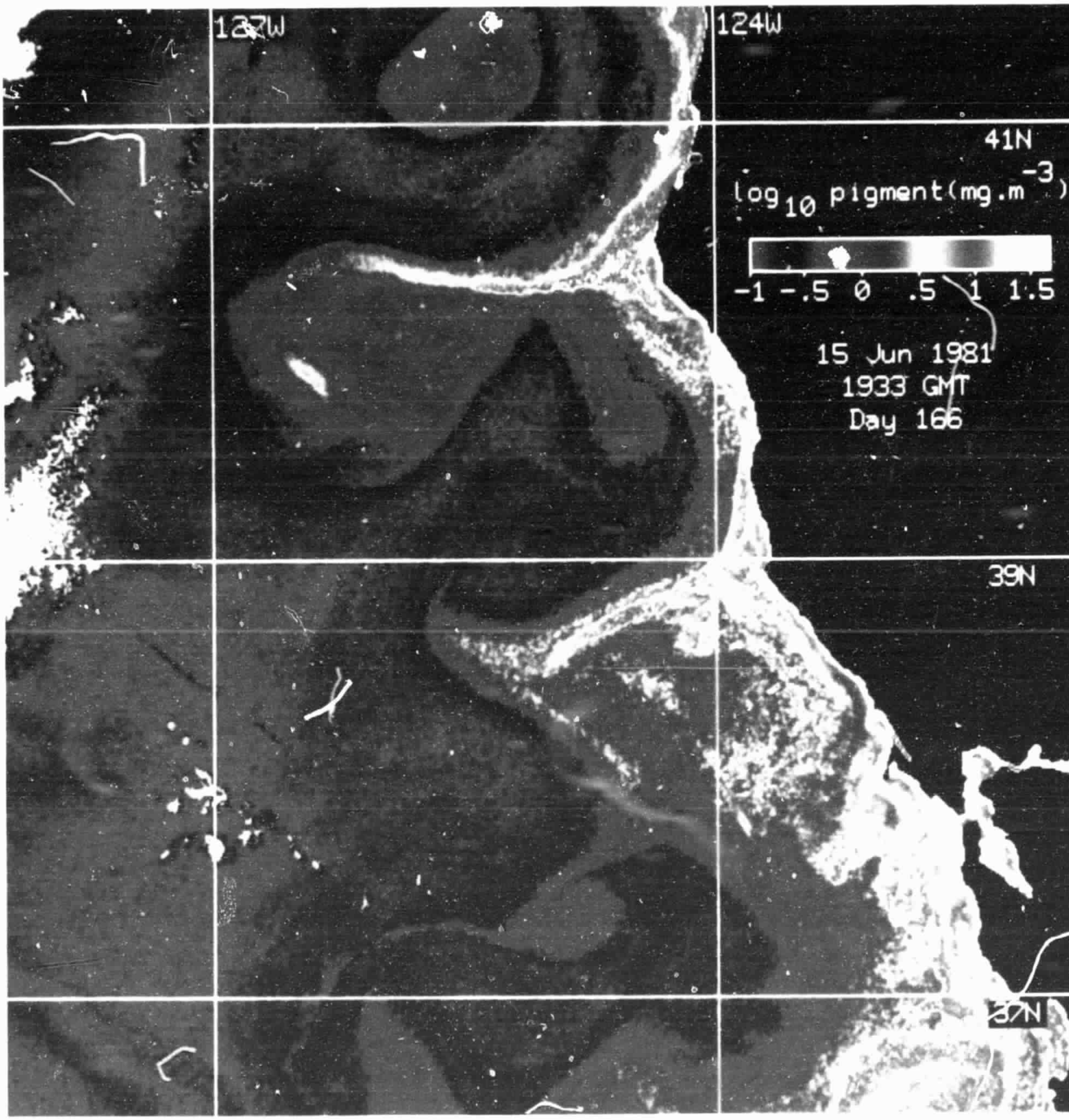

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The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Abstract

As part of the first Coastal Ocean Dynamics Experiment, images of ocean color were collected from late March until late July, 1981, by the Coastal Zone Color Scanner aboard Nimbus-7. Images that had sufficient cloud-free area to be of interest were processed to yield near-surface phytoplankton pigment concentrations. These images were then remapped to a fixed equal-area grid. This report contains photographs of the digital images and a brief description of the processing methods.

Preface

This publication is No. 27 of a sequence of technical and data reports describing the various CODE measurement programs. Both a list of the reports and copies are available from Program Coordinator R. C. Beardsley, Woods Hole Oceanographic Institution, Woods Hole, MA 02543. A short description of the CODE-1 field program is in Allen et al. (1982).

Contents

Description

Data from the Coastal Zone Color Scanner (CZCS) aboard Nimbus-7 were collected at the Scripps Satellite Oceanography Facility (SSOF) during the first Coastal Ocean Dynamics Experiment (CODE-1). Seventy-one CZCS passes were collected and archived at SSOF from 1 March through 31 August 1981. Of these, 34 images had sufficient cloud-free areas near the CODE-1 site to be processed further.

Nimbus-7 is a polar-orbiting, sun-synchronous satellite that passes over SSOF near local noon (1830–2030 GMT). Data were transmitted to the SSOF tracking antenna where they were recorded and archived on digital magnetic tape. The CZCS (Hovis 1981) is a multispectral radiometer with four bands in the visible wavelengths at 443, 520, 550, and 670 nm. Another band at 700–800 nm is used for land and cloud detection. The CZCS has a tiltable mirror ($\pm 20°$ in $2°$ increments) to avoid areas of sun glint. Although the CZCS could scan a given location nearly every day, this does not happen because the CZCS is limited to operating 2 hours per day.

Selected images were processed on hardware provided by the Pilot Ocean Data System (PODS). Software was provided by O. Brown, R. Evans, J. Brown, and A. Li of the University of Miami.

The first processing step was to correct for geographic errors in the satellite location information, which is part of the telemetry stream. The Miami software can reduce these errors to about ± 3 km (Gordon et al. 1983a). A 1024-by-1024-pixel segment centered at 39°N, 125°W was sampled from the complete pass received at SSOF. These sectors were then processed by the CZCS algorithm to derive near-surface pigment concentrations. (We define pigment as the combination of chlorophyll and chlorophyll-like pigments.) The Miami software is based on procedures described in Gordon et al. (1983a) and Gordon and Clark (1981). A description of these algorithms can be found in Zion (1983). The final step was to resample the near-surface pigment images to a fixed, 512-by-512, equal-area grid. The final images were approximately 560 km on a side. Some of these images are smaller, the result of being on the edge of the CZCS pass or of a cessation of data reception at SSOF.

The radiance data measured by the CZCS are converted to near-surface phytoplankton pigment concentrations. There are three steps to this process: calibration, atmospheric removal, and bio-optical algorithms. Calibration converts satellite digital counts to sensor-apparent radiances. This depends in part on the nature of the time-dependent degradation of the CZCS, most notably the change in the 443-nm sensitivity. The Miami software uses the degradation function proposed by Gordon et al. (1983b). As nearly 80–90% of the satellite-sensed radiance is from atmospheric effects, it is essential that this radiance be removed from the imagery. Atmospheric removal is based on the methods described by Gordon et al. (1983a). In the Miami software, $\epsilon(\lambda, \lambda_0)$—which is the ratio of the products of the aerosol albedo, optical thickness, and aerosol characterization function as a function of wavelength, where $\lambda_0 =$ 670 nm—can be modified to account for changing aerosol types from scene to scene. The removal procedure can account for varying aerosol concentrations; varying aerosol types require more sophisticated processing (Gordon et al. 1983a). The final step uses the bio-optical algorithm (Clark 1981) to convert water-leaving radiances into near-surface pigment concentrations.

The atmosphere is generally clearer and more uniform on the west coast of the U.S.A. than on the east coast (R. Evans, personal communication). In general, we have used $\epsilon(\lambda, 670) = 1$, which is appropriate for a marine-type atmosphere (i.e., relatively humid). Although more accurate pigment values can be obtained by iterating the set of epsilons (Gordon et al. 1983a), our choice is conservative and works reasonably well. Comparison of images closely spaced in time revealed no large jumps in pigment values. While the accuracy may not be as good as previous results (± 0.3 log (concentration)), it is probably within a factor of 2.

The current CZCS algorithms are designed for pigment concentrations < 1.5 mg.m^{-3}. At higher concentrations, the radiometric sensitivity is not adequate to detect concentration changes. This presents a potential problem as much of the California Current has levels significantly higher than 1.5 mg.m^{-3}. However, preliminary comparisons between satellite-estimated and ship-measured pigment values at high concentrations are quite good in other regions. Also, the regions in the CODE-1 CZCS imagery that have high pigment concentrations have been detected by earlier ship measurements (e.g., Simpson 1984).

The CZCS algorithms are designed for case-1 waters (Morel and Prieur 1977), where the concentration of suspended sediment is low. Except near the mouth of San Francisco Bay, it is safe to assume that sediment concentrations are low. The narrow shelf and the few small rivers (which have low flows during summer) do not contribute a significant sediment load to the coastal waters in the CODE-1 area.

There are several other variables that can affect CZCS images. As the CZCS scans from west to east (left to right in the images), an apparent "shadow" is occasionally visible to the right of clouds. The presence and extent of this shadow depends in part on the cloud brightness. The CZCS algorithms automatically flag land as well as most clouds, but it is difficult to detect thin cirrus clouds. Thus, they are processed as though they were ocean. Often their effects are removed, but if the cirrus are thick enough, these effects will be left in the imagery. Occasionally these effects can be seen as parallel streaks in the images. Another variable is missing scan lines, which is an intermittent problem with the CZCS. Finally, some scenes are near the edge of the scan. The quality of the derived pigment values is lower as a result of the longer pathlength through the atmosphere.

The pictures in this report were made by photographing the images on a digital image display provided by PODS. Each image corresponds to an array of near-surface phytoplankton pigment concentrations with dimensions of 512 by 512. For the particular fixed grid used for this report, 198,225 points correspond to ocean; the remaining 63,919 points correspond to land. There is a significant loss in resolution when photographing the images in black and white; compare the observed detail in the color frontispiece with the same image in black and white.

Each image has a gray scale showing the corresponding pigment concentration. Superimposed is a latitude-longitude grid. Each image is labeled with date, time, and Julian day of the pass. Each image was scanned by the CZCS in approximately 1 minute.

The data will be analyzed for the dominant patterns of temporal and spatial variability. These patterns will be compared with the patterns of physical forcing. Results will be compared with other CODE measurements, in particular studies of sea-surface temperature using the Advanced Very High Resolution Radiometer (AVHRR), as reported by Kelly (1983).

Acknowledgments

This work was supported by NASA under a contract with the California Institute of Technology. SSOF is supported by the Office of Naval Research, the National Science Foundation, and NASA. We thank O. Brown, R. Evans, J. Brown, and A. Li of the University of Miami for advice on the Miami software. B. Houghton and F. Kuykendall also assisted with the hardware and software.

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Images

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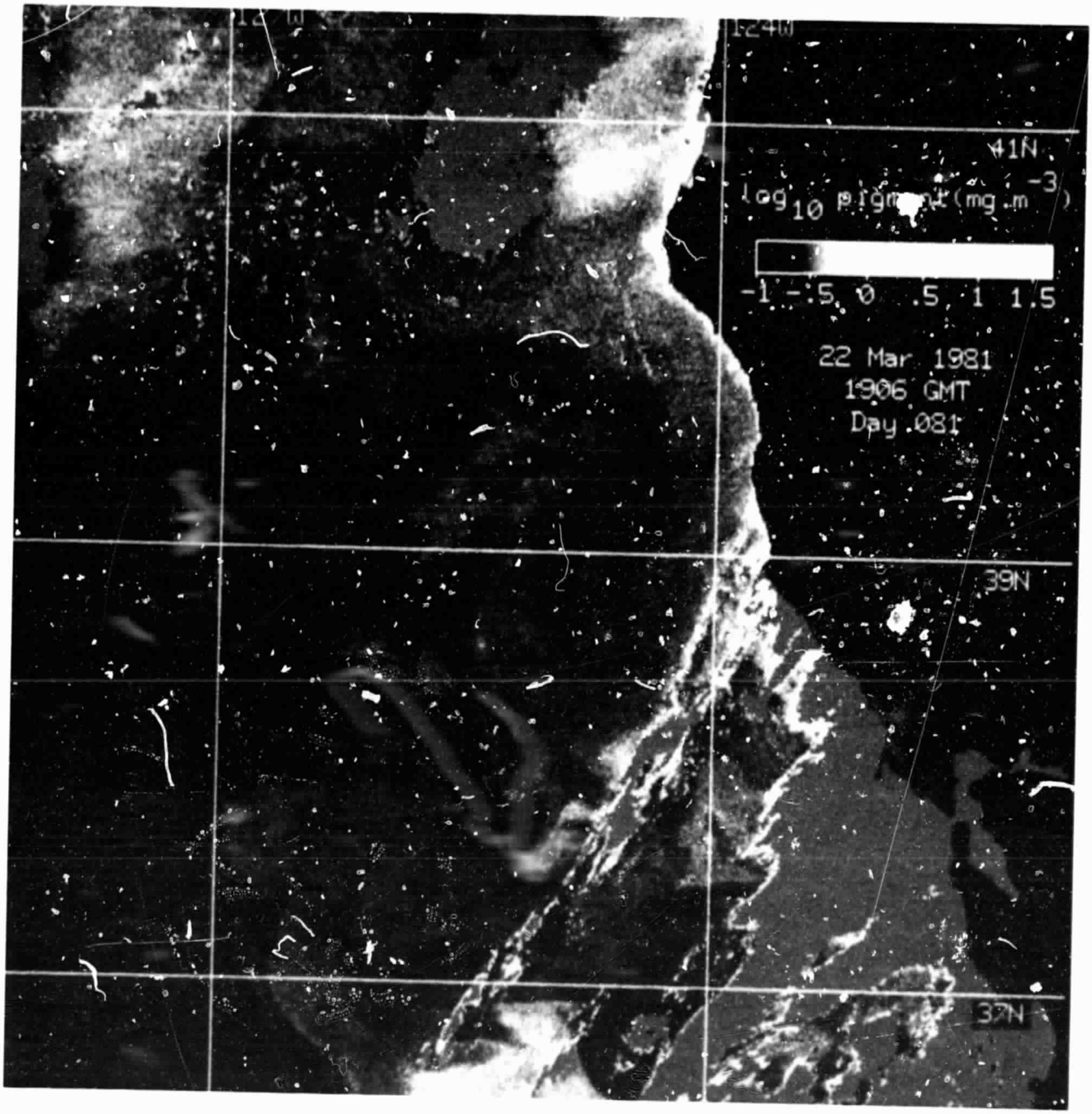

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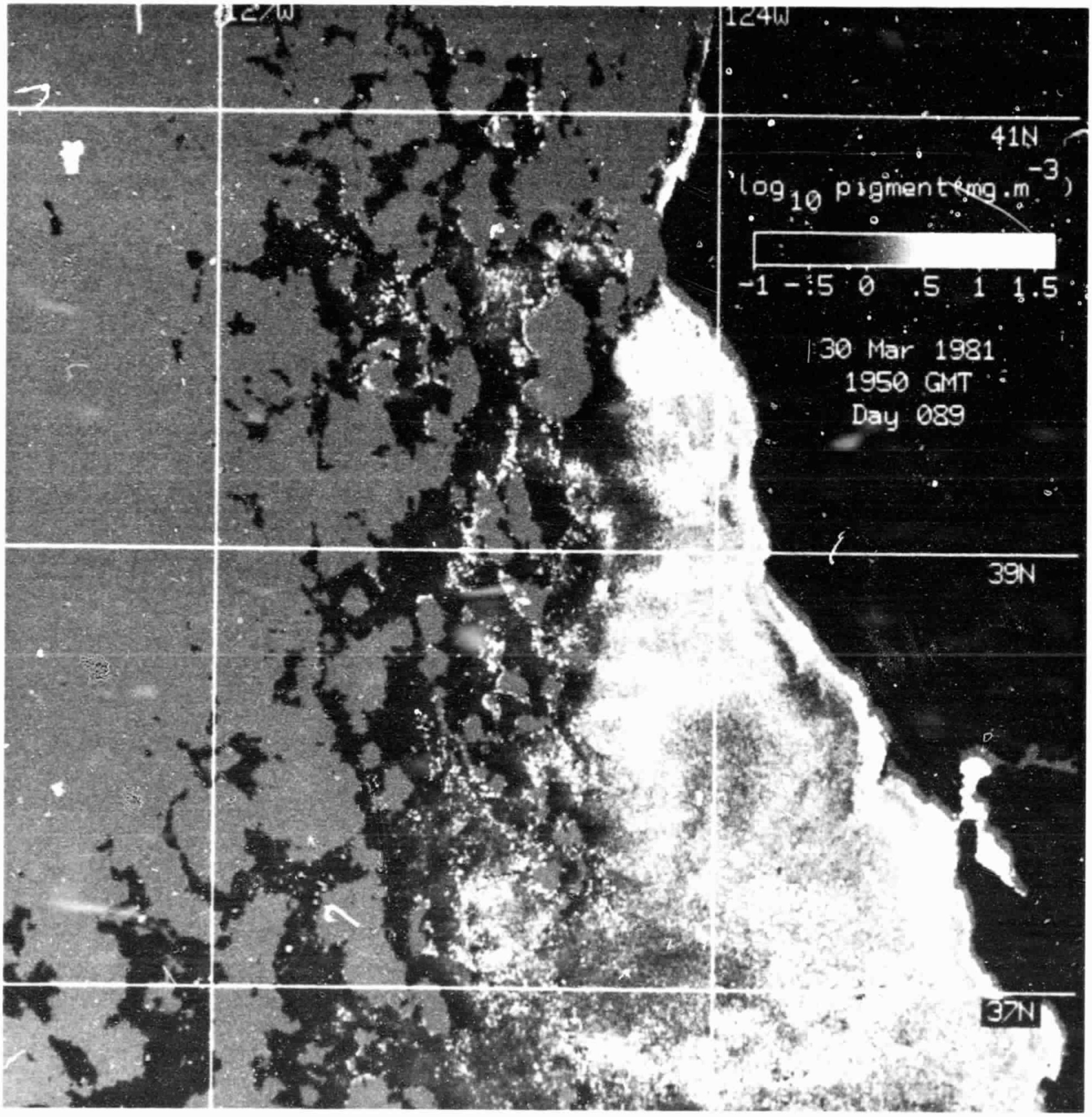

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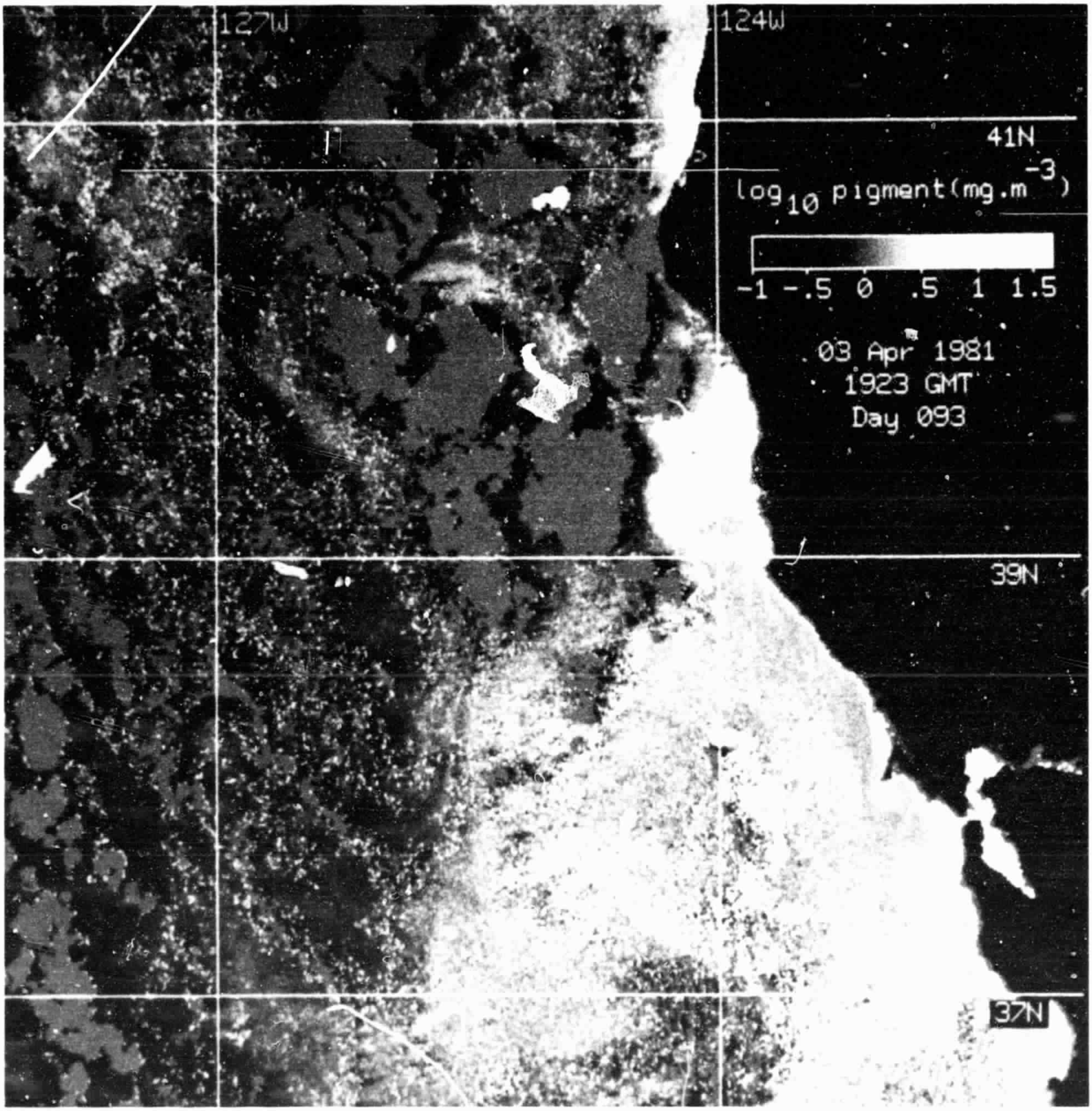

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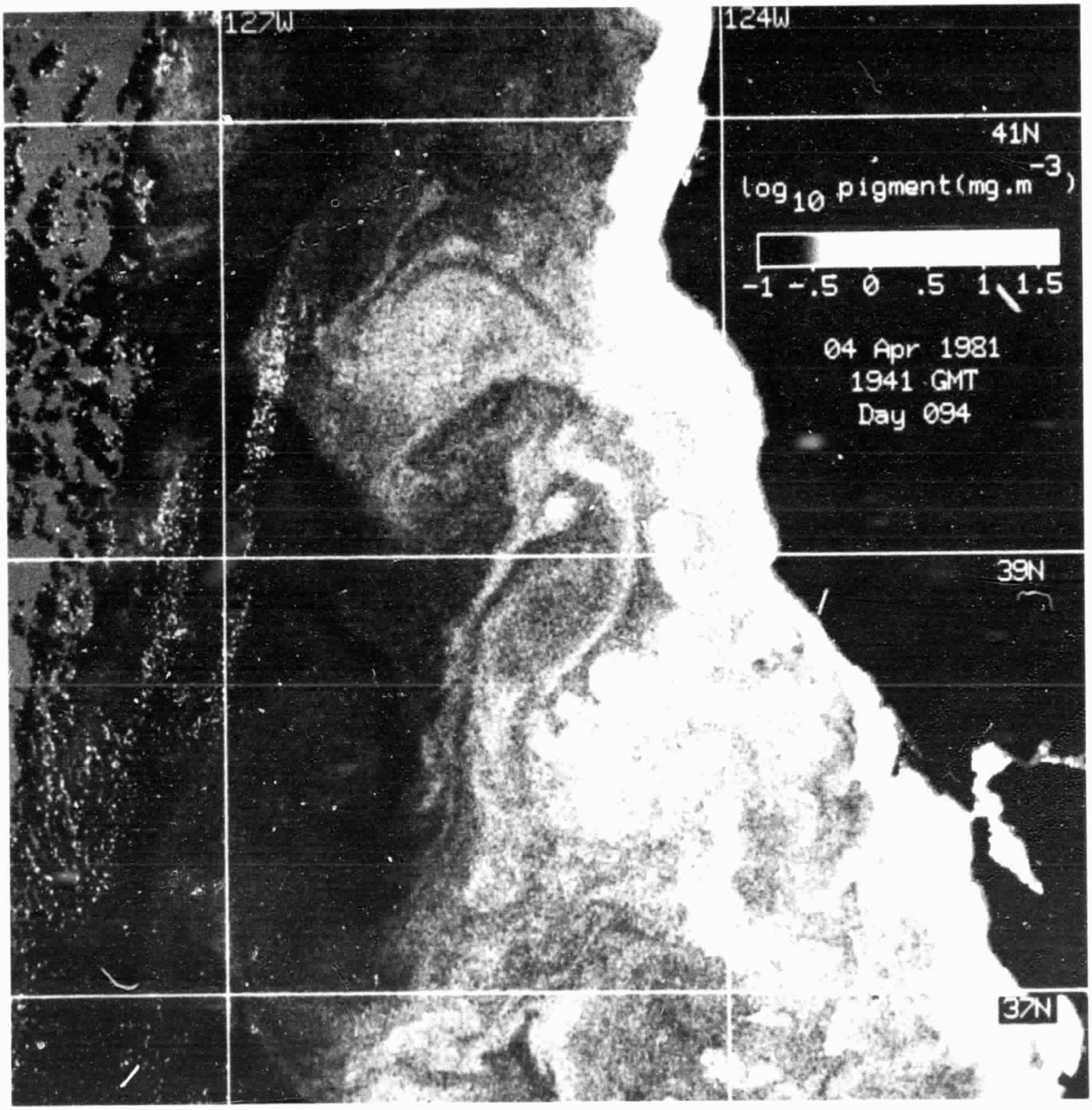

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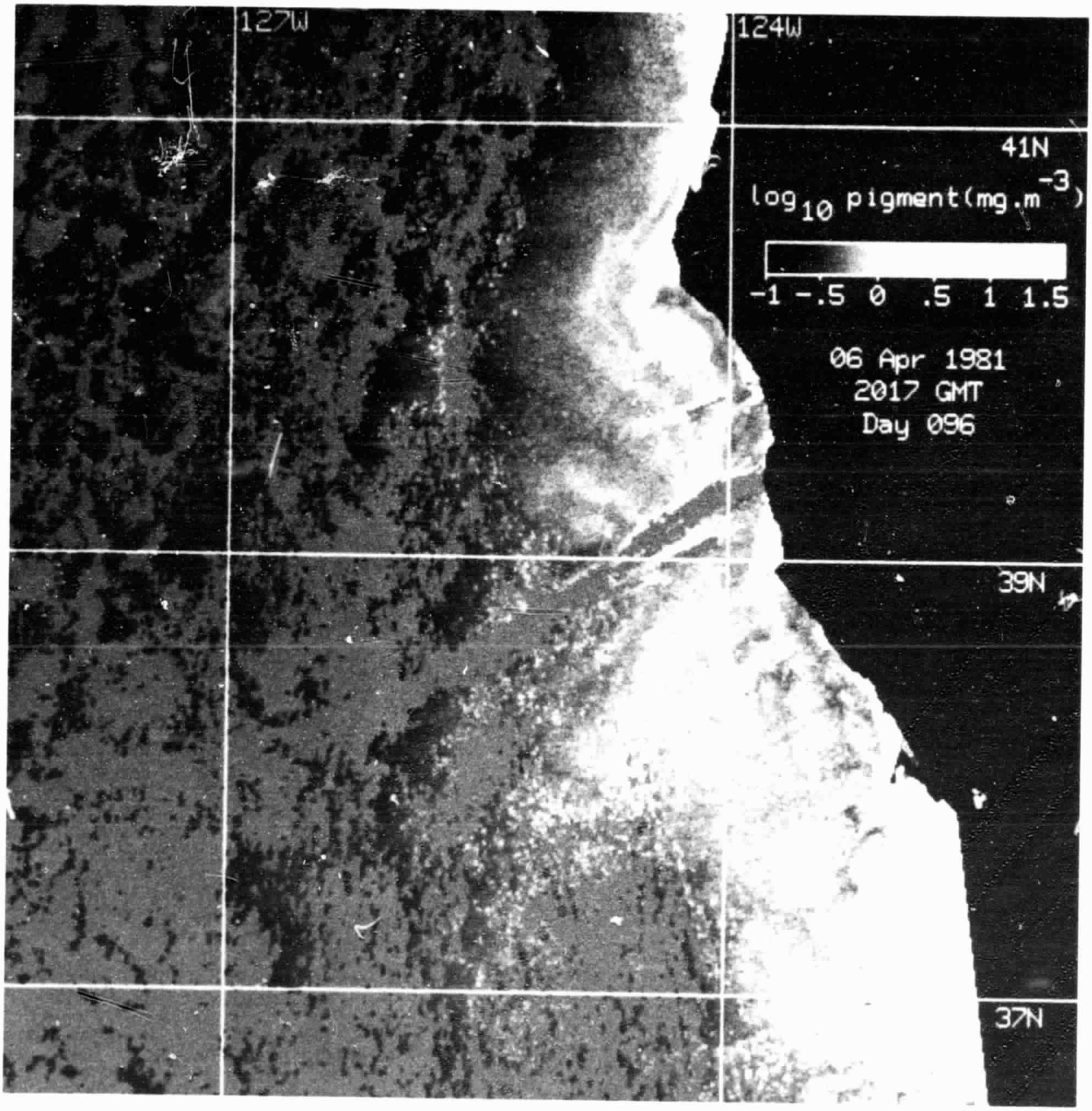

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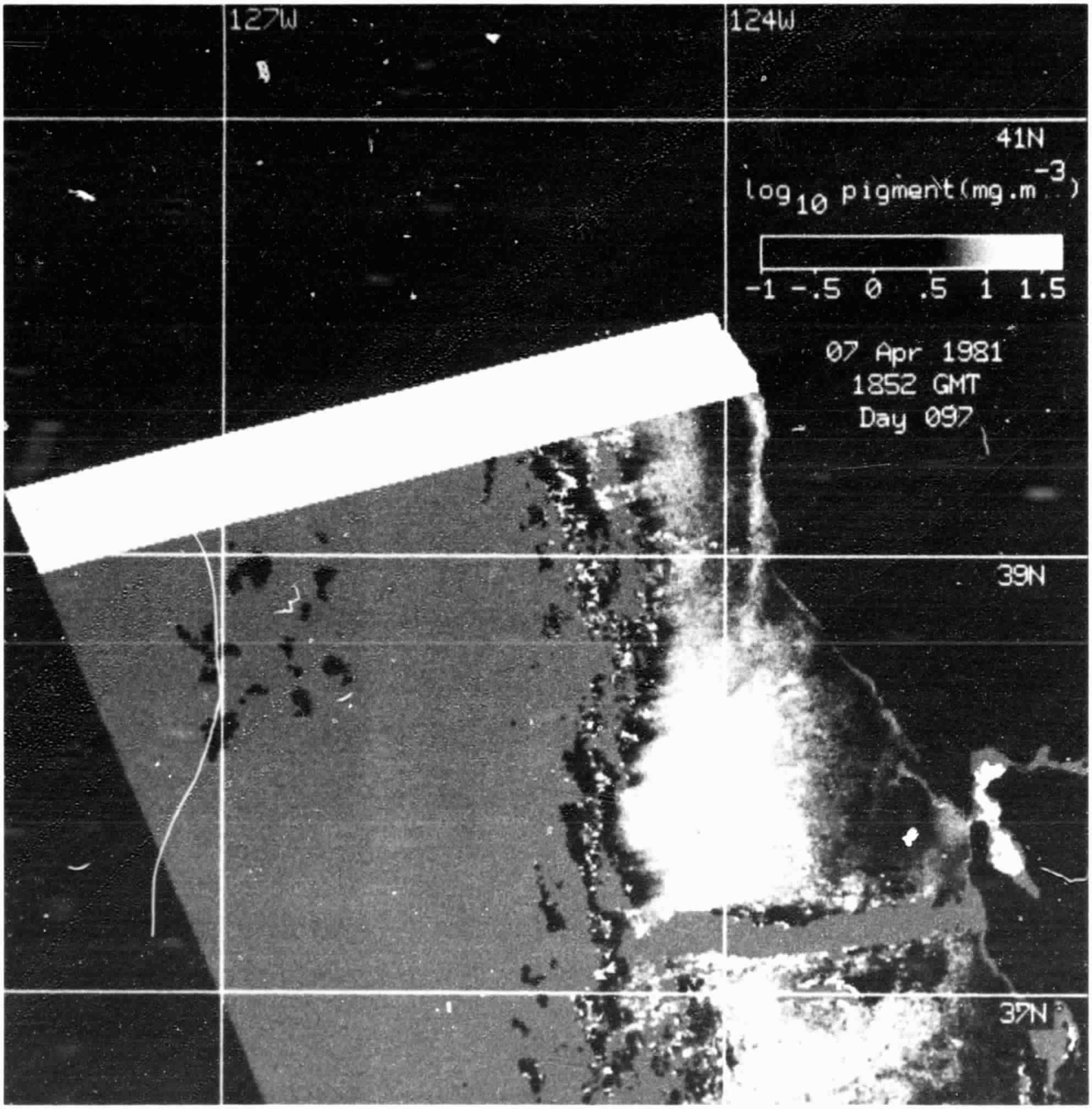

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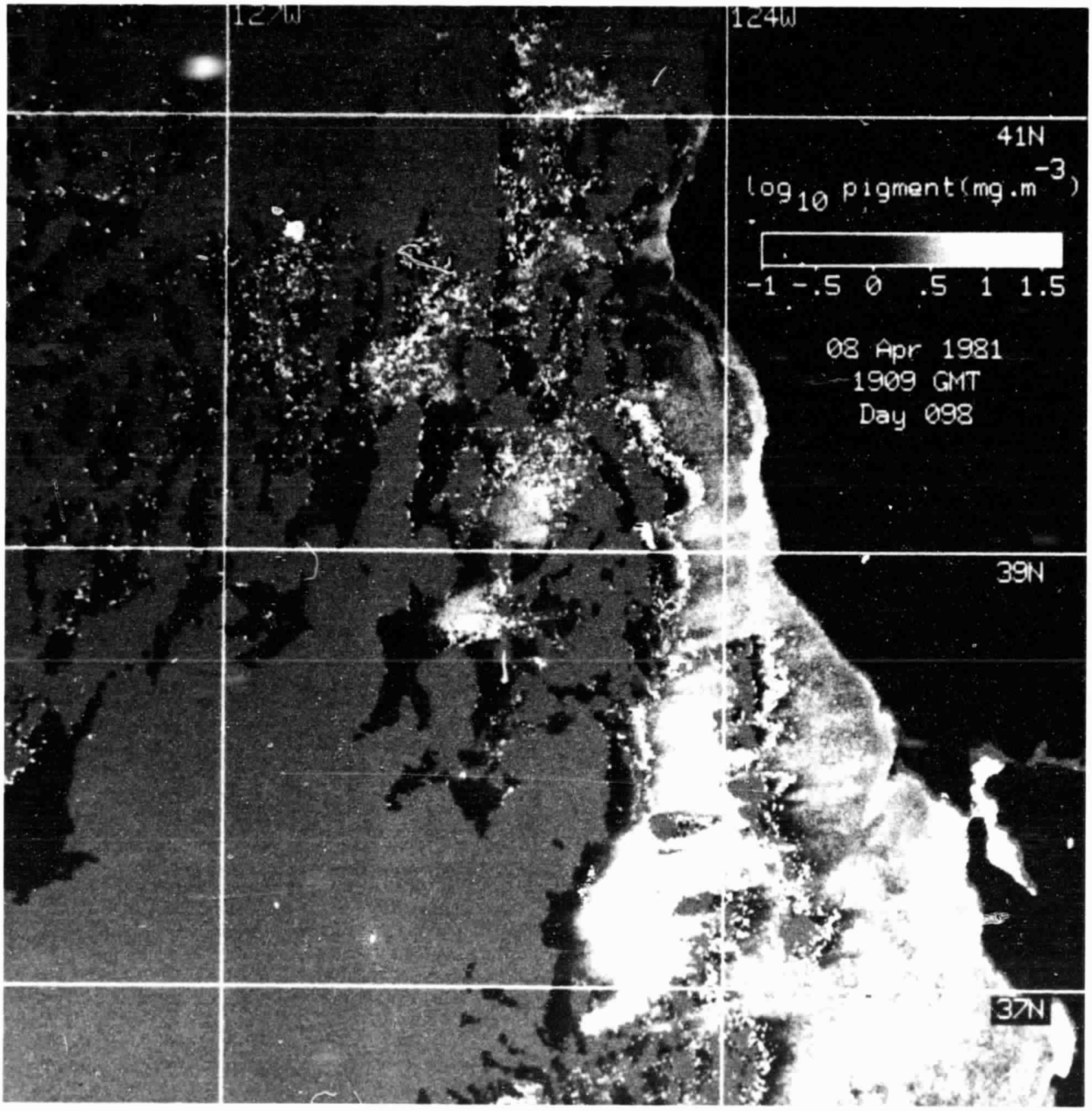

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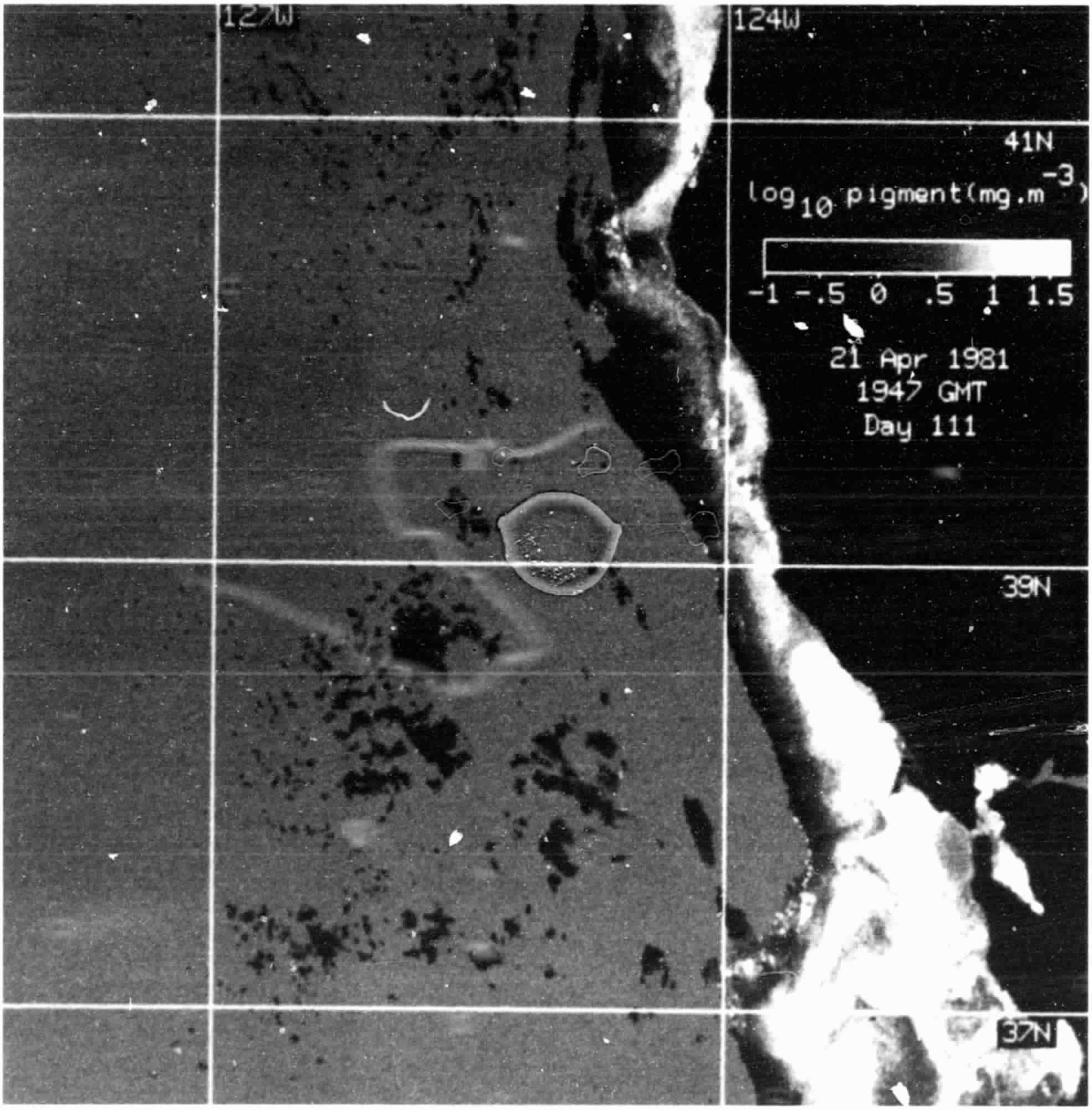

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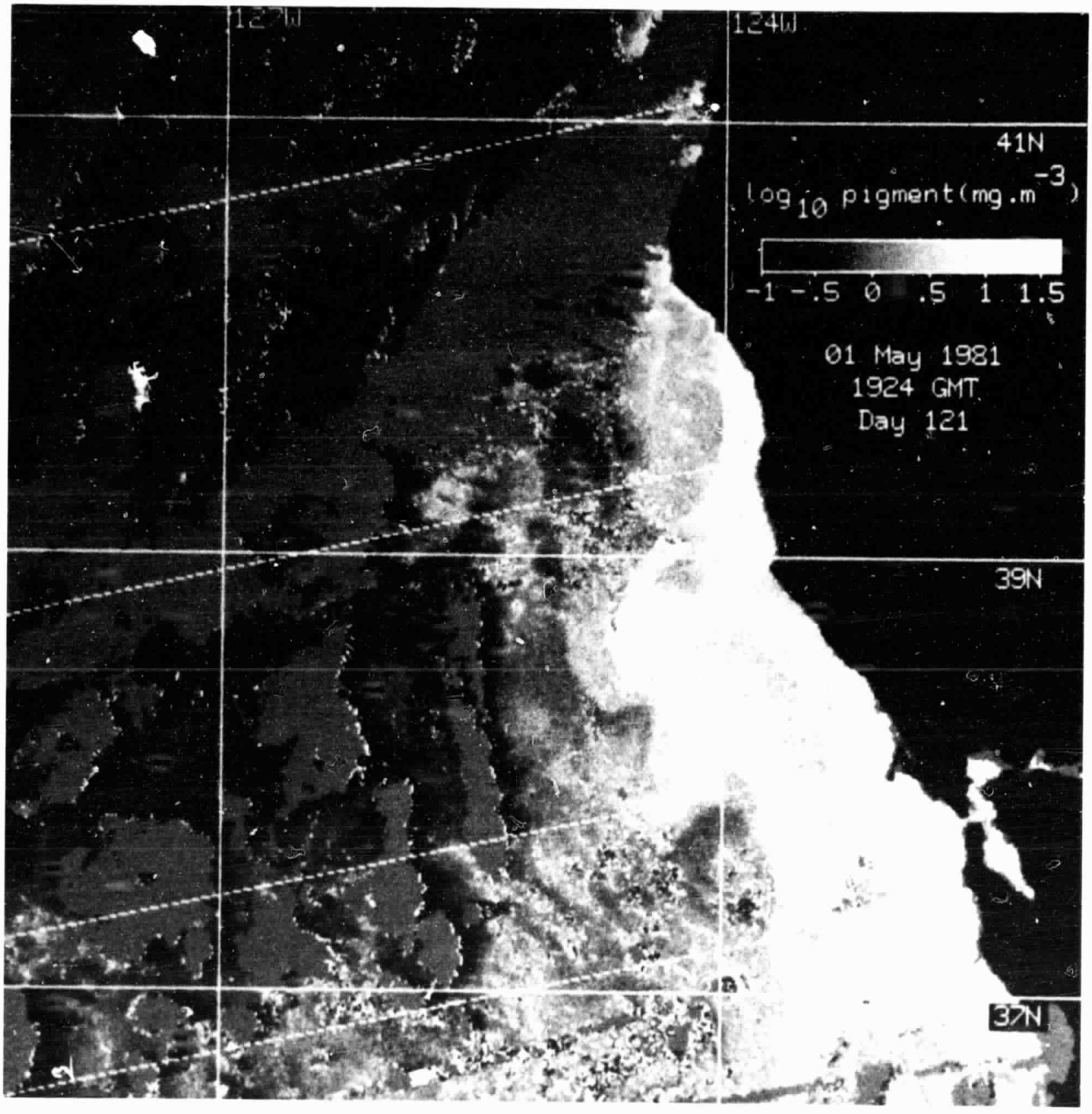

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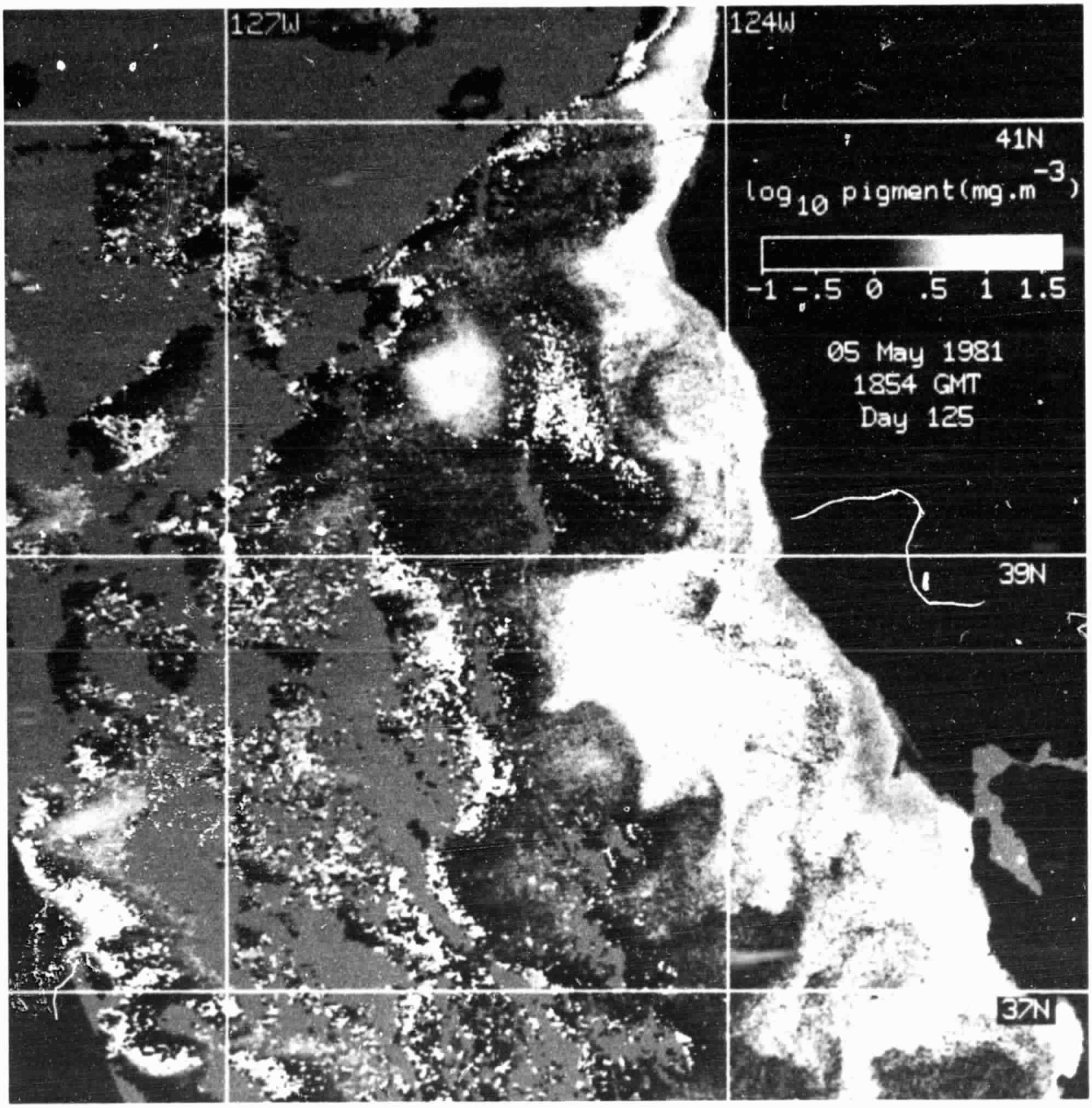

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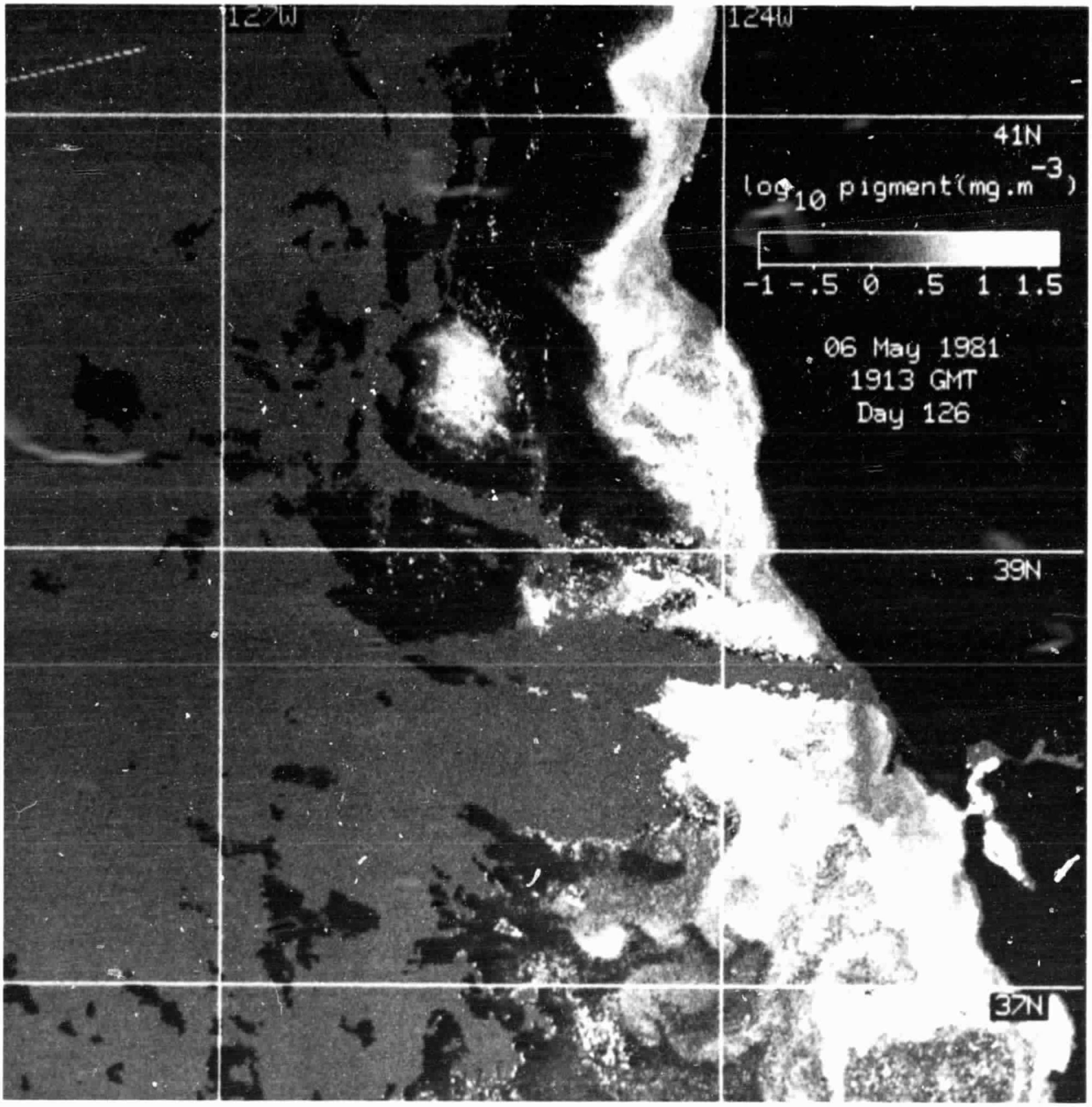
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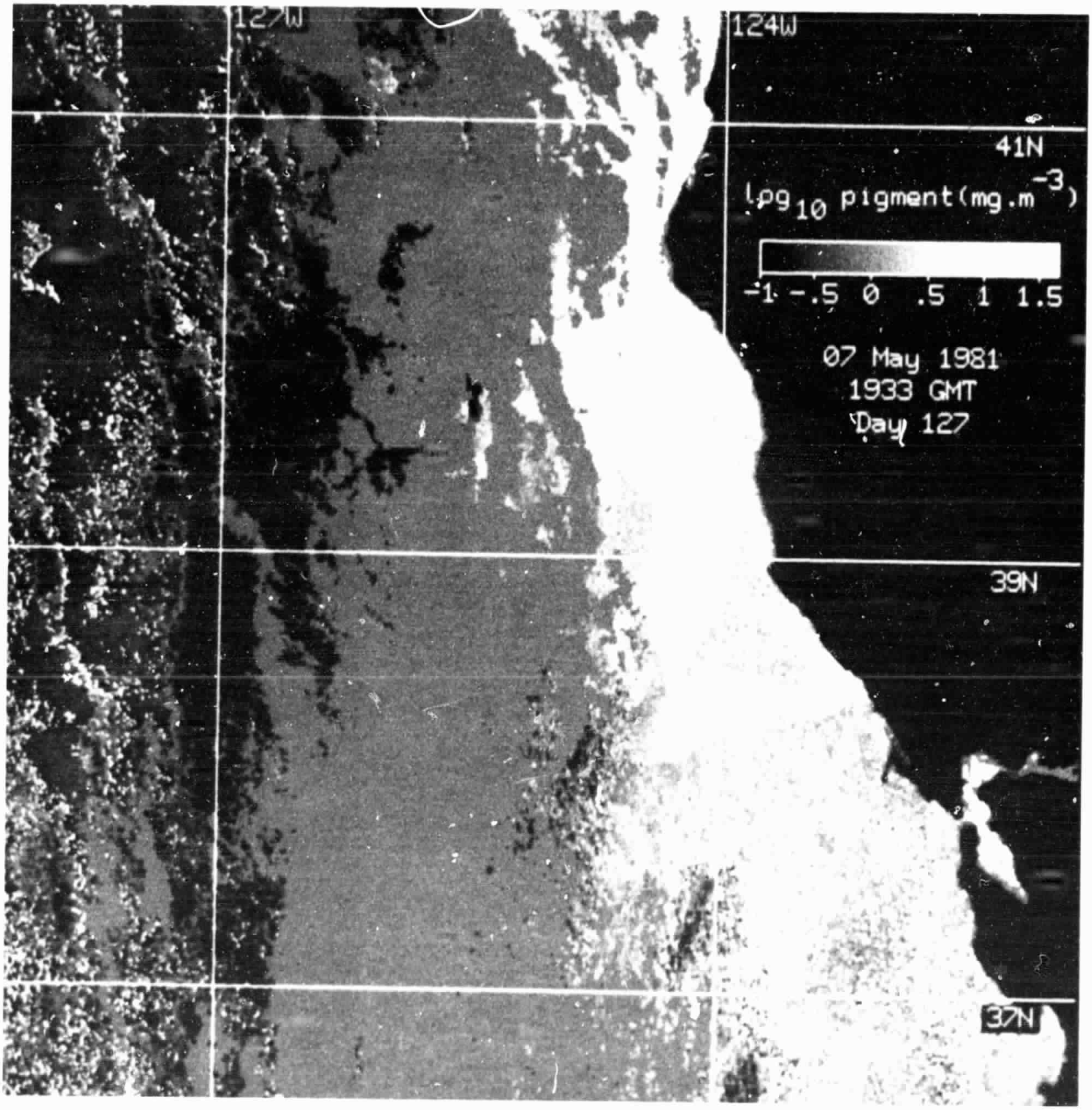

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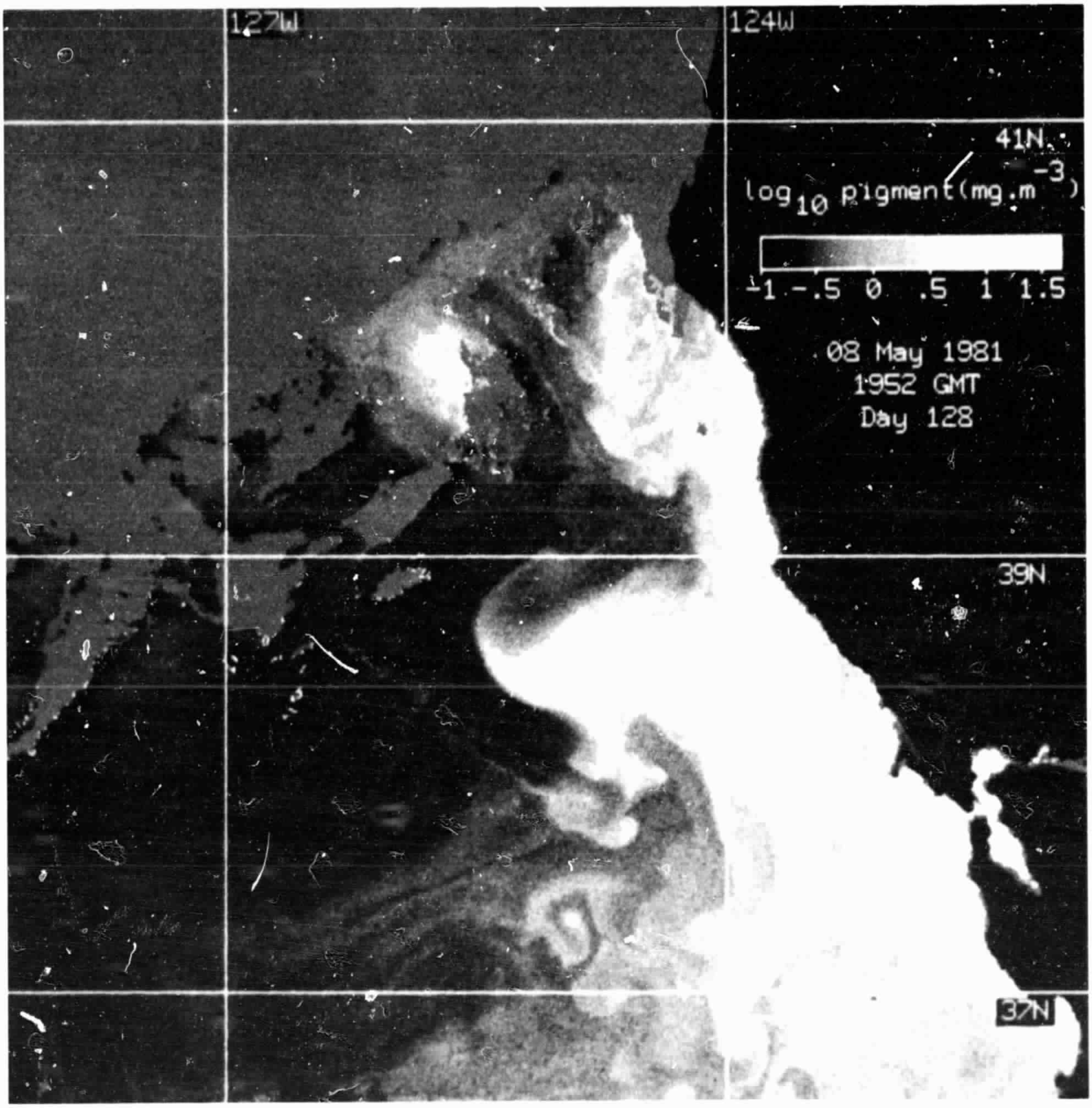

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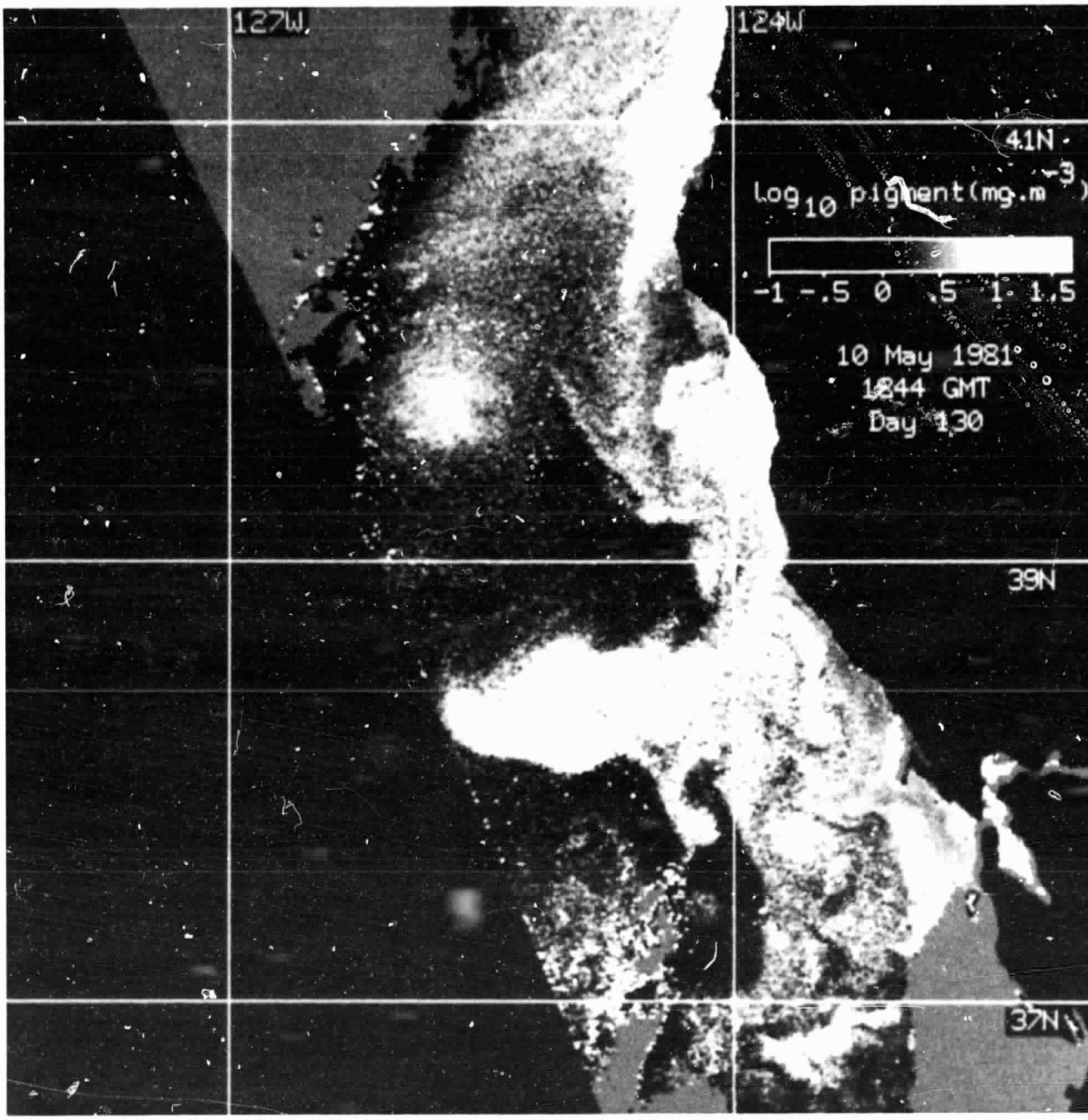

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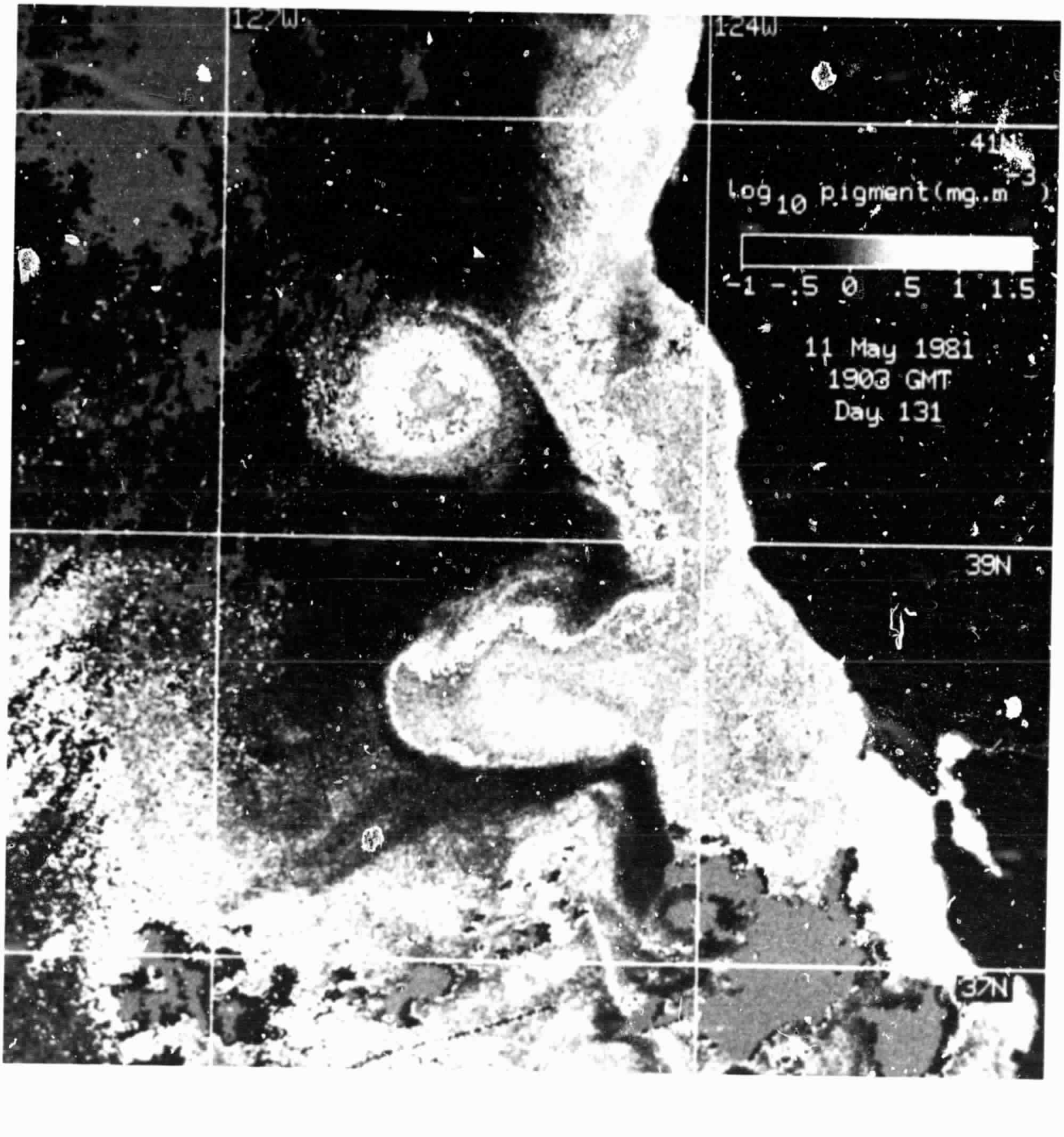

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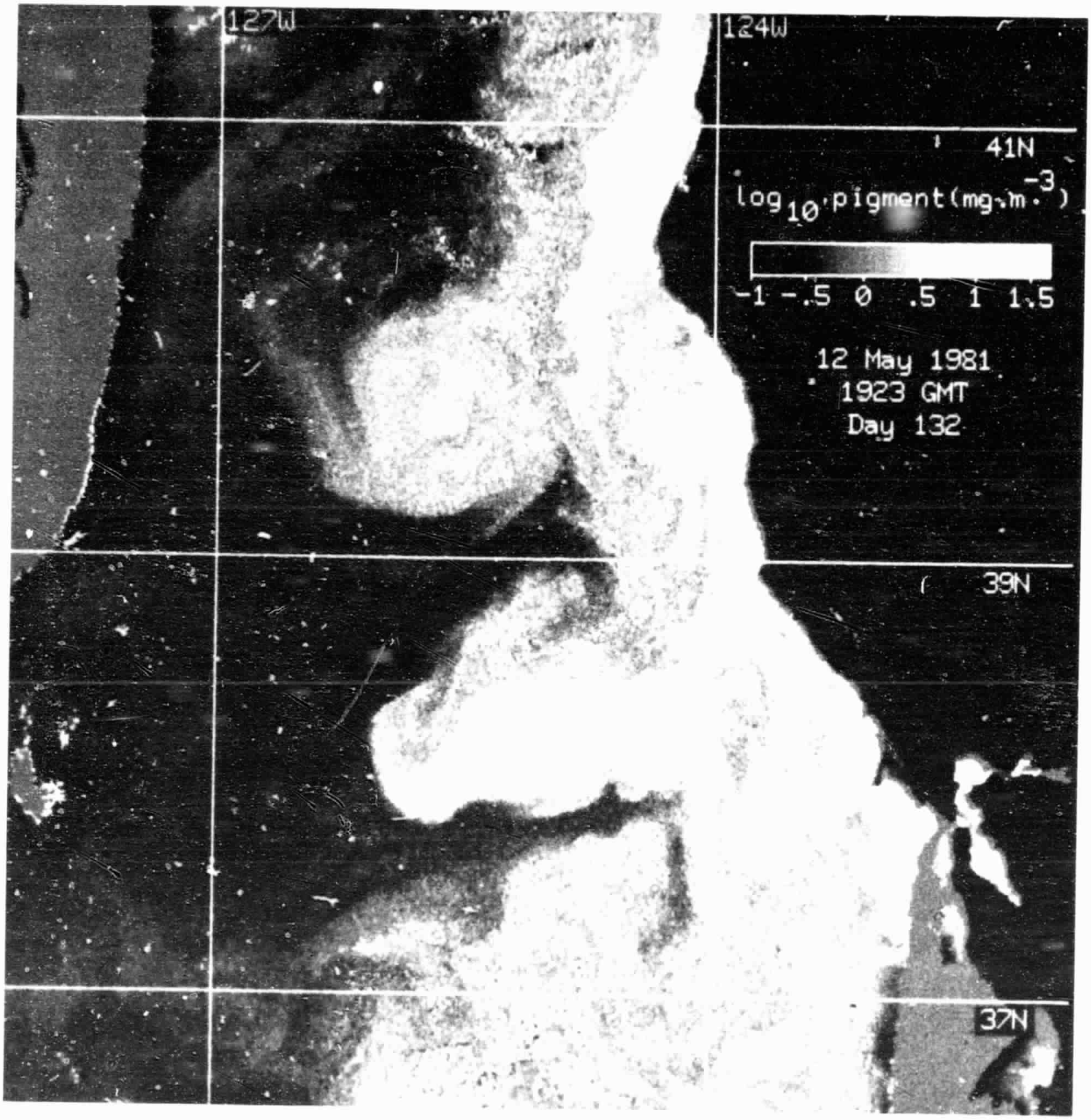

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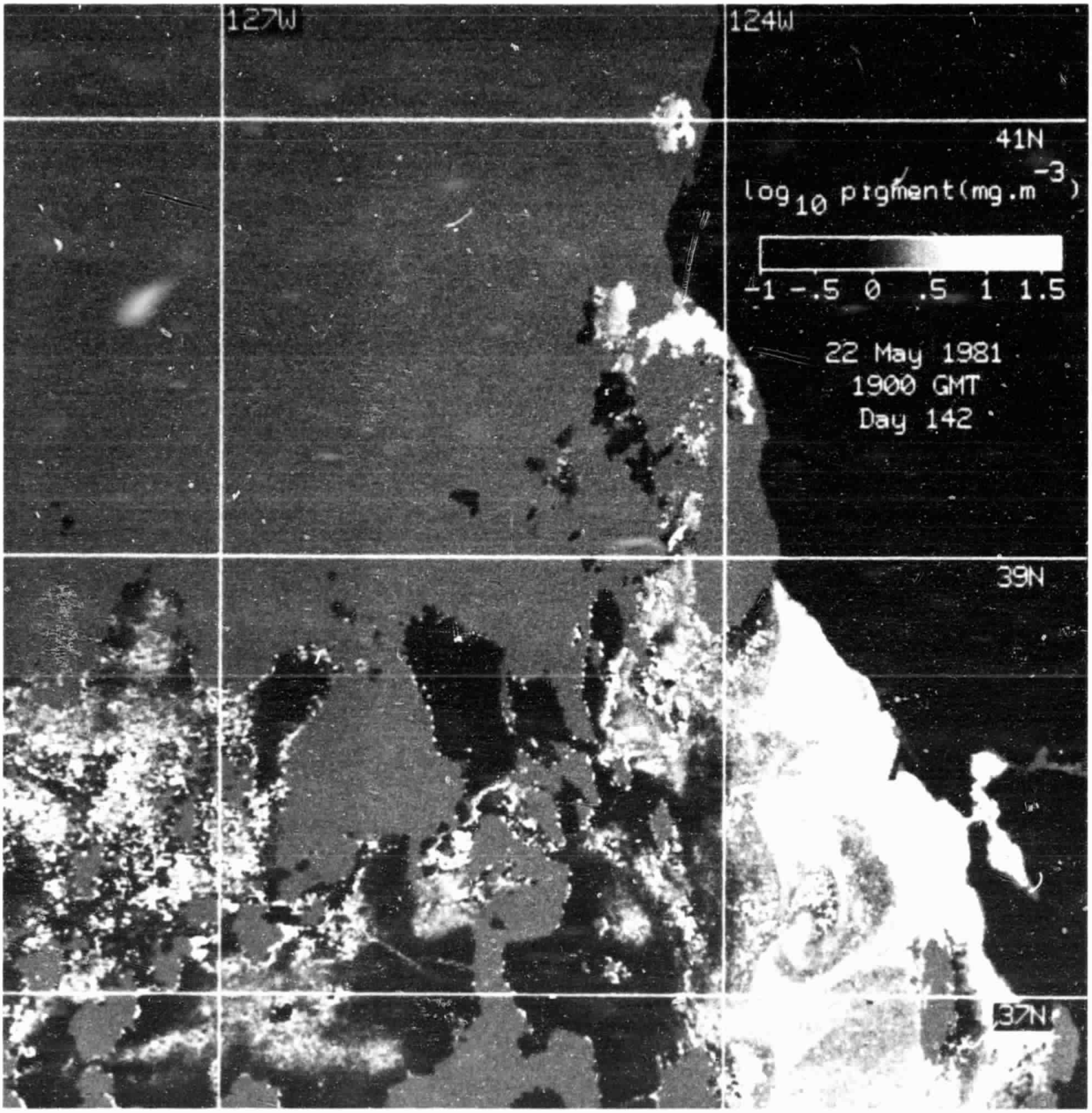

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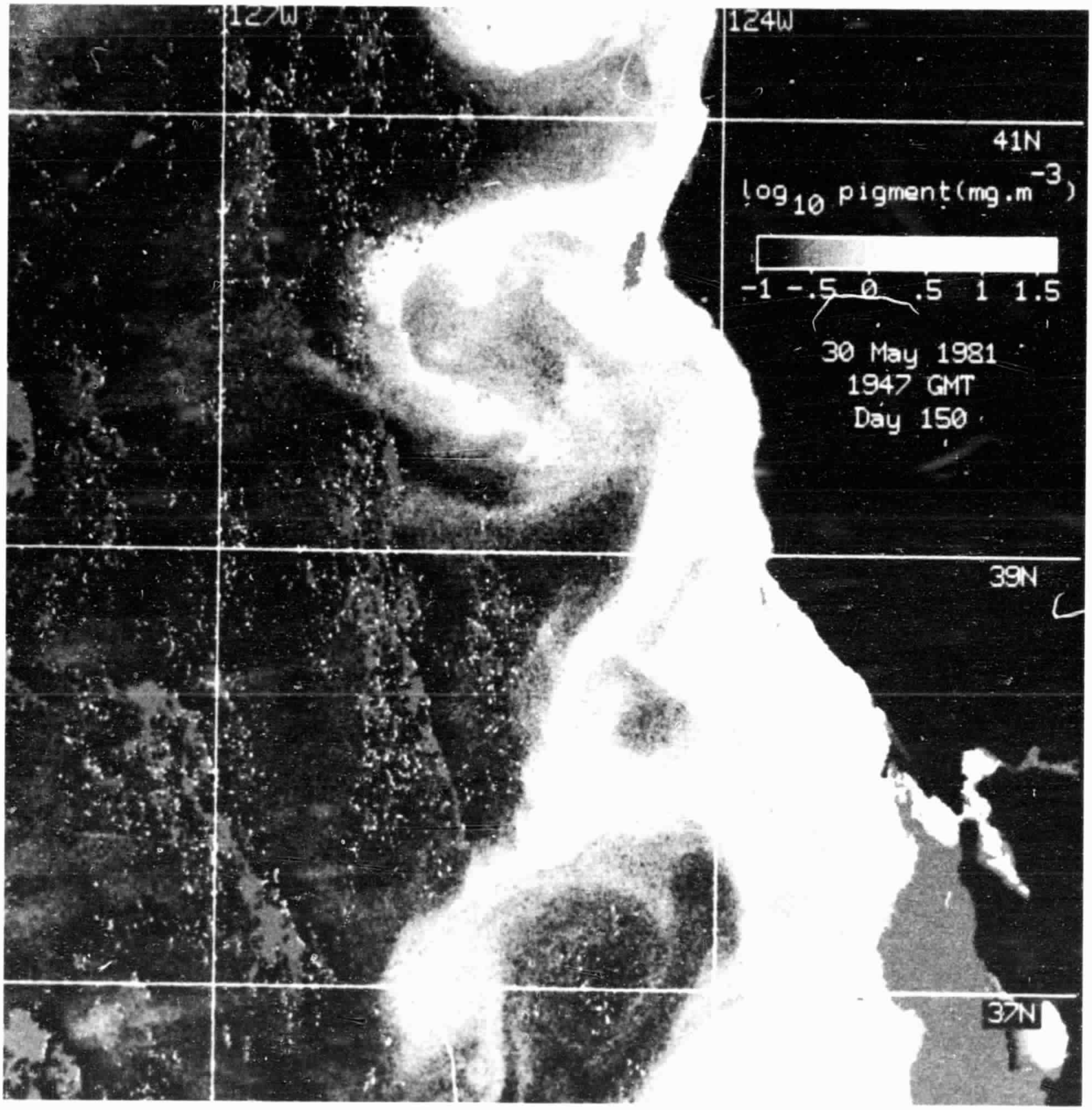

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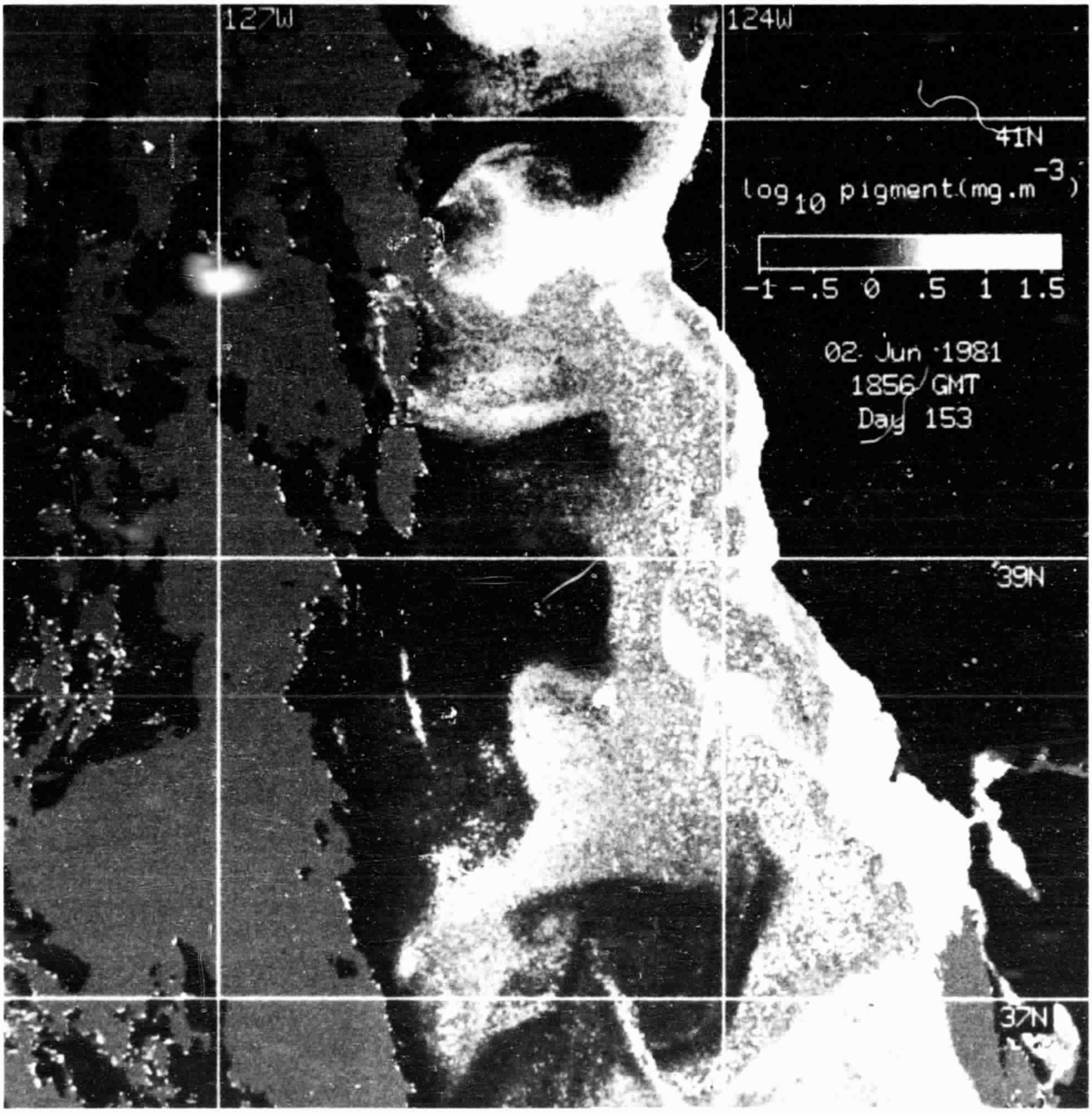

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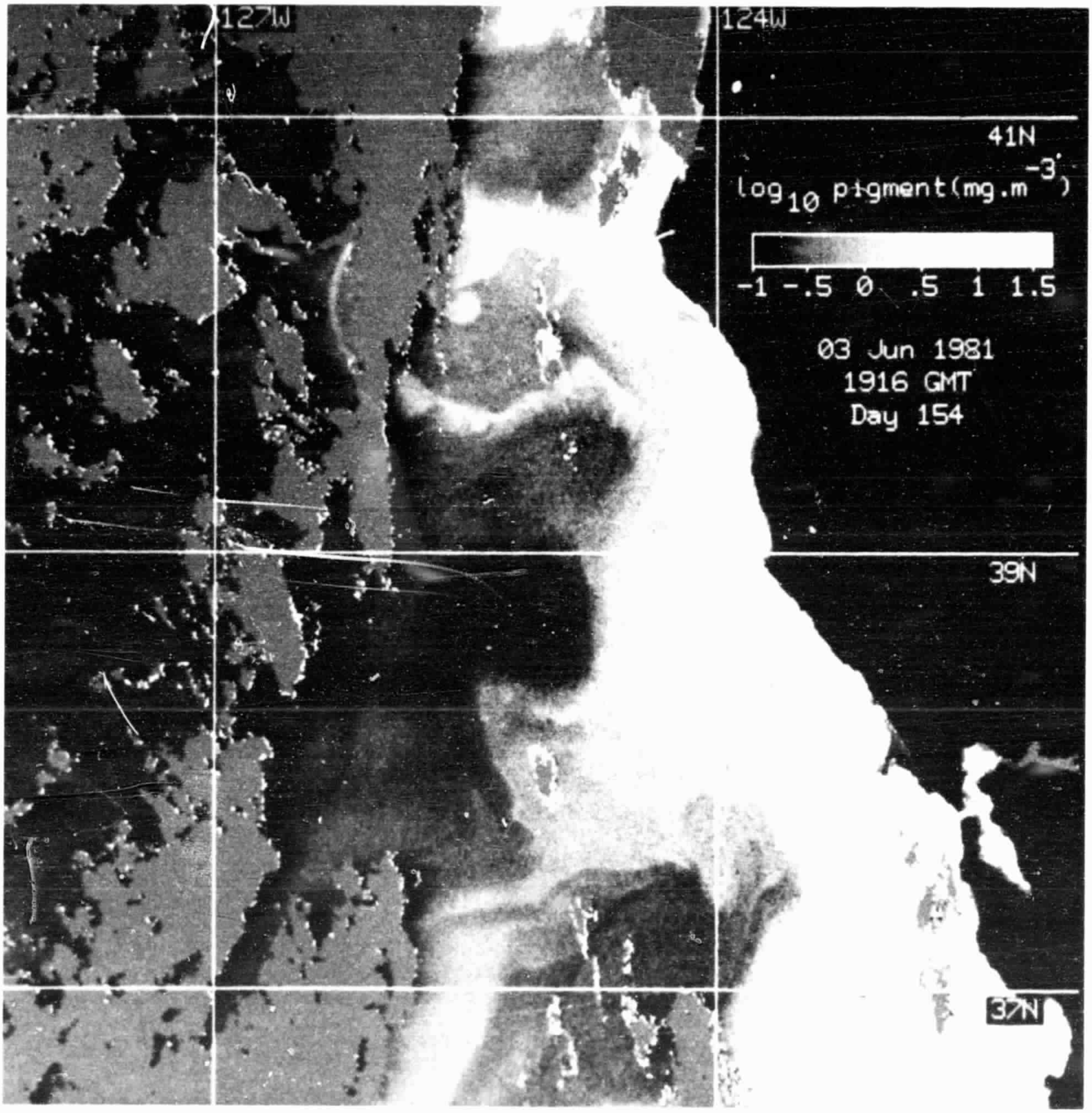

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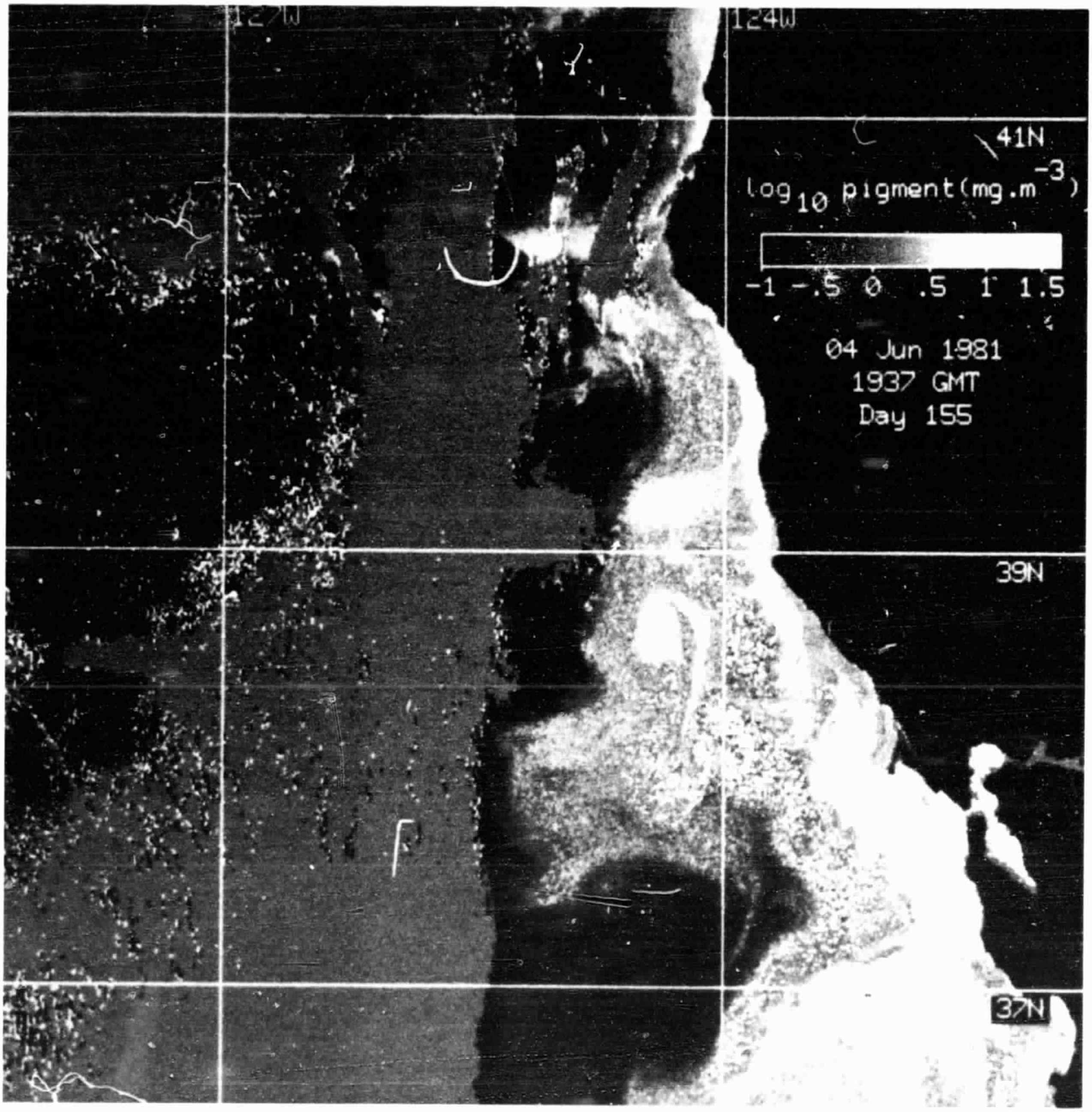

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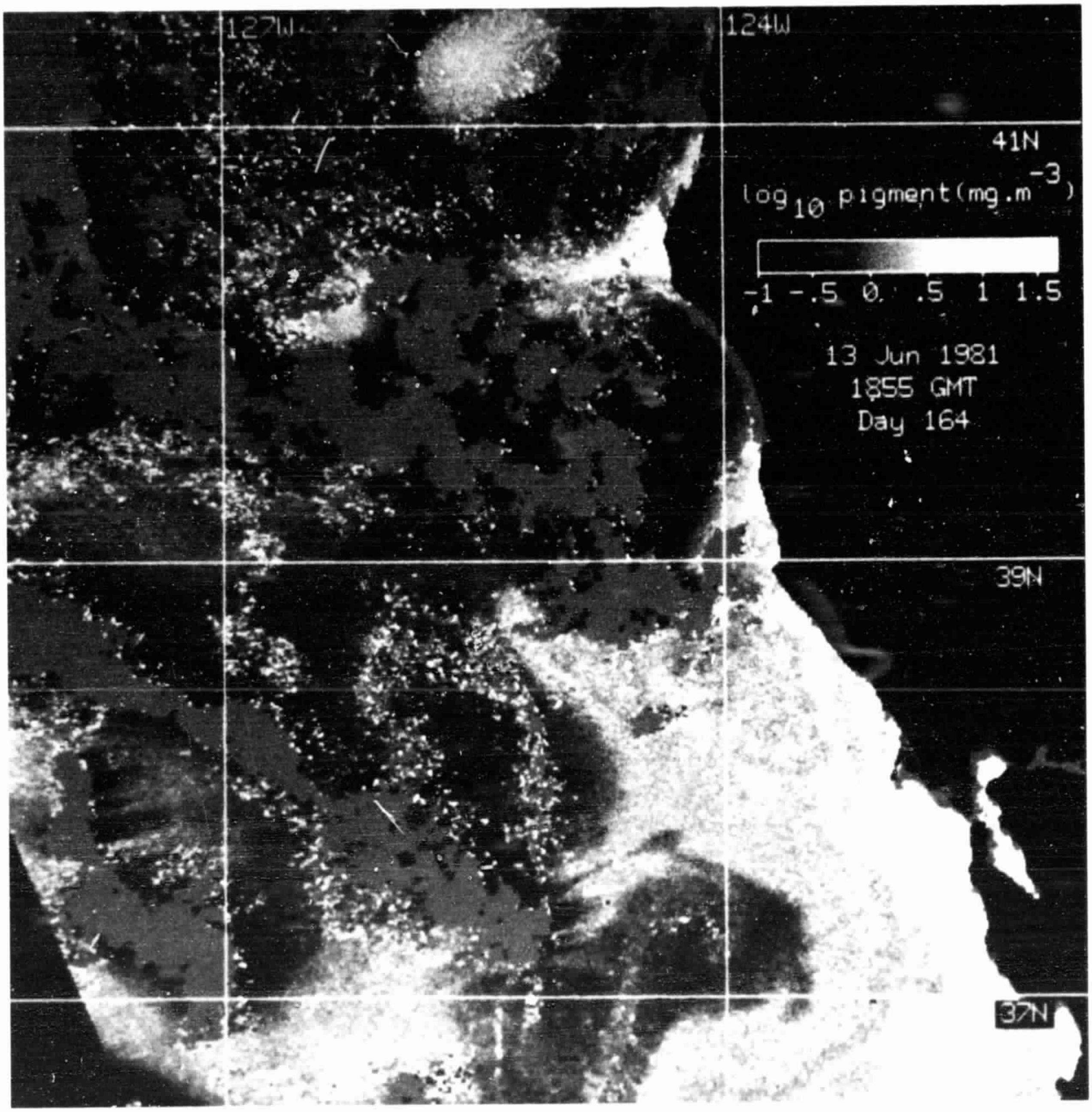

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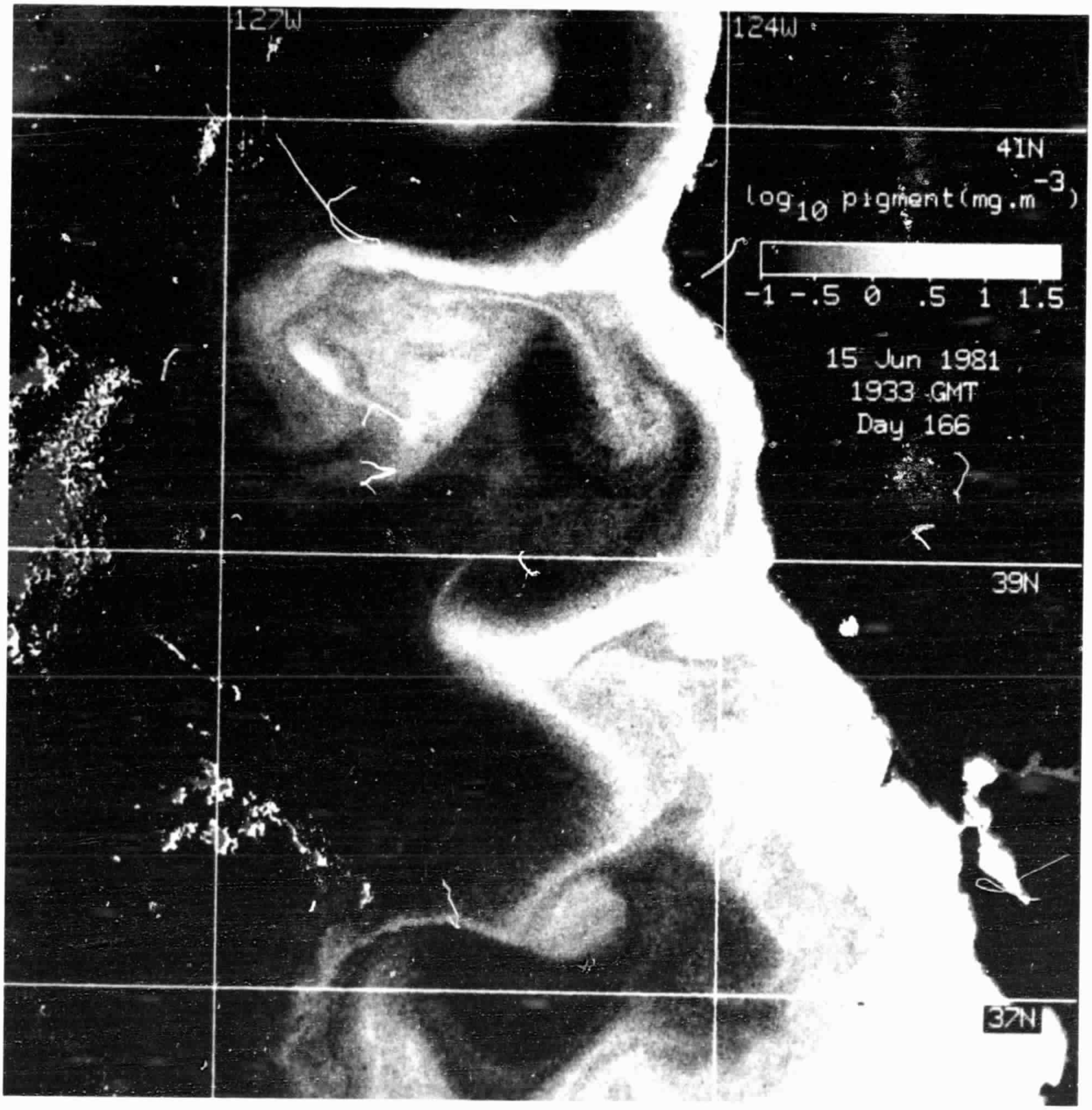

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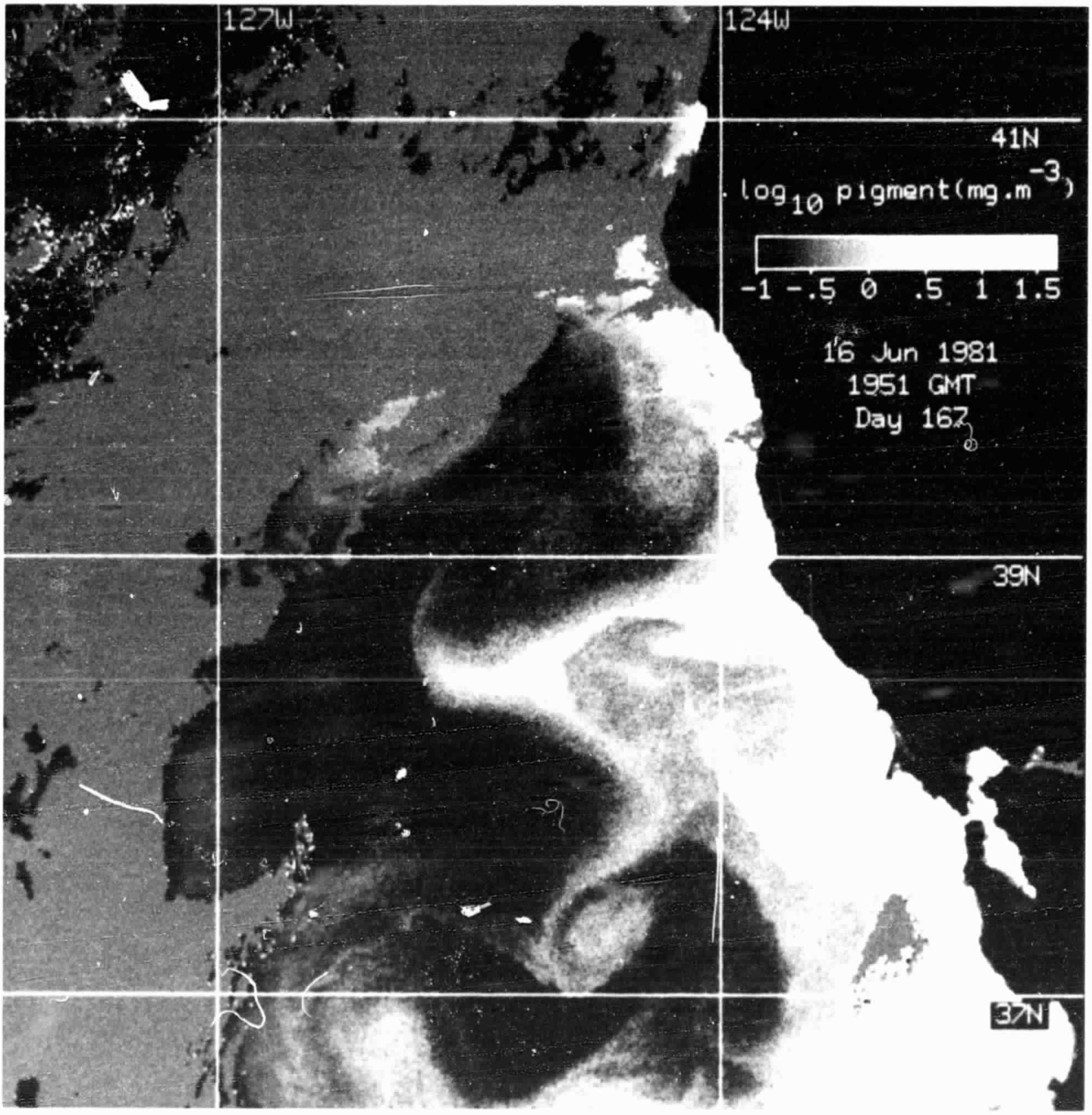

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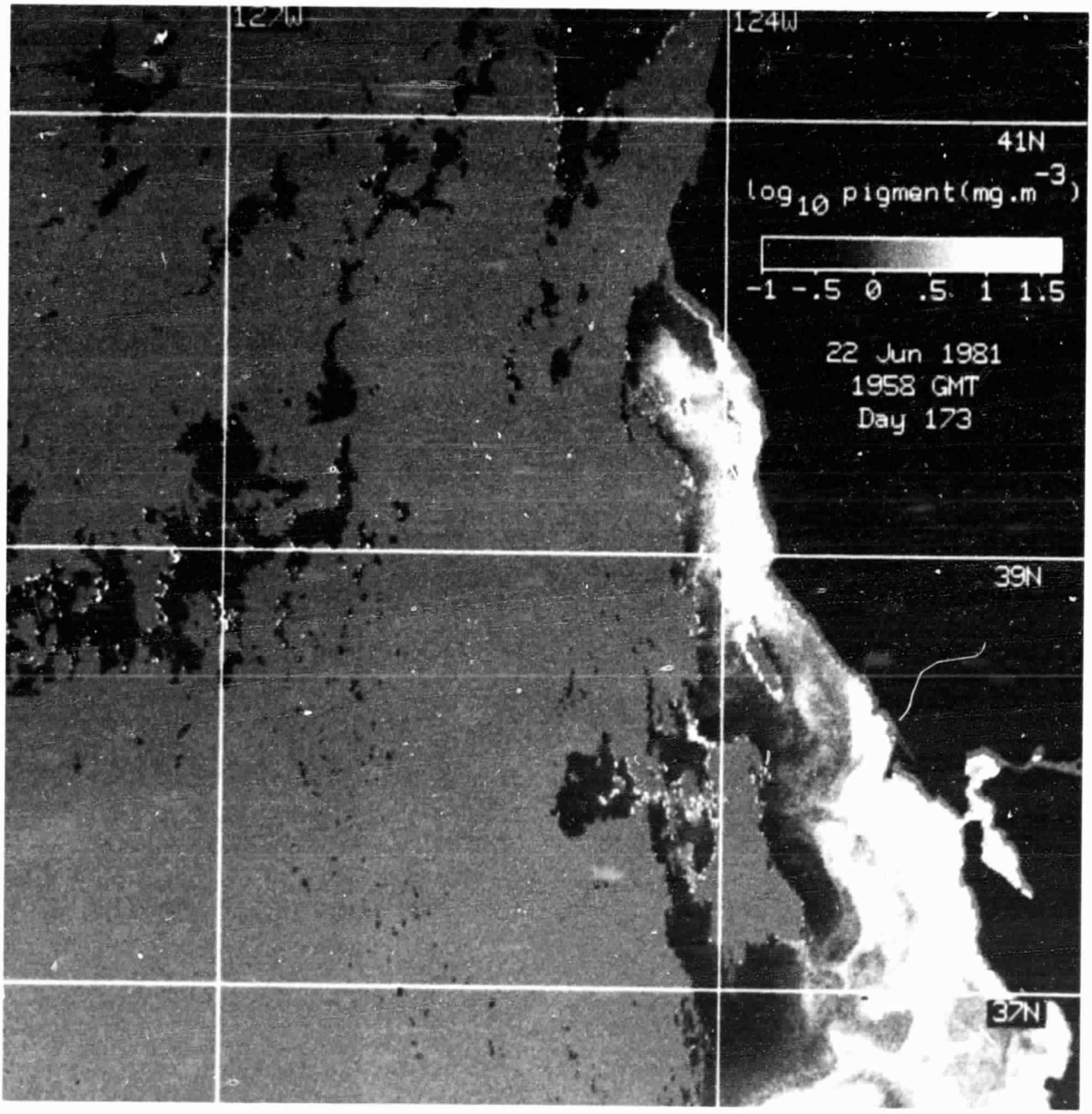

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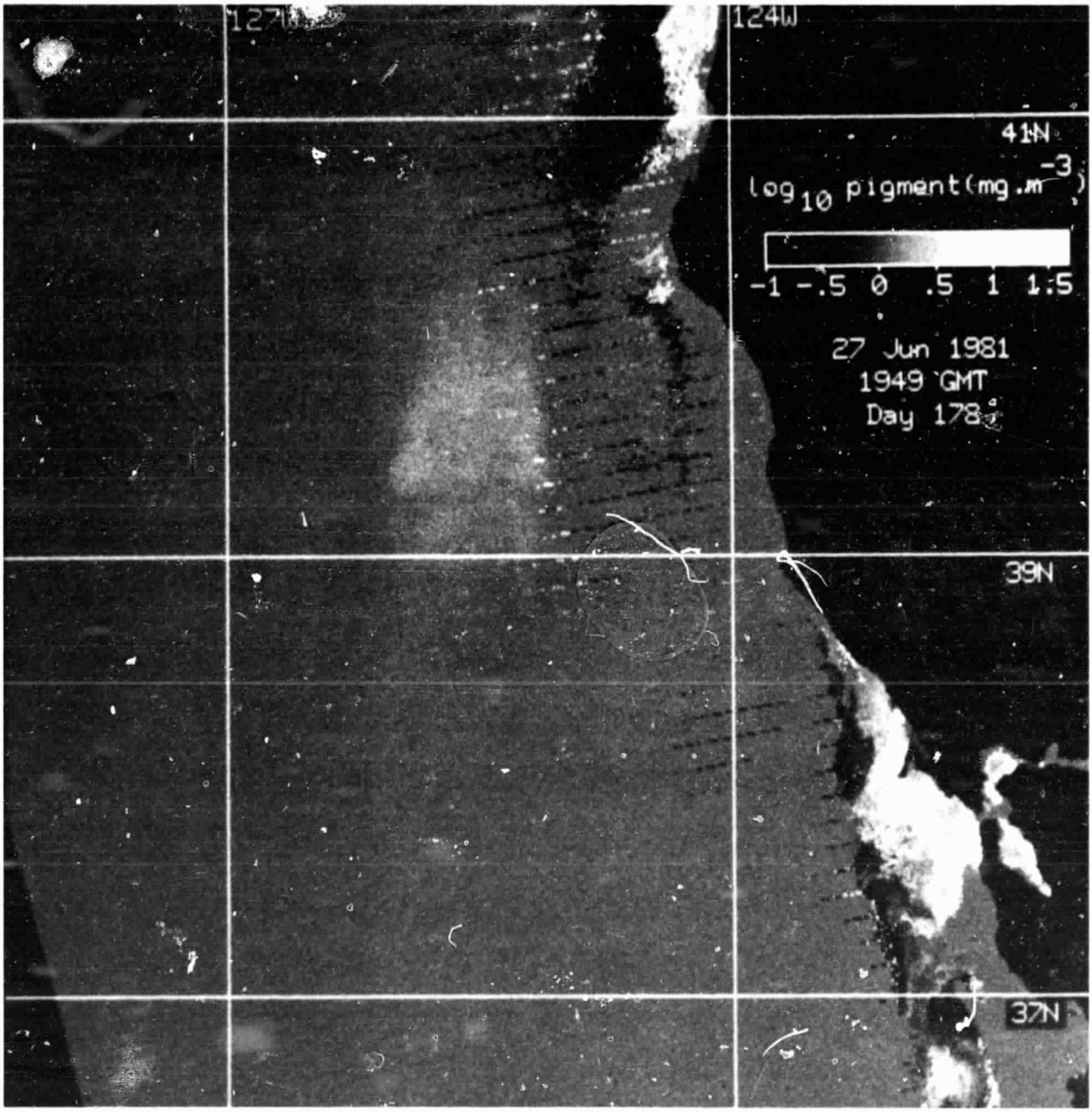

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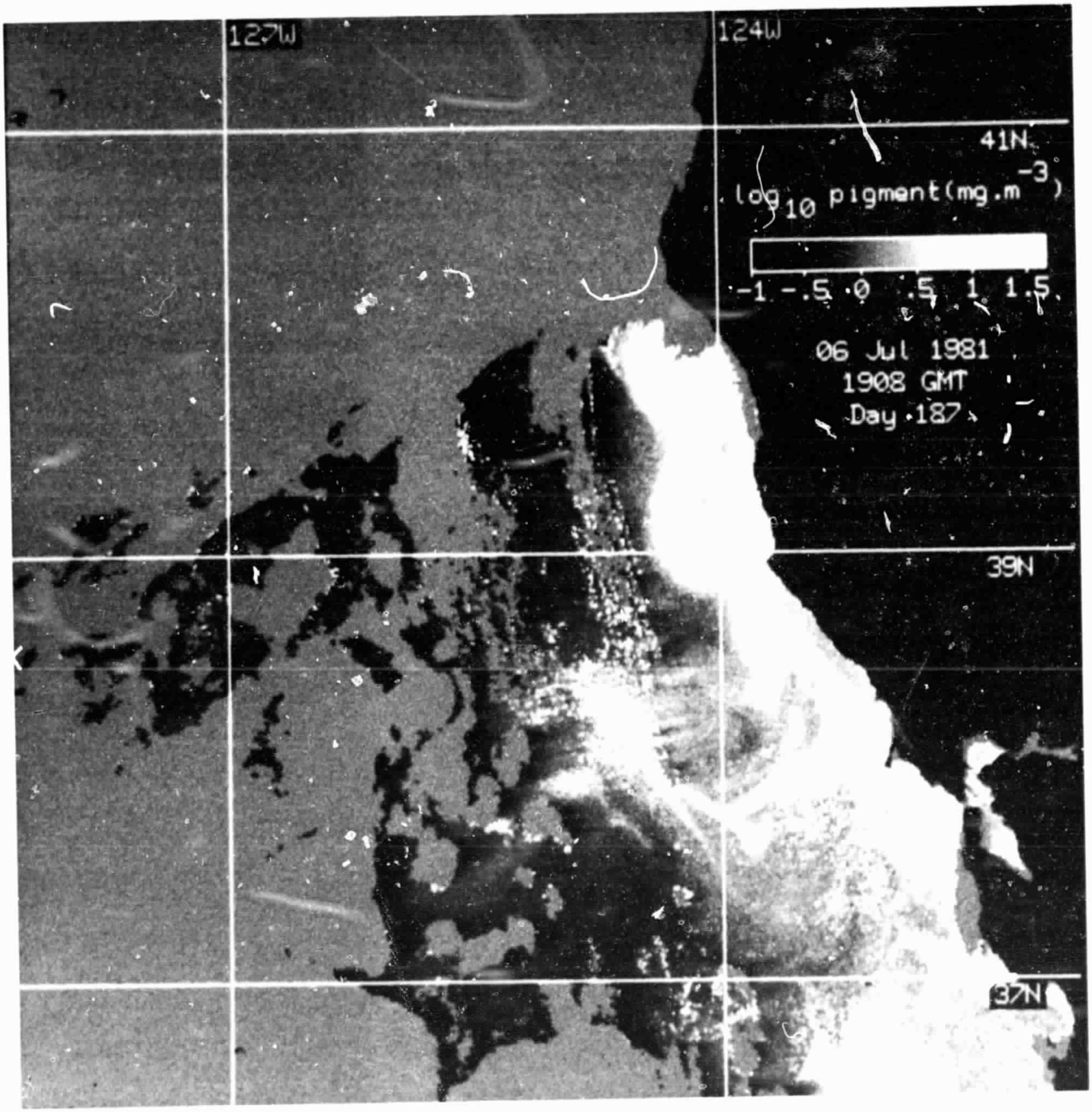

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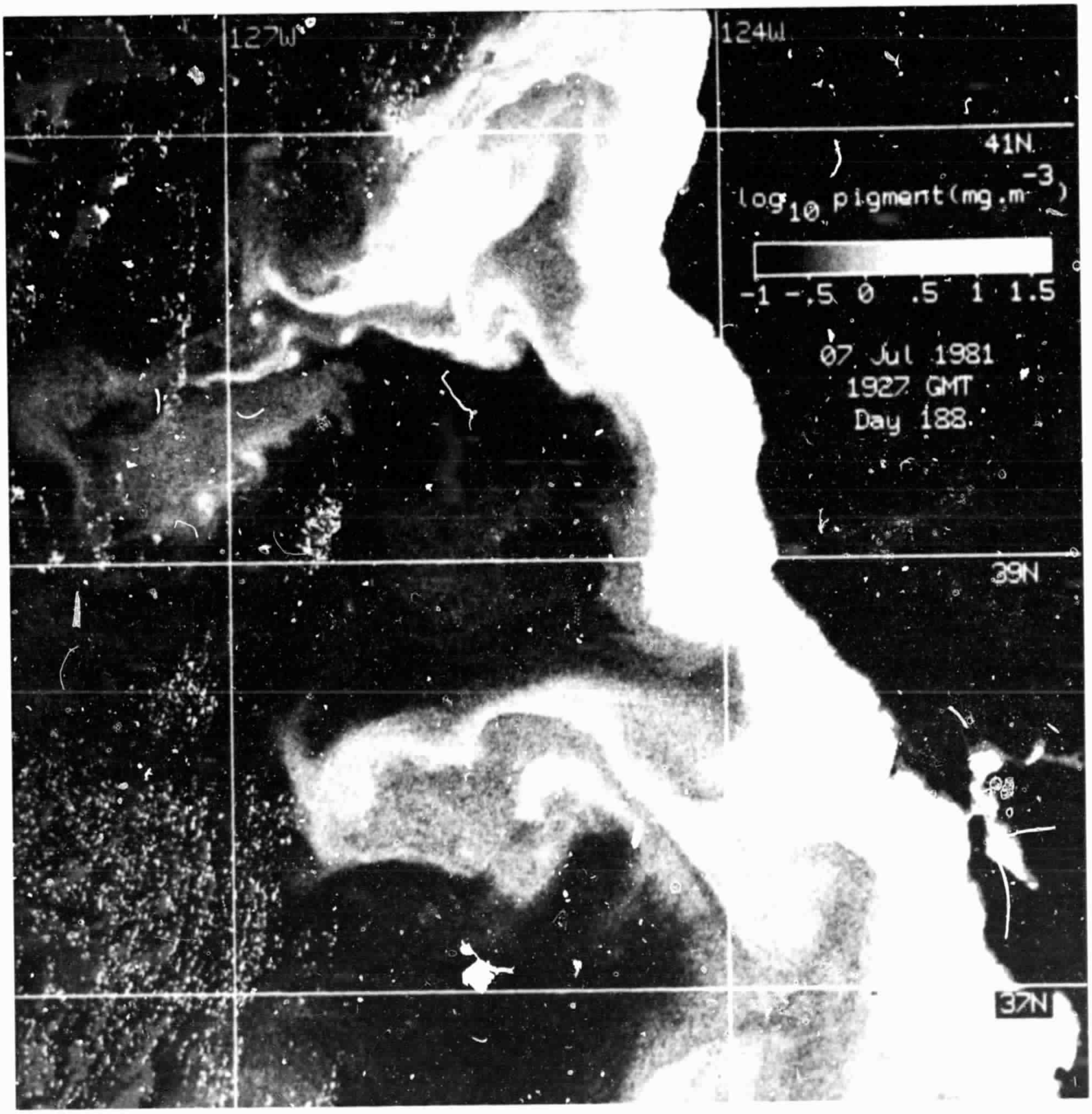

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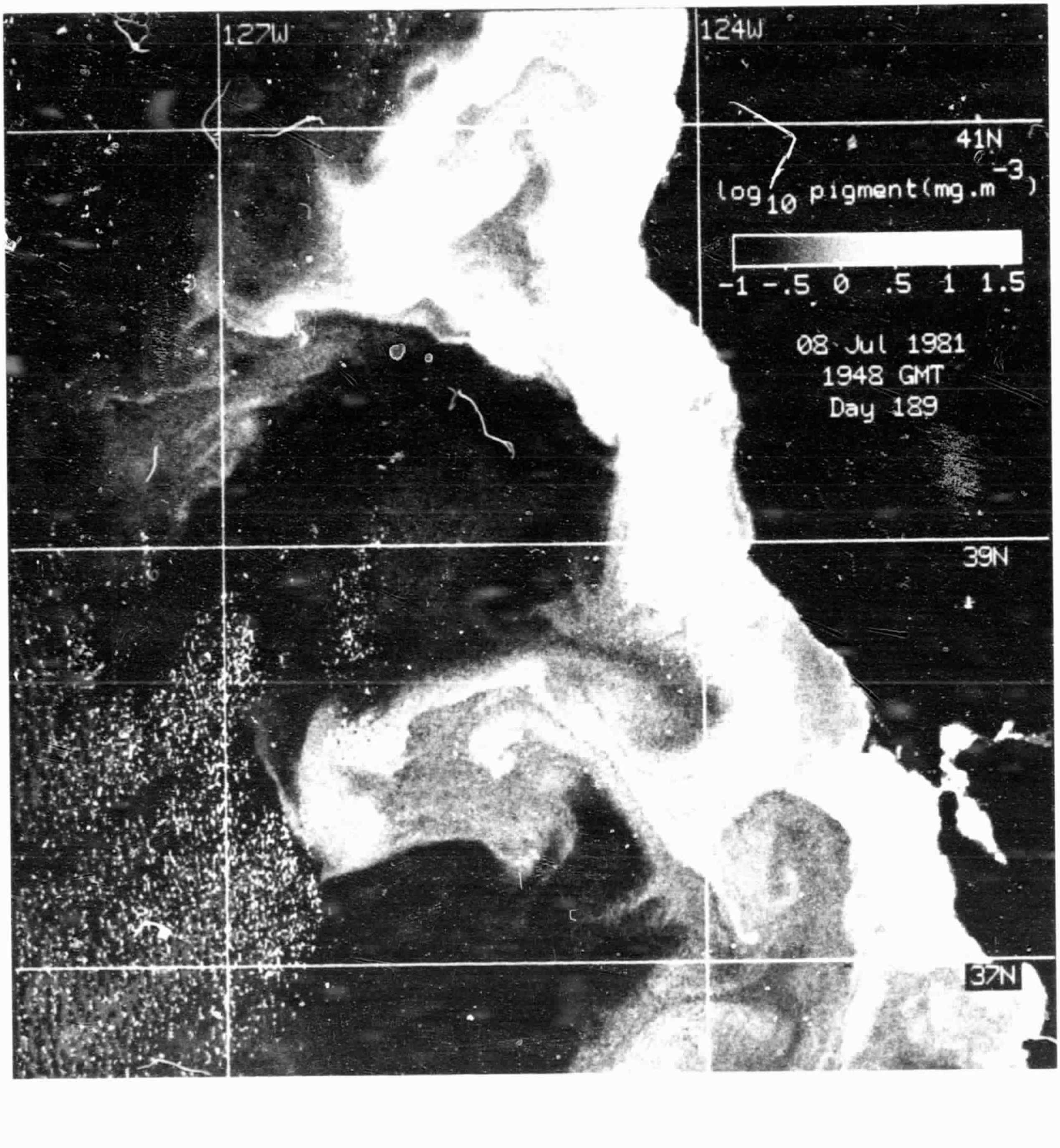

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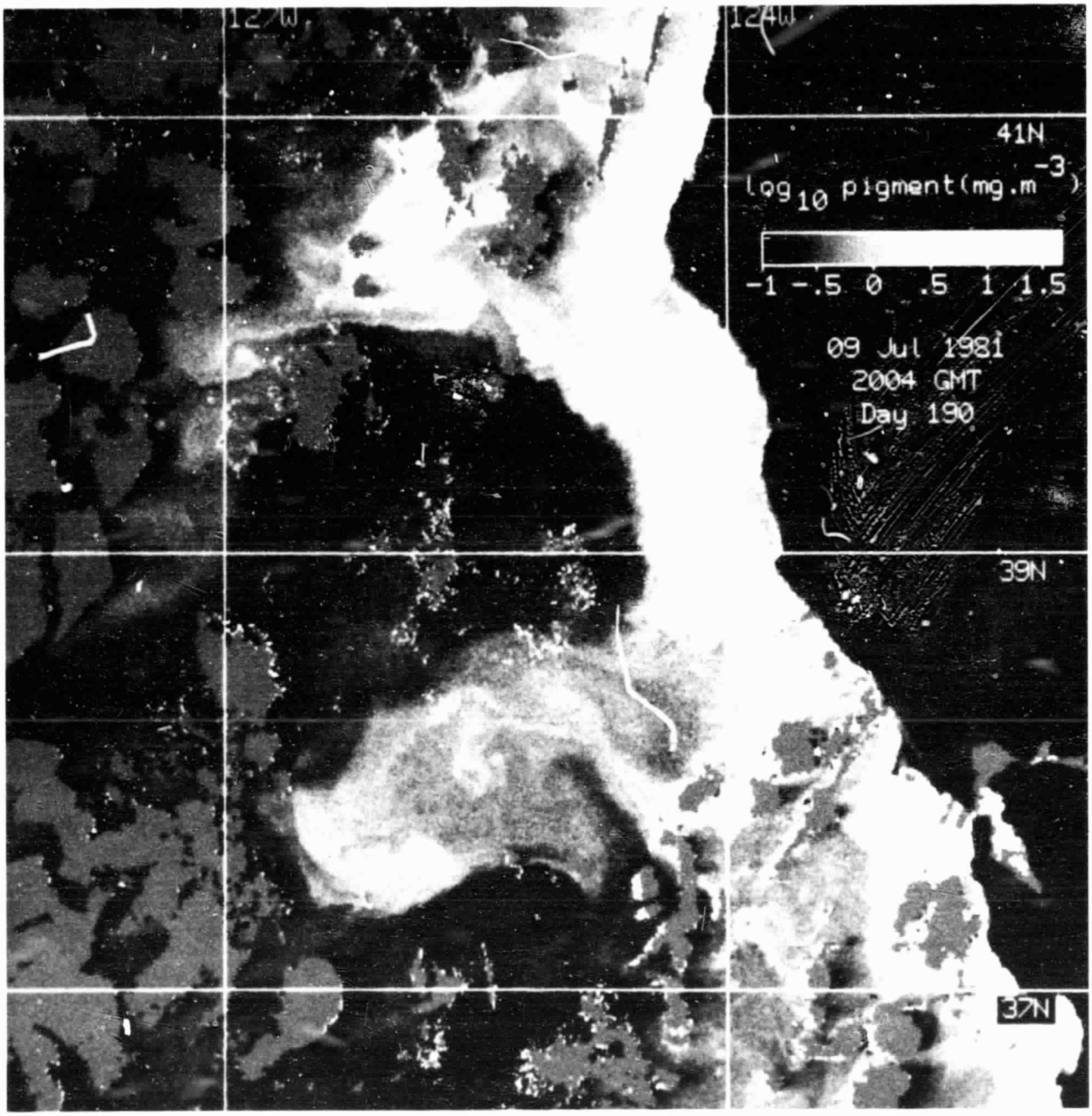

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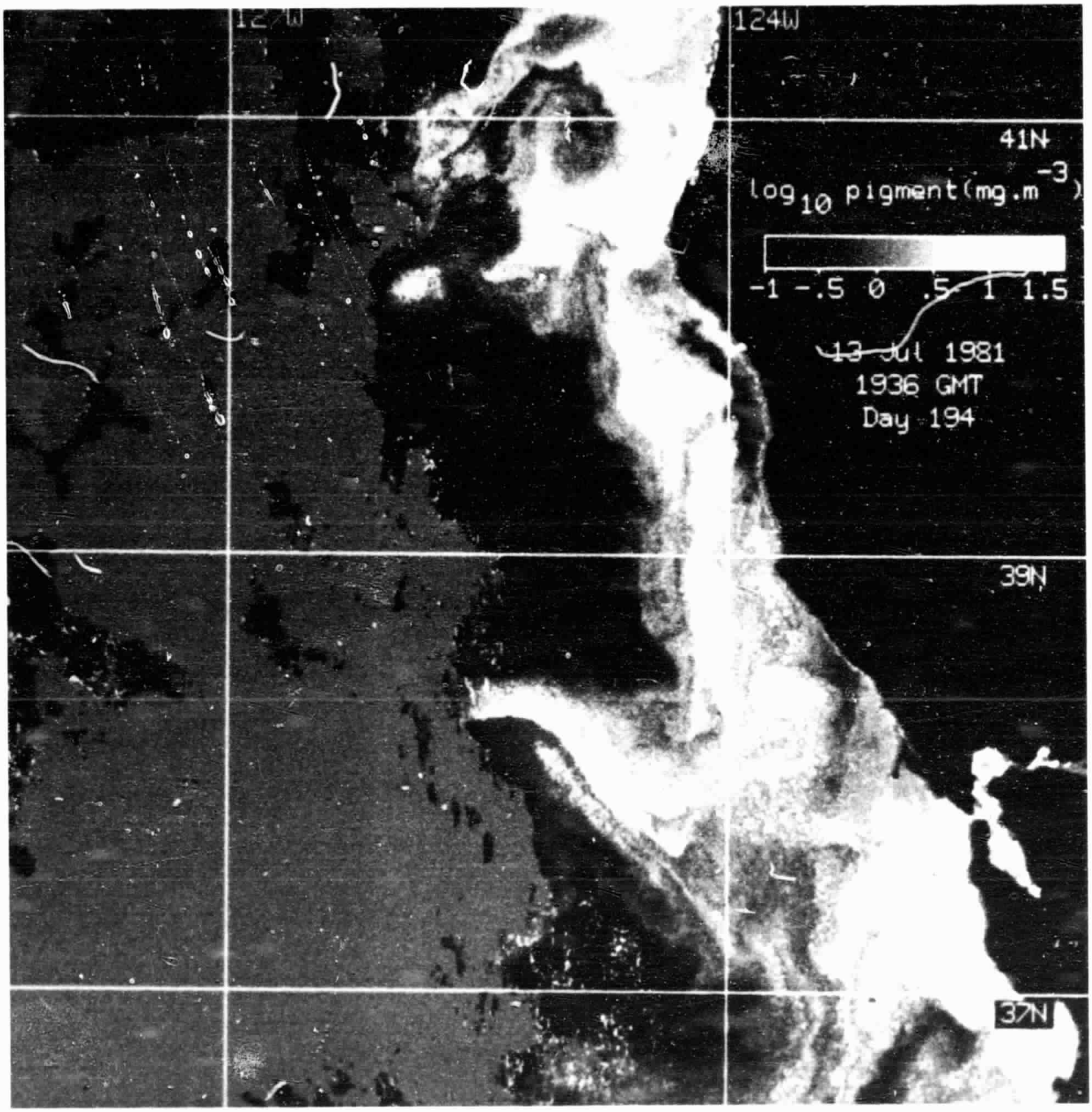

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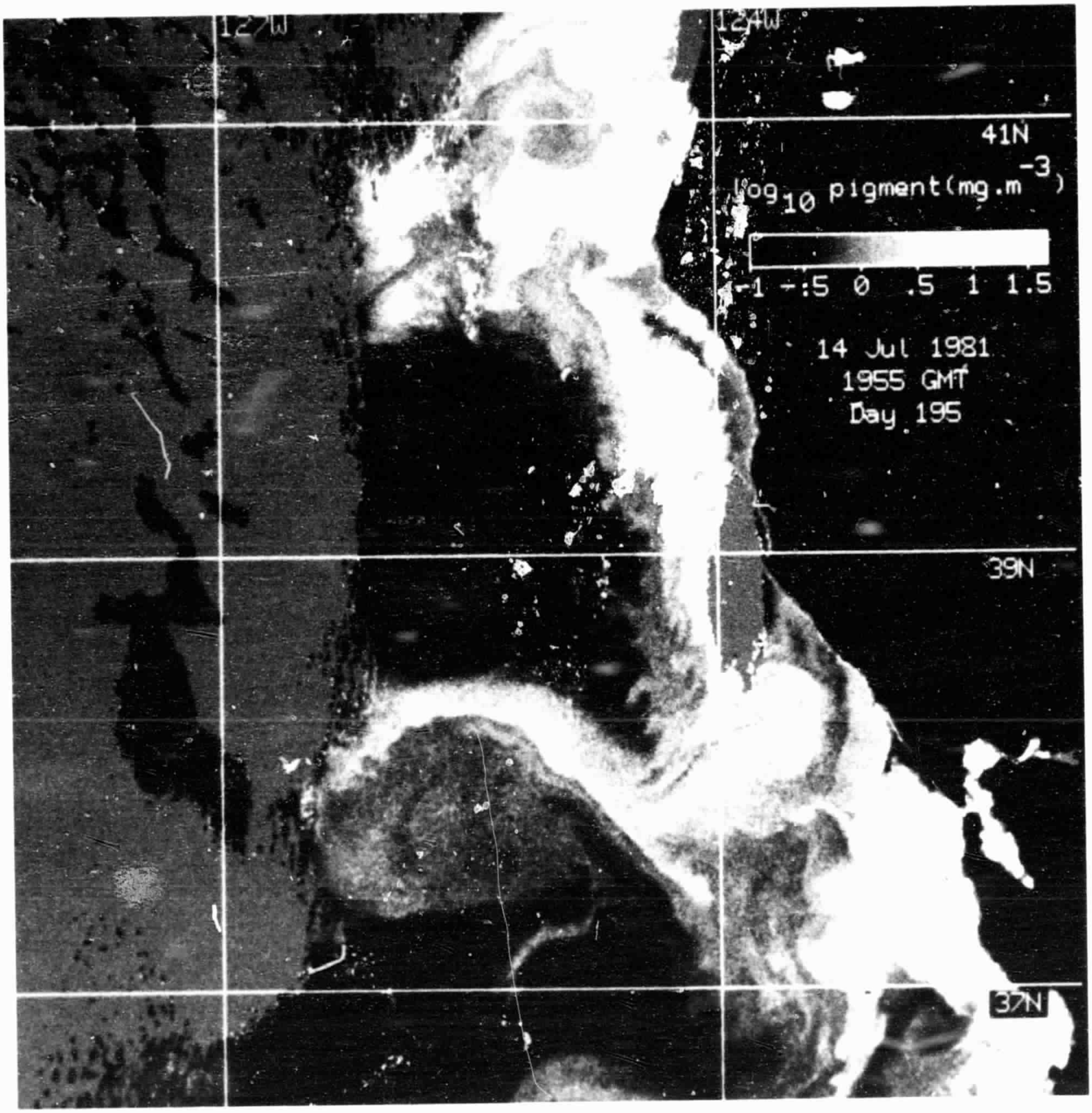

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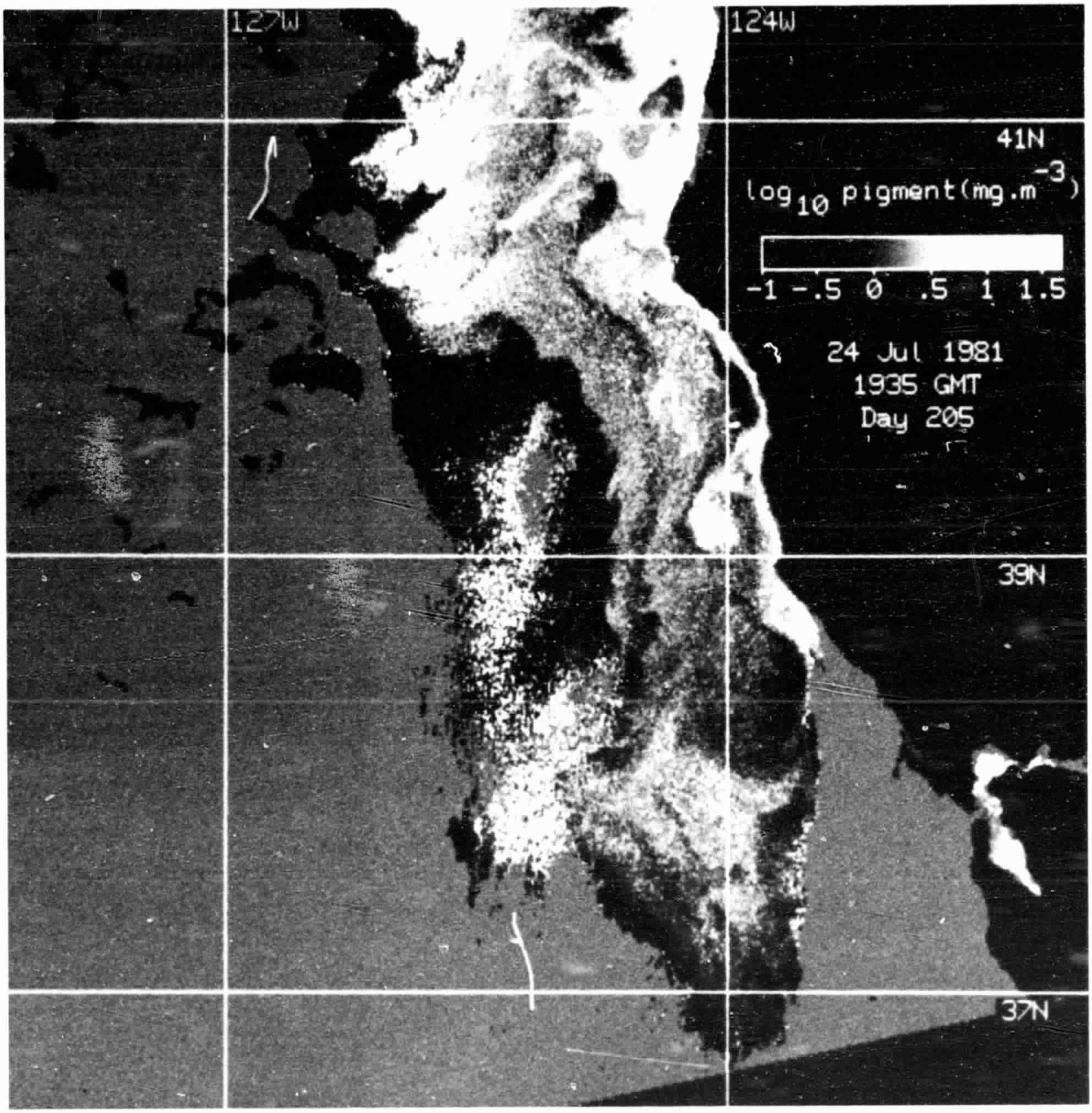

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