NASA Technical Memorandum

NASA TM-103513

MESOSCALE LIGHTNING EXPERIMENT (MLE): A VIEW OF LIGHTNING AS SEEN FROM SPACE DURING THE STS-26 MISSION

By O. H. Vaughan, Jr.

Space Science Laboratory
Science and Engineering Directorate

July 1990

(NASA-TM-103513) MESOSCALE LIGHTNING EXPERIMENT (MLE): A VIEW OF LIGHTNING AS SEEN FROM SPACE DURING THE STS-26 MISSION (NASA) 64 p

N90-28951

CSCL 04B

Unclas

G3/47 0305600

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

MSFC - Form 3190 (Rev. May 1983)

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No. NASA TM-103513	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Mesoscale Lightning Experiment (MLE): A View of Lightning as Seen From Space During the STS-26 Mission		5. Report Date July 1990
		6. Performing Organization Code ES43
7. Author(s) O.H. Vaughan, Jr.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared by Space Science Laboratory, Science and Engineering Directorate.

16. Abstract

This report provides information on the data obtained from the Mesoscale Lightning Experiment (MLE) flown on STS-26. The experiment used onboard TV cameras and a 35-mm film camera to obtain data. Data from the 35-mm film camera are presented. During the mission, the crew had difficulty locating the various targets of opportunity with the TV cameras. To obtain as much data as possible in the short observational timeline allowed due to other commitments, the crew opted to use the hand-held 35-mm camera.

17. Key Words (Suggested by Author(s)) Lightning, Space Shuttle, Space Research, Observational Techniques, Photography		18. Distribution Statement Unclassified – Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 67	22. Price NTIS

NASA FORM 1626 OCT 86

For sale by the National Technical Information Service, Springfield, VA 22161-2171

ACKNOWLEDGMENTS

The successful conduct of the experiment reported here requires the efforts and cooperation of the many individuals and groups that are useful in most scientific studies. Foremost among those to whom we are indebted are the astronauts; Commander Fredrick H. Hauck, Pilot Richard O. Covey, Mission Specialists John M. Lounge, David C. Hilmers, and George D. Nelson. They succeeded in getting data on lightning and storms despite the many other duties connected with the return-to-flight of the shuttle after the Challenger accident. Nelson and Covey were assigned the task of performing the mesoscale lightning experiment and, although they experienced some difficulties in locating targets and using the video cameras in the payload bay, they were able to obtain some very good data for this type of observational experiment. We are also indebted to those team members who helped integrate and coordinate the many requirements in documentation and other types of shuttle-related information that are required to get an experiment flown on the shuttle. These individuals are J. Dodge, NASA Headquarters, E. Jung and C. Parker, Johnson Space Center, and Ed Vallentine, Marshall Space Flight Center. Photo/TV operations documentation was provided by Judy Alexander and Bill Bowers of Rockwell. We are indebted to the personnel of the USAF Global Weather Center at Offutt AFB, Omaha, Nebraska, for their forecasting support on the tropical weather systems that developed in the Western Pacific during the mission. Paul Meyers provided weather data from the McIdas system here at MSFC for real time support of the experiment.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TECHNICAL MEMORANDUM

MESOSCALE LIGHTNING EXPERIMENT (MLE): A VIEW OF LIGHTNING AS SEEN FROM SPACE DURING THE STS-26 MISSION

I. INTRODUCTION

Data from unmanned instrumented space probes that have flown in space have provided a wealth of information about the atmosphere and its construction. The USAF Defense Meteorological Satellite Program has provided data on man's influence on his environment (1-4). The NASA planetary probes, Pioneer and Voyager, have also shown that there are lightning-type discharges on the other planetary bodies and that lightning is not unique to our planet. Lightning has been seen on Jupiter (5,6), Venus (7,8), and Saturn (9).

Comments from the astronauts who have flown in Mercury, Gemini, Apollo, Skylab, and the shuttle say that lightning, when viewed from the vantage point of space, either in low-Earth orbit or on a flight to the moon, offers a sight that is not only spectacular but is extremely interesting.

Bob Cenker, Payload Specialist on STS-61, had the following comments to make: "While I was not specifically documenting thunderstorms, the thunderstorms over Africa were a very impressive sight. What particularly caught my attention was the frequency of the lightning flashes, not unlike the bursting of popcorn. Although I did not see any lightning strikes per se, but rather 'instantaneous' (at least short lived) illumination of the clouds, the illumination appeared to be about the size of a quarter and I would estimate the size to be approximately 10 miles in diameter on the cloud top." Joe Allen, STS-5 Mission Specialist, talked of numerous brush fires in Africa and of lightning as it moved 1000 miles across Australia. Robert Stewart, Mission Specialist, on STS-51J was also impressed with the lightning displays of Typhoon Brenda and got some excellent video data of the first observations of typhoons with lightning from orbit. These lightning flashes were estimated to be on the order of hundreds of kilometers in diameter, based on an analysis of this type of data by Breslawski (10) at the State University of New York at Albany, NY.

This new view of lightning from space suggests that lightning events can be so organized and highly extensive that they deserve to be considered to be a mesoscale meteorological phenomenon to be studied in more detail. Because of the data that were obtained on these earlier shuttle flights an experiment called the Mesoscale Lightning Experiment (MLE) was conceived to study this phenomena and was submitted to NASA in 1985 and accepted as an experiment to fly on future shuttle flights. The Principal Investigator was Otha H. Vaughan, Jr., NASA Marshall Space Flight Center (MSFC), Huntsville, AL, and his Co-Investigators were Dr. Bernard Vonnegut, State University of New York at Albany (SUNY), Albany, NY, and Dr. Marx Brook, New Mexico Institute of Mining and Technology (NMIT), Socorro, NM. The experiment was planned to be relatively simple. The onboard TV cameras, located in the payload bay, were to be used to survey lightning and the unique storm complexes that might be occurring around the world. The crew would use these cameras at various times to look at targets of opportunity that would be transmitted up to the crew by personnel on the ground who, using meteorological data from other orbiting satellites, would provide the crew with prime targets, thus releasing the crew from the task of looking for targets themselves and allowing more crew time for conducting the more complicated experiments. In addition to the onboard payload bay color TV camera the crew would also use a hand-held 35 mm camera to obtain film data that could be used in determining the brightness of the flashes that were observed. Previous shuttle crew members had commented that many times the flashes of lightning were so bright that they lit up the payload bay area. A color video camera, although intensified and using a three-color wheel to achieve color, was selected since it had less sensitivity to the lightning brightness and it would not have the tendency to bloom as much as when the normal intensified black and white TV cameras see lightning, as seen on previous shuttle missions. This camera also had the capability of manual iris control, which should help in reducing the blooming effect.

II. OBSERVATIONAL EQUIPMENT

To observe the thunderstorms and lightning from the vantage point of space the shuttle crews of STS-26 were to use the onboard payload bay color TV camera and a hand-held 35 mm film camera. The shuttle TV camera's lens field of view (FOV) was 40.9 degrees (diagonal) and when pointed directly toward the ground produced a footprint of 120 nmi by 120 nmi when at an orbital altitude of 160 nmi. The 35 mm film camera used T-MAX 400 film with a time exposure of 2 sec. The lens used was a 85 mm, F/1.4, giving a field of view of 28 degrees resulting in a footprint of 80 MN by 80 nmi when the shuttle was at an altitude of 160 nmi, and the camera was looking directly downward toward the ground.

III. OPERATIONAL PROCEDURES

To locate potential MLE targets of opportunity consisting of the large convective storm systems with lightning, hurricanes, and typhoons, a number of Earth observing satellites and supporting hardware was used quite successfully during the STS-26 mission. The NOAA Geostationary Earth Observing Satellite (GOES), the European Geostationary Earth Observing Satellite (GEOMET), and the Defense Meteorological Satellite Program (DMSP) provided visual images and IR images of the cloud tops. Using these data in real time potential targets were identified. Also working with the USAF Global Weather Center, forecasts were obtained on the tropical depressions that might have a potential to develop into very severe weather storm systems. After a potential target was identified a target note was sent up to the crew and they were advised when they could be expected to see the target and when to turn on the video camera. Whenever they saw targets that were not in the field of view of the TV camera they were advised to use the 35 mm camera to collect the lightning data. Normally they would try to get photographic data at the same time they were collecting the video data.

IV. PAYLOAD BAY TV CAMERA OPERATIONS

During the course of the mission the crew had difficulty in locating the various targets of opportunity because the targets were tropical depressions which were in their developing stages and did not have very much lightning activity. After a number of attempts to obtain data and loosing a lot of time, the crew opted to gather as much data as they could using the hand-held 35 mm camera. In retrospect this was a good thing to do because we were able to get some information on tropical depressions that were in their developing stages. Multiple lightning flashes were located and photographed in various locations in the storm systems. The photographic data from the 35 mm operations will be presented and discussed in the next paragraphs.

V. DISCUSSION

Space Shuttle Discovery STS-26 was launched from Kennedy Space Center on September 29, 1988, at 10:36:59 EDT (Day 273 15:36:59 GMT) and after achieving orbit the crew began to conduct a number of vehicle operational checkout procedures. After these were successful, they conducted a number of scientific experiments. Since the mesoscale lightning experiment was not an automated-type experiment, the crew was required to look for lightning at specific times in the time line or at other times when personnel on the ground advised them when lightning might be observed during their orbital flight path. These potential targets of opportunity were identified using GOES images, DMSP images, and other sources of weather data during the mission. The crew used the payload bay TV cameras and a 35 mm hand-held film camera to photograph storm cells and their associated lightning during nighttime passes over selected targets. The crew had some difficulty in using the TV camera so they opted to collect as much data as they could with the 35 mm camera. Very good 35 mm photo sequences were obtained and should prove useful in developing an understanding lightning and storm developments that were occurring over the oceans.

During the flight the crew took a number of 35 mm hand-held photographs of potential tropical depression storm systems they observed. The times on the photos are in Greenwich mean time. In discussions with the crew and other personnel at JSC it was determined that the photos were taken in the following sequence:

Roll	GMT Start DAY:HR:MIN:SEC	GMT Stop DAY:HR:MIN:SEC
120	275:18:48:24	275:18:51:33
121	275:20:10:12	275:20:14:21
	276:08:18:31	276:08:19:24
122	276:15:15:23	276:15:15:57
	276:21:33:33	276:21:34:16
	277:00:25:49	277:00:27:55

Figures 1, 2, and 3 show the orbital tracks of the shuttle when the rolls of 35 mm film (rolls 120, 121, and 122) were exposed. Figure 4 (roll 120) is an excellent photo showing a single lightning flash and appears to be a downward looking near vertical photo. Based on the orbitil altitude at the time this photo was taken, this flash is calculated to be approximately 10 kilometers in diameter. This size agrees quite well with the size as seen in photography taken from the NASA AMES U-2 Research Aircraft during MSFC's Atmospheric Electricity Research Thunderstorm Overflight Programs that have been conducted over the past few years. Figures 4, 5, 6, and 7 are also photos from roll 120 and show a sequence of multiple flashes. A time exposure of 2 sec was used for each exposure. Since these hand-held photos were taken at oblique angles it is difficult to estimate the size of the lightning flashes in this sequence.

Roll 121 shows a number of lightning flashes that were observed in a large tropical storm in the vicinity of a Sumatra. Twenty-one lightning flashes were photographed during a time interval of 113 sec. This gives a flash rate of 11.15

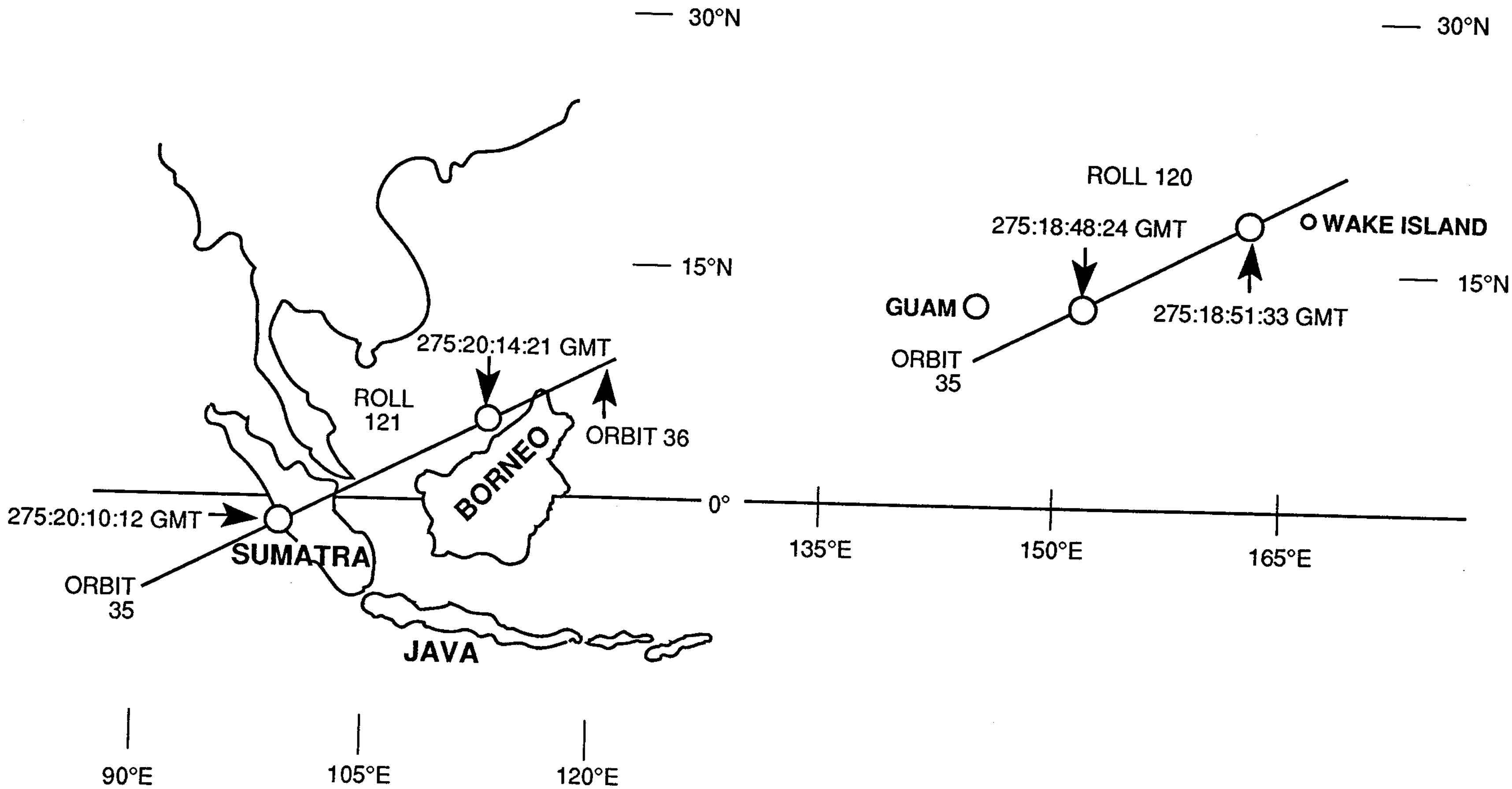


Figure 1. STS-26 orbital tracks, orbits 35 and 36.

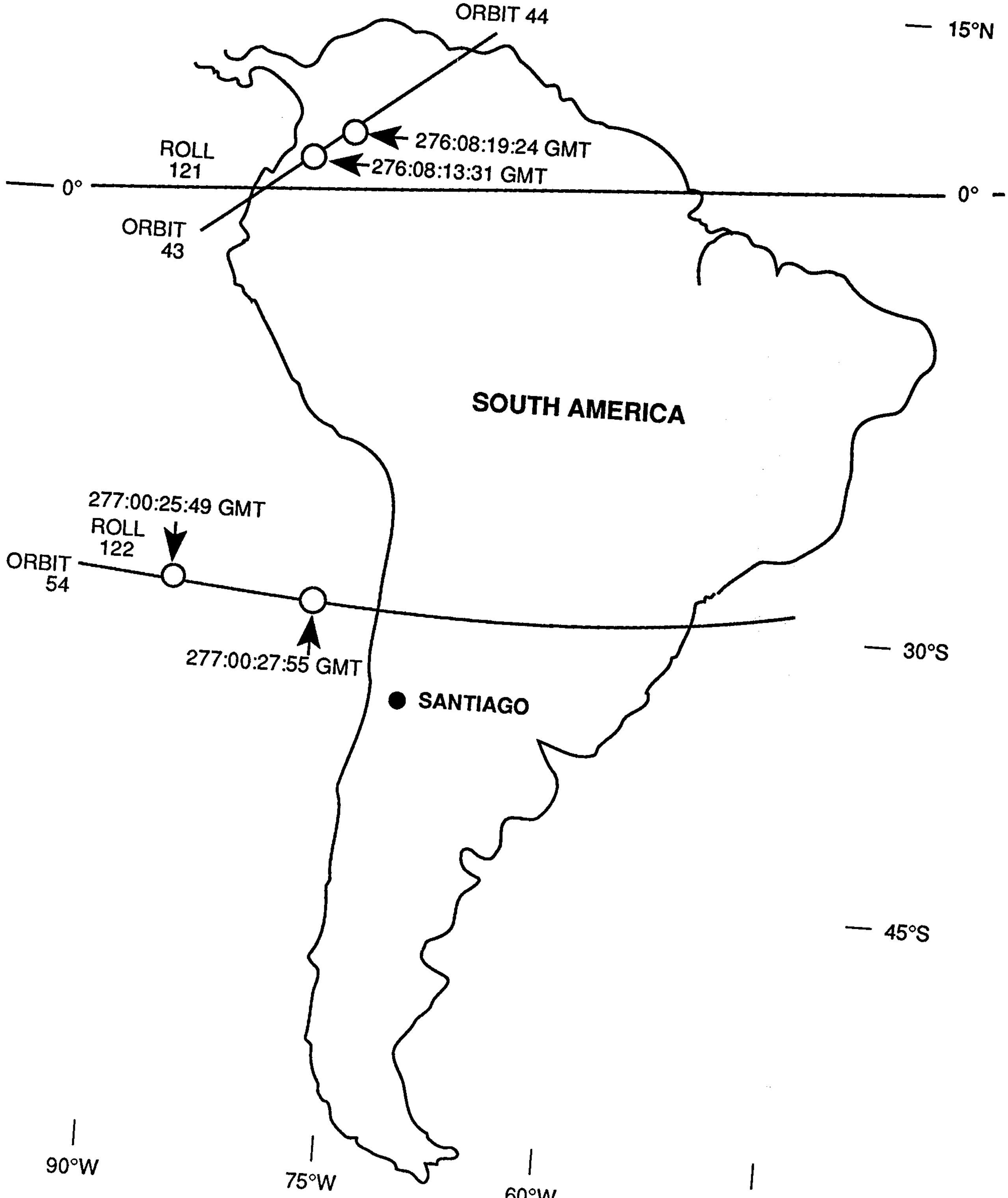


Figure 2. STS-26 orbital tracks, orbits 43, 44, and 54.

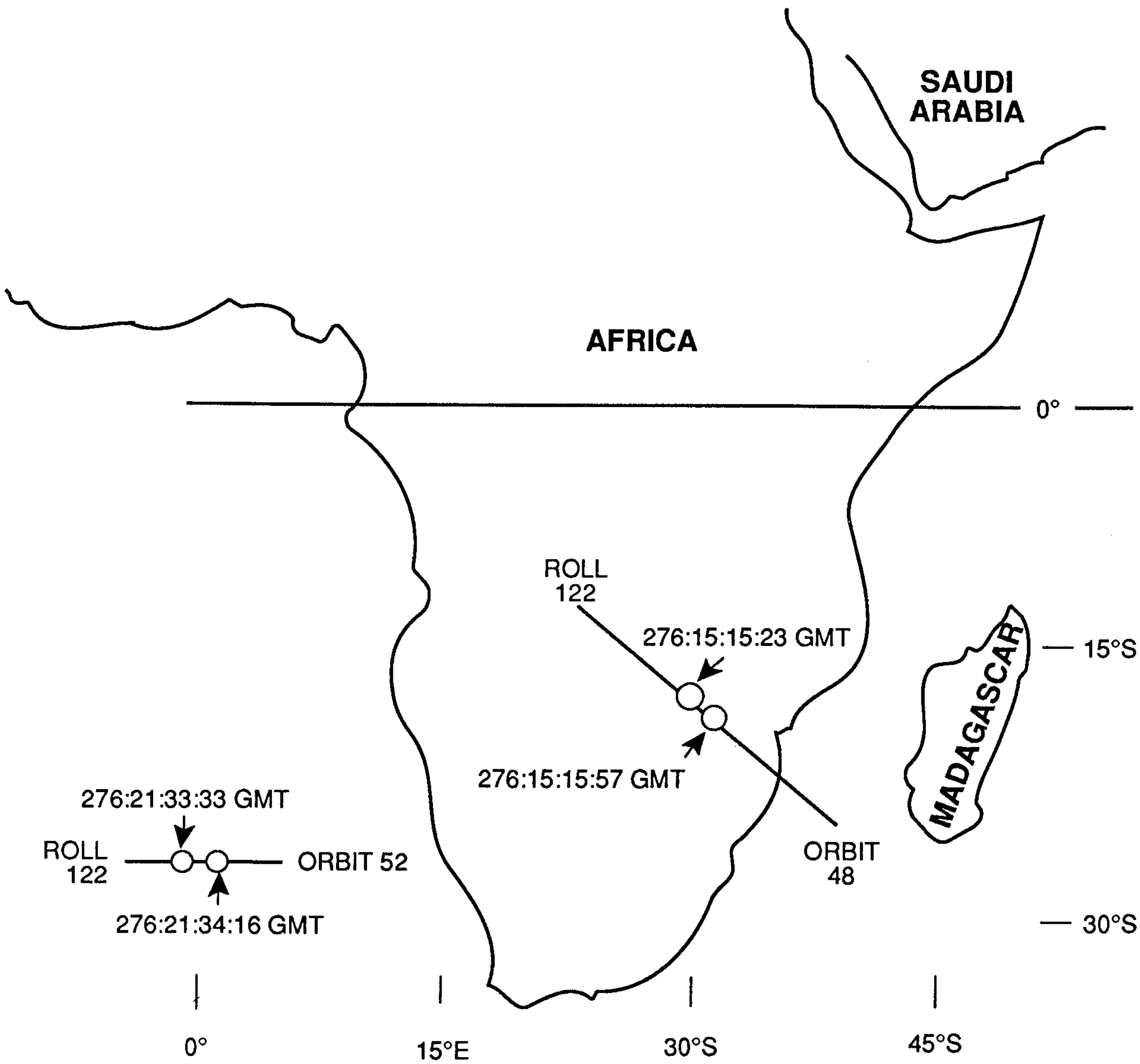


Figure 3. STS-26 orbital tracks, orbits 48 and 54.

Figure 4. Single lightning flash (near vertical photo), orbit 35. Flash size approximately 10 km in diameter.

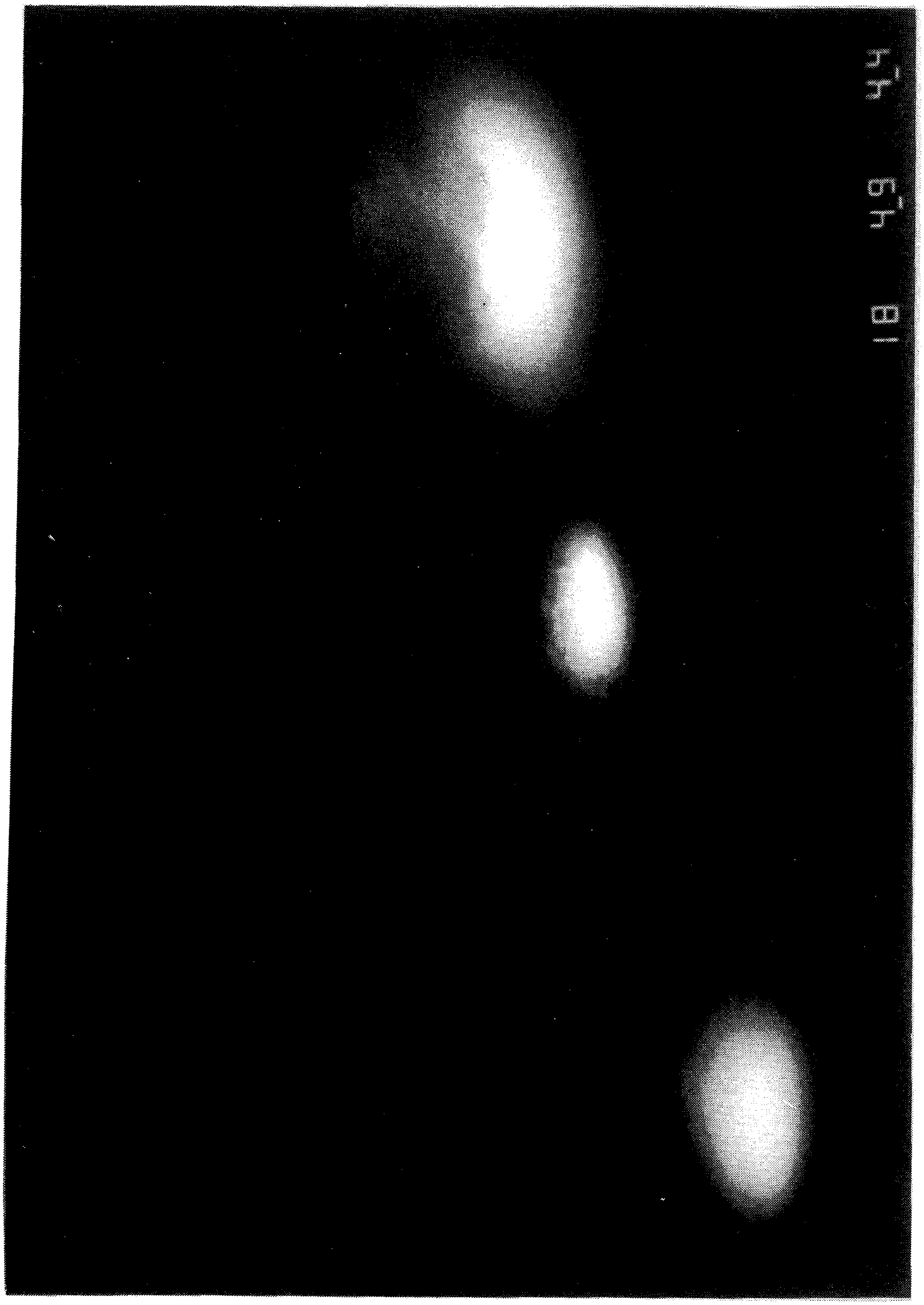


Figure 5. Oblique photo of three lightning flashes, orbit 35.

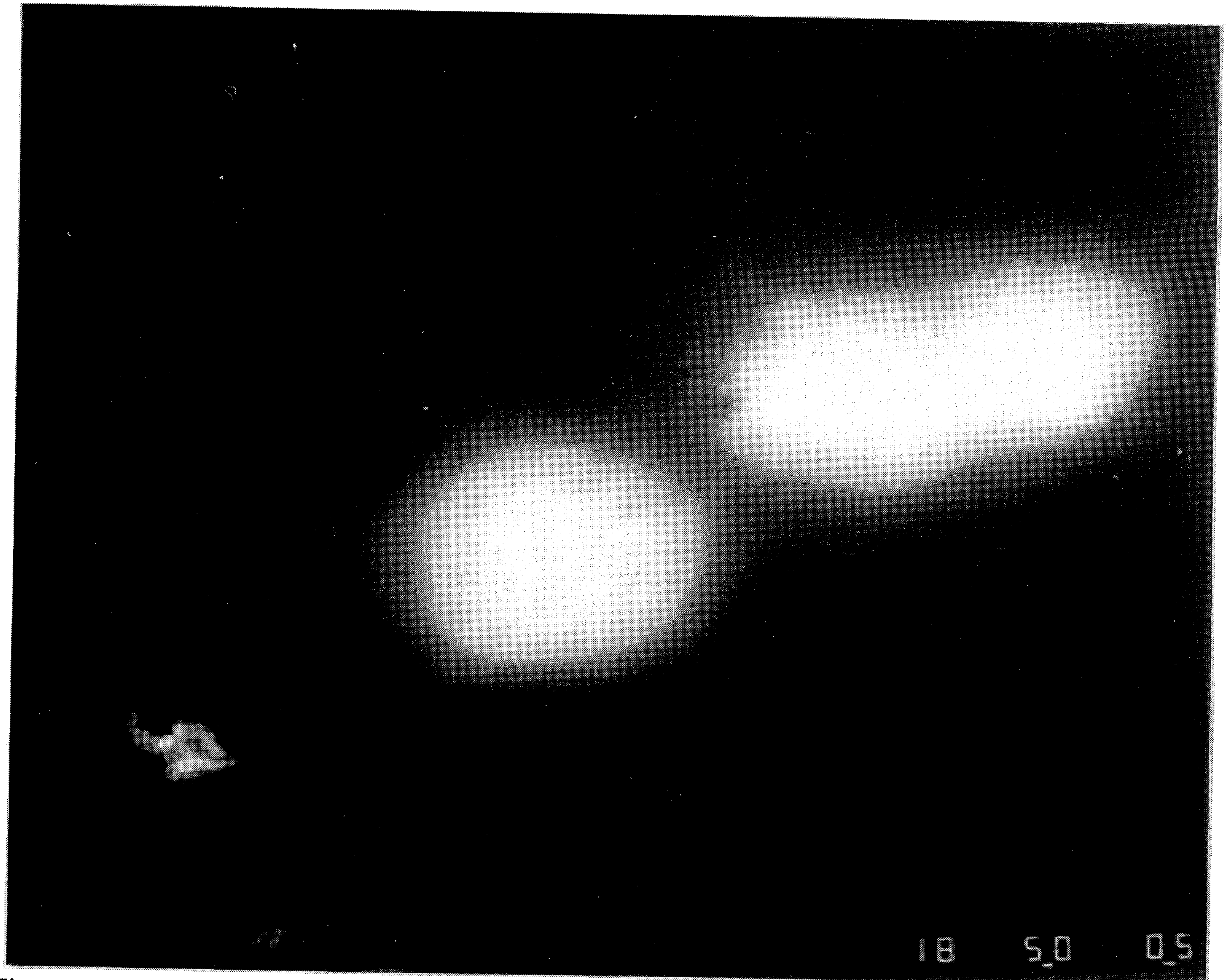


Figure 6. Oblique photo of the two large flashes and one small flash showing some cloud structure, orbit 35.

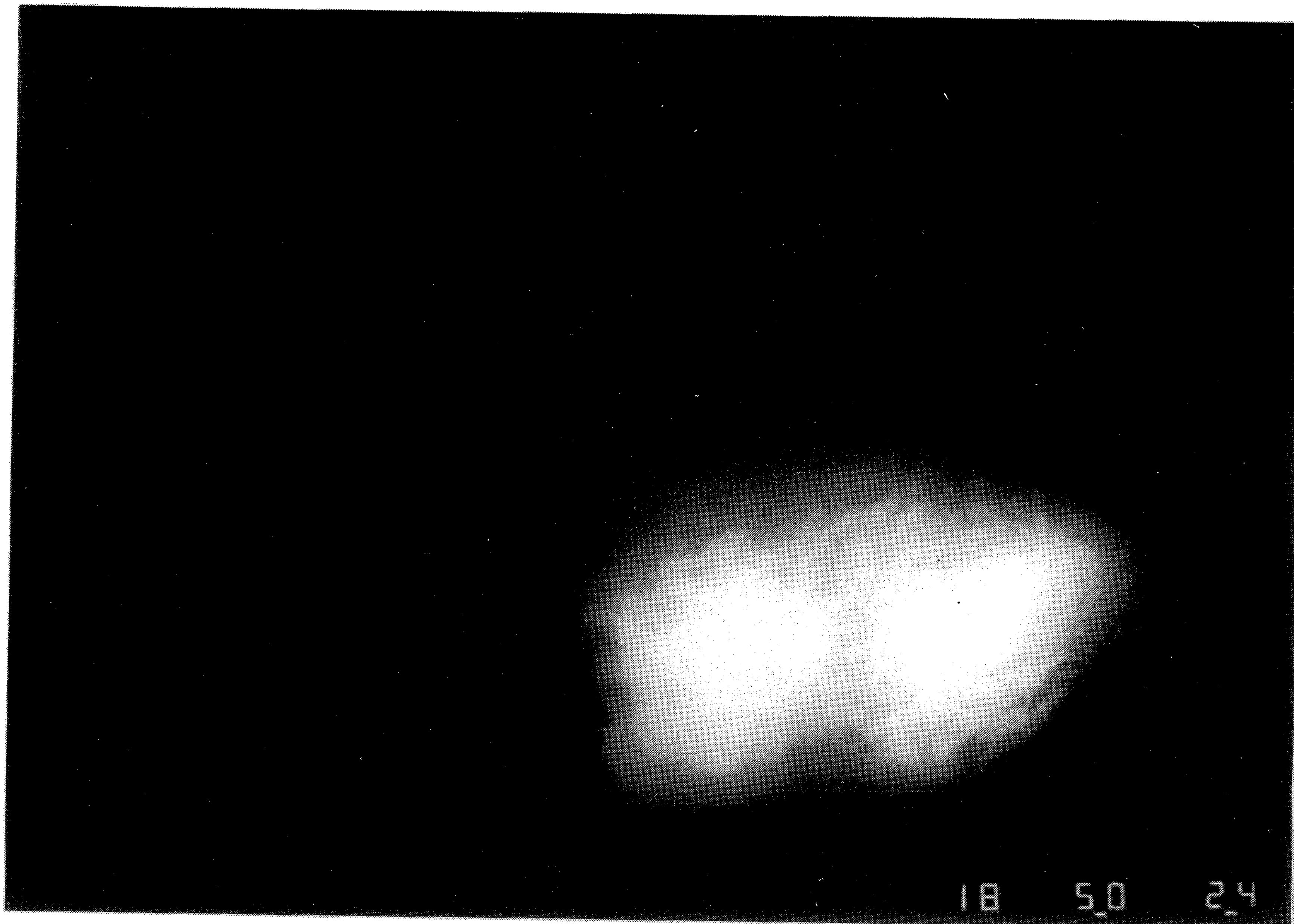


Figure 7. Oblique photo of a large, single flash, orbit 35.

flashes per min. This storm system was in the developmental stage, and, although not very impressive from a lightning viewpoint, it is a good example of a developing tropical depression.

Figure 8 shows the orbital track of the shuttle during the time that another tropical storm was photographed during orbit 54 as the shuttle was approaching the west coast of South America as seen on Figure 3. A number of lightning flashes were occurring in this storm cell, and the sequence of photos was taken during the exposure of roll 122. Figure 9 shows an excellent example of some of these lightning flashes. Since the photos show the limb of the Earth and since the airglow can be seen, one can estimate the sizes of the flashes using scaling techniques. The size of these flashes is estimated to approximate an areal diameter of 45 nmi. We will discuss this sequence of photos from roll 122 in more detail in the following text and show how this data can be used to obtain additional information about the storm from photography only.

This storm is a good example of small storm cell development over the ocean and it had a large number of lightning flashes. If one counts the flashes that are seen in these photographs and we know the length of time that the storm was being photographed, we can estimate the flash rate. The flash rate is 27.8 flashes per min or a total of 48 flashes during the time span of 111.6 sec. When one considers that the pictures were taken in a 2-sec exposure time and with an average time of 3 sec that the camera was not being used between photos, one can safely say that we are not seeing all the flashes that occurred during this time interval; thus, we are underestimating the total number of flashes for this storm. Since we were not able to observe this storm for a long period of time, we can tell by the flash rate that this was a very active storm. By using the total number of flashes that we see in the photos and using techniques developed by Piepgrass and her associates in their studies of convective Florida storm cells during the 1978 and 1979 Thunderstorm Research Program (TRIP) at Kennedy Space Center to estimate rainfall for a particular storm which had lightning, and the work of Goodman and his associates in their studies of lightning and storm development during the 1986 Cooperative Huntsville Meteorological Experiment (COHMEX), we can also get an estimate of the rainfall that is probably coming from this storm. By using radar data, lightning data, and satellite images, Goodman et al. were able to estimate the rainfall for a particular storm that they studied. They found that for a particular storm which had a total of 116 flashes per minute at peak flash rate produced a rainfall of 1.2×10^8 kg. Since the STS-26 photography lasted 111.6 sec and there were a total of 48 flashes over this time interval, a flash rate of 27.8 flashes per min results. Since the flash rate in this storm is a little more than the 23 flashes per min as reported by Goodman et al., we can estimate the rainfall as follows:

If we use the ratio of 1.2×10^8 kg/116 flashes and multiply this by our number of flashes (48) produced by our storm, we get a rainfall of 4.9×10^7 kg.

VI. CONCLUSIONS

The video data from the earlier shuttle flights, such as STS-8, STS-9, STS-41D, and STS-51J, indicate that there is a lot of lightning activity in developing thunderstorm cells and typhoons and that the shuttle is particularly well suited for obtaining data on this type of large-scale lightning phenomena. If the crew of STS-26 had been able to remain in orbit a few more days, then additional lightning

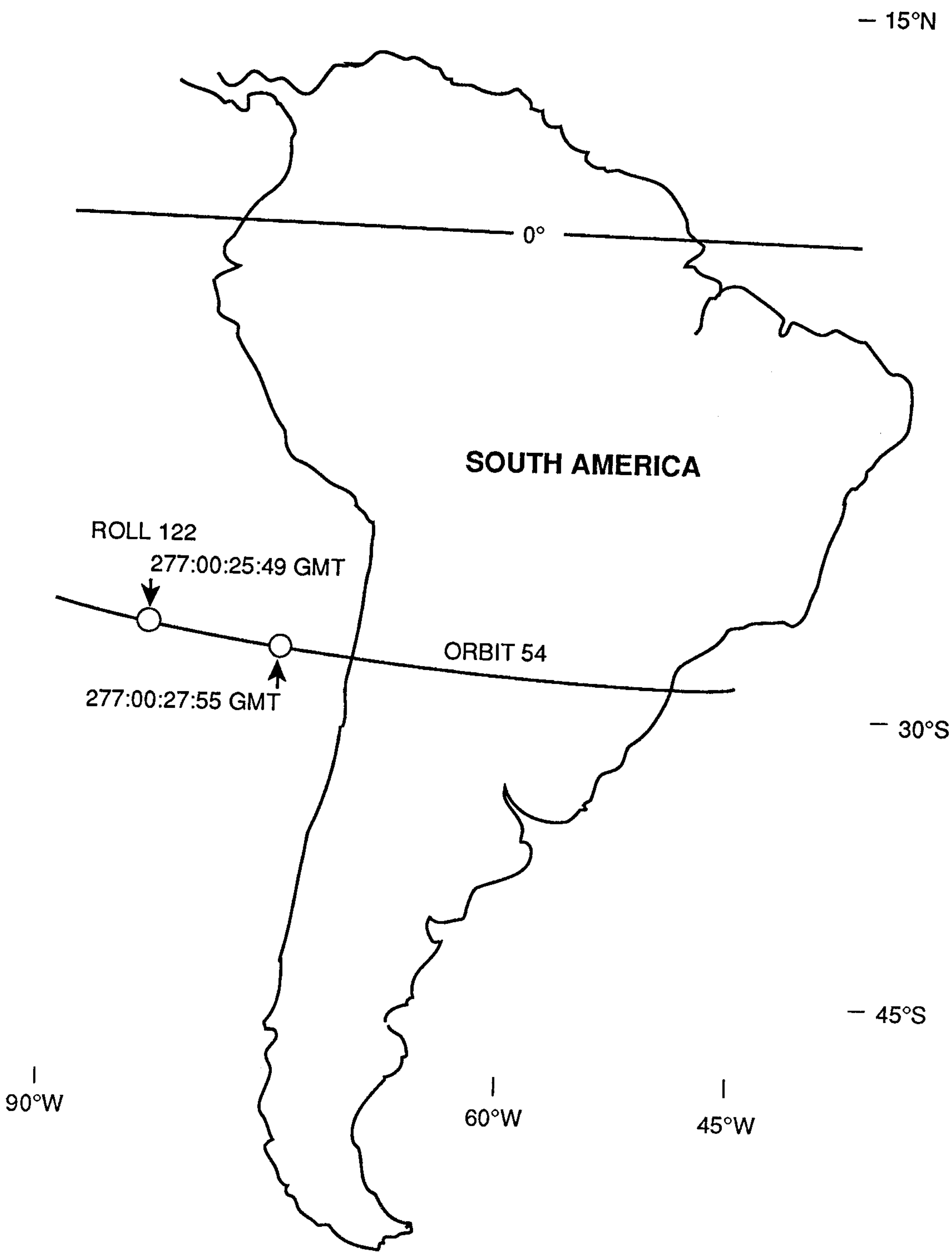


Figure 8. STS-26 orbital tracks, orbit 54.

Figure 9. Oblique photo of multiple lightning flashes in storm cell, orbit 54.

data for a developing typhoon might have been obtained to support what we had seen on the STS-51J mission. A tropical depression was noted to be developing in the Western Pacific during the STS-26 flight and it was finally designated as a typhoon as the STS-26 flight ended. This typhoon was called Nelson and it was the first significant tropical cyclone of October to develop in the Western Pacific and was the only super typhoon of 1988. Once the Space Station is placed in orbit or if the shuttle's mission time can be extended, then the crews will have more time to observe and collect data on this type of tropical storm and other related atmospheric phenomena. Although the crew of STS-26 had difficulty operating the onboard color TV camera in obtaining lightning data, they were still able to obtain some very interesting 35 mm photos for analysis. On future shuttle flights, it is planned to operate the onboard payload cameras from the ground thus allowing data to be collected when the crew cannot operate the cameras, for example, when they are asleep or too busy doing other experiments that have higher priority.

REFERENCES

1. Sparrow, J. G., and E. P. Ney, "Lightning Observations by Satellite", Nature, 232, 540-541, 1971.

2. Thurman, B. N., "Analysis of Lightning Data from DMSP Satellites," J. Geophys. Res., 83, 5019-5024, 1978.

3. Radio Research Laboratories, Japan, "World Distribution of Thunderstorm Activity Obtained from Ionospheric Sounding Satellite-B Observations, June 1978 to 1980," 57 pp., 1981.

4. Orville, R. E., "Global Distribution of Mid-Night Lightning, September to November 1977," Mon. Wea. Rev., 109, 391-395, 1981.

5. Cook, A. F., T. C. Duxbury, and G. E. Hunt, "First Results on Jovian Lightning," Nature, 280, 794, 1979.

6. Taylor, W.W.L., F. L. Scarf, C. T. Russell, and L. B. Brace, "Evidence for Lightning on Venus," Nature, 279, 614-616, 1979.

7. Ksanformaliti, L. V., "Discovery of Frequent Lightning Discharges in Clouds on Venus," Nature, 284, 244-246, 1980.

8. Scarf, F. L., W.W.L. Taylor, and C. T. Russell, "Lightning on Venus: Orbiter Detection of Whistler Signals," J. Geophys. Res., 85, 8158-8166, 1980.

9. Kaiser, M. L., J.E.P. Connerney, and M. D. Desch, "Atmospheric Storm Explanation of Saturnian Electrostatic Discharges," Nature, 303, 50-53, 1983.

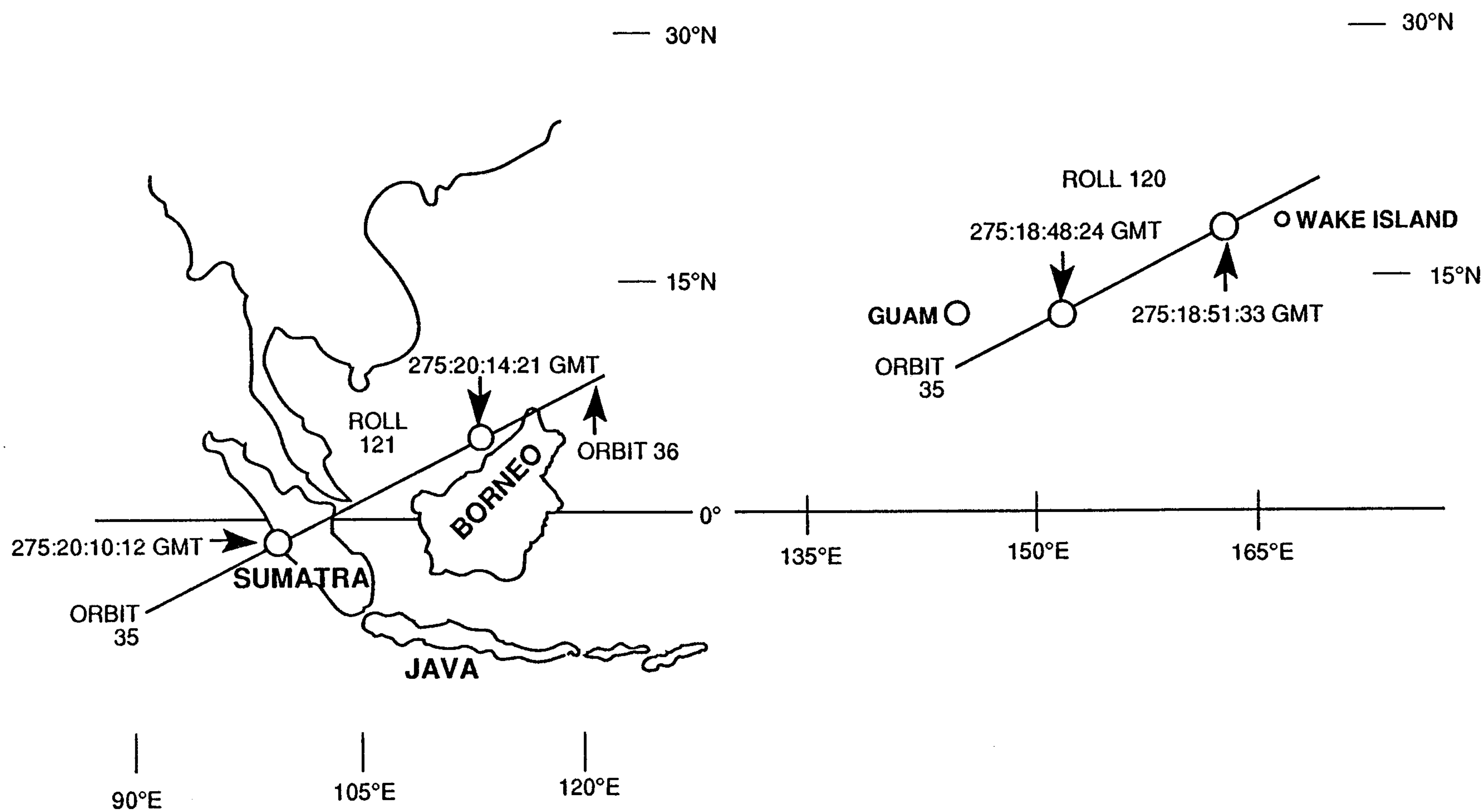
10. Breslawski, C., "Size, Duration, and Rate of Growth of Nocturnal Lightning Events Appearing on Space Shuttle Video Tapes," Master of Science Thesis, College of Science and Mathematics, Department of Atmospheric Science, State University of New York at Albany, Albany, New York, 1989.

11. Piepgrass, M. V., P. K. Krider, and C. Moore, "Lightning and Surface Rainfall During Florida Thunderstorms," J. Geophys. Res., 87, 11,193-11,201, 1982.

12. Goodman, S. J., D. E. Buechler, and P. D. Wright, "Lightning and Precipitation History of a Microburst-Producing Storm," J. Geophys. Res. Lett., 15, 1185-1188, 1988.

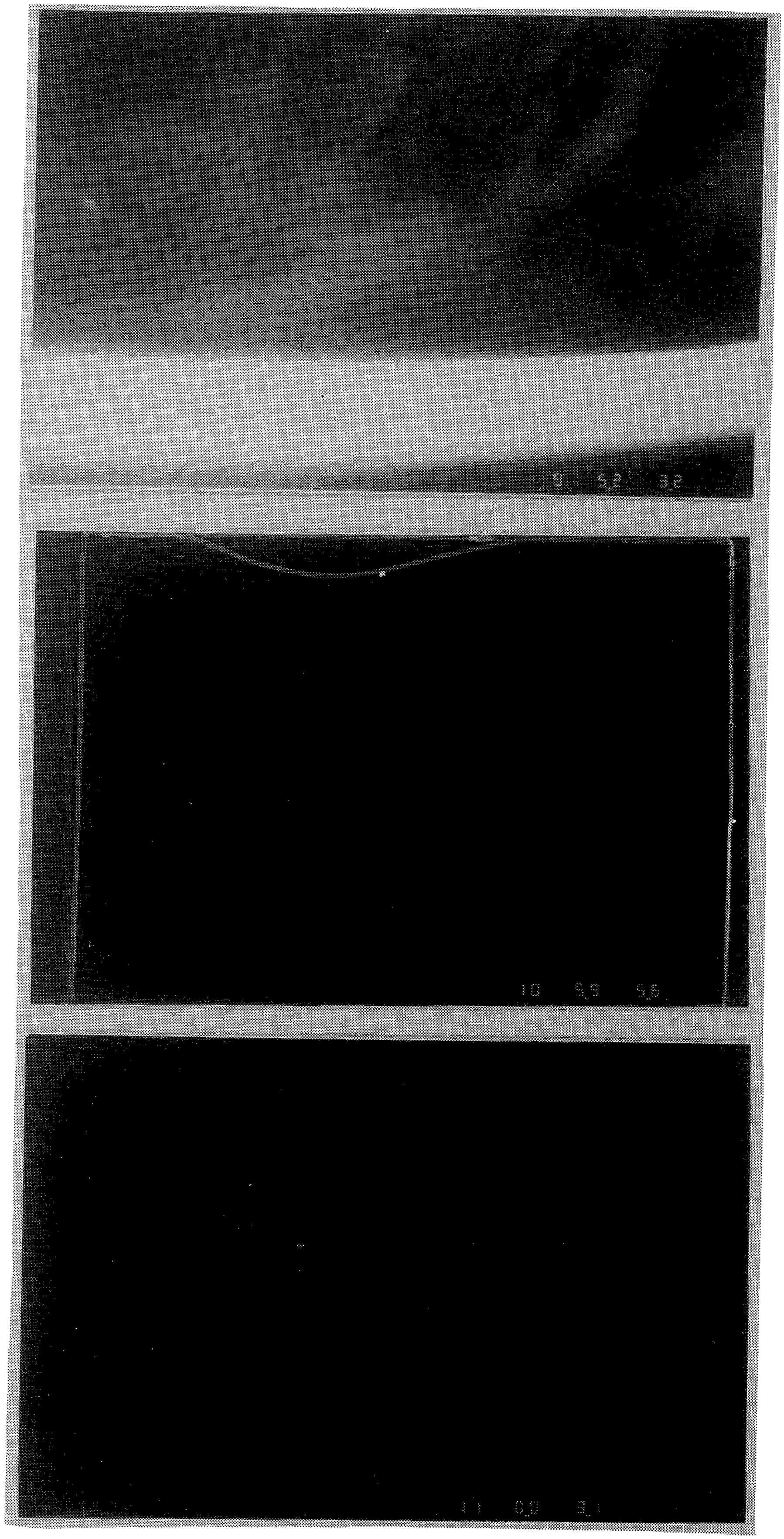
APPENDIX A

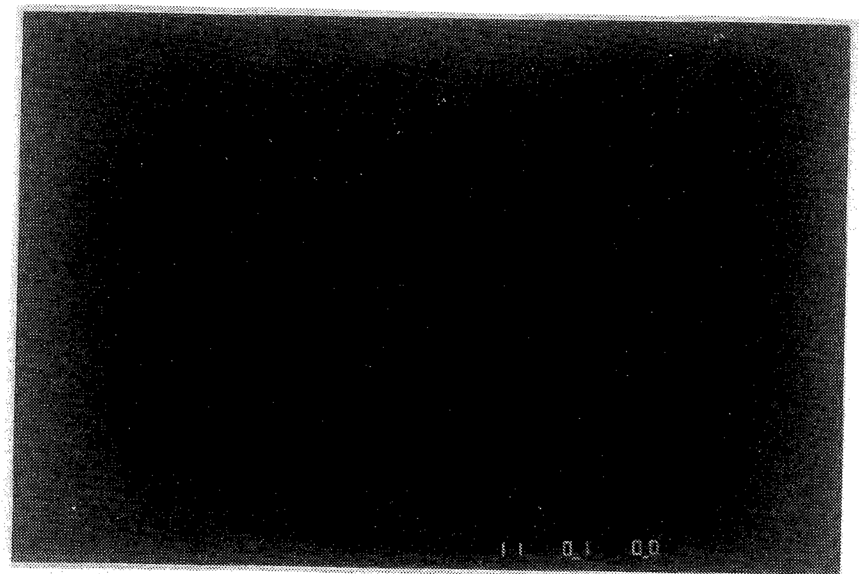
PHOTOGRAPHY OF LIGHTNING TAKEN DURING THE STS-26 MISSION
ROLL 120

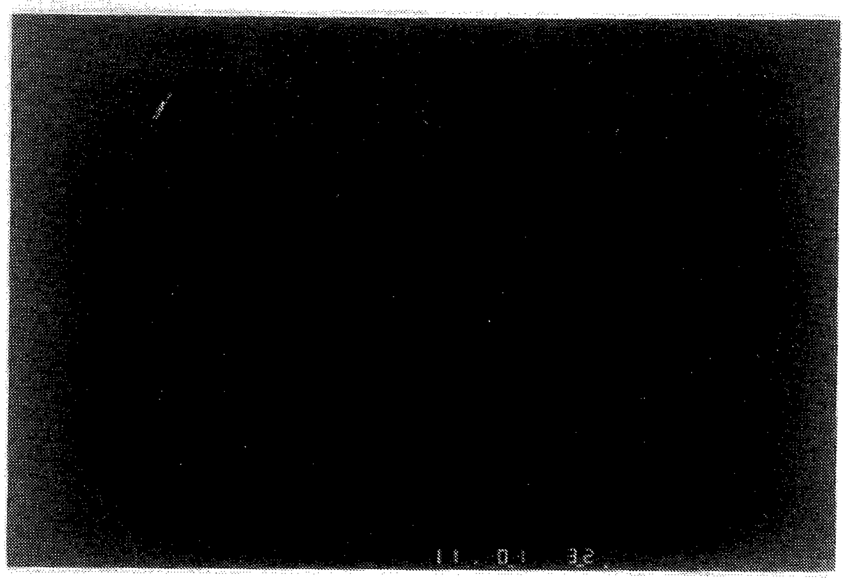


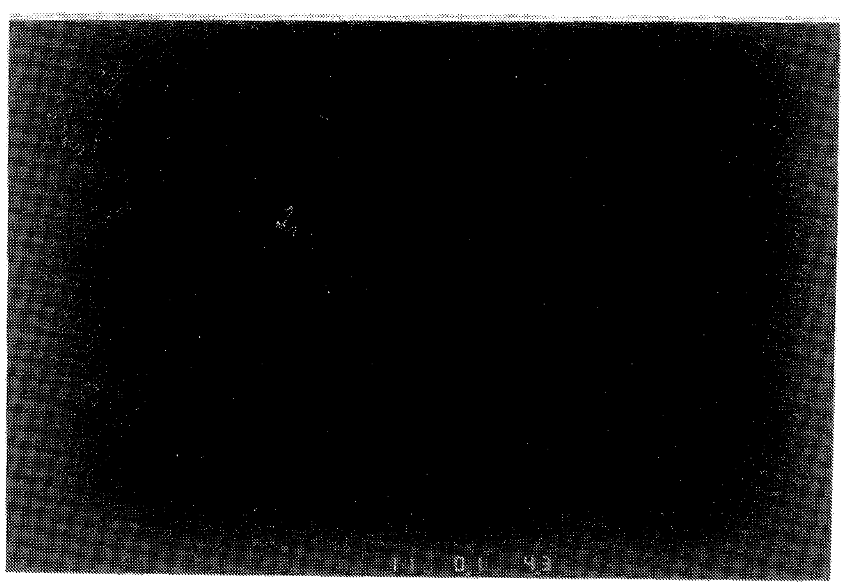
Orbital tracks for rolls 120 and 121, orbits 35 and 36.

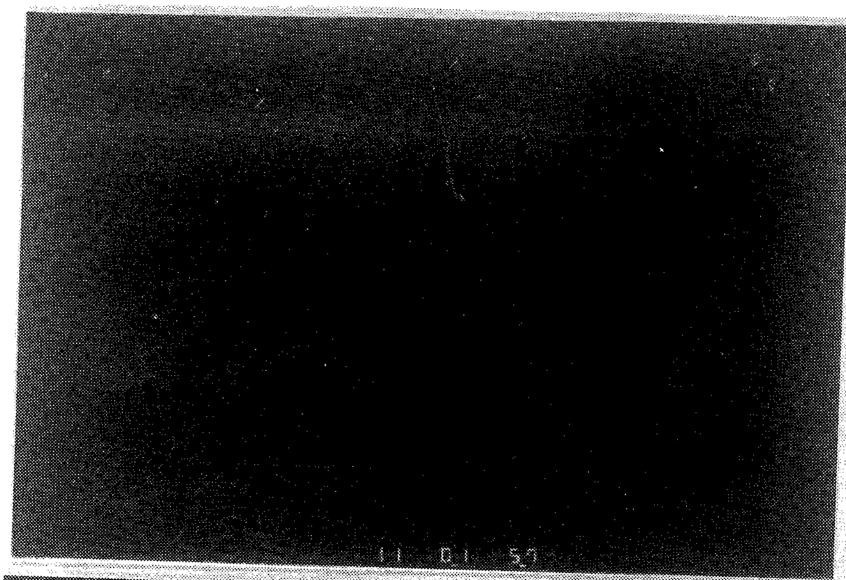
Sequence of films for roll 120, day 275.

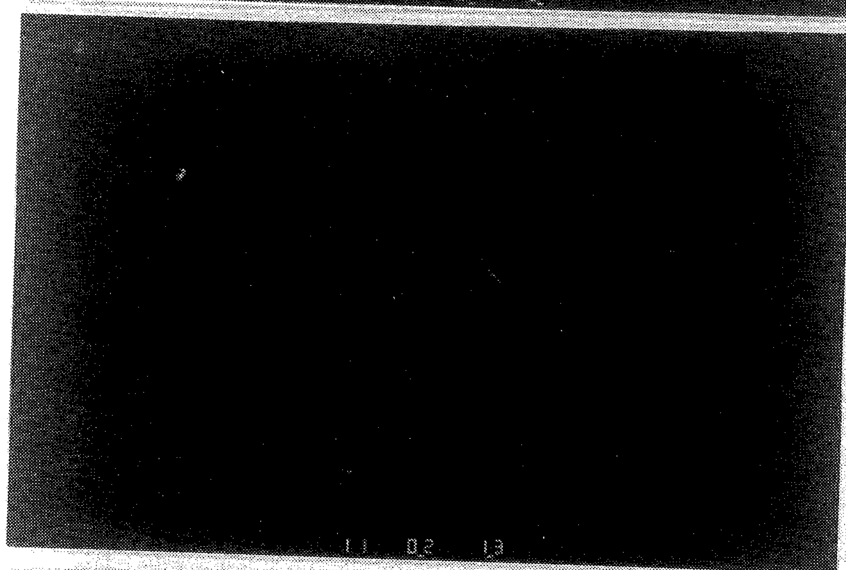


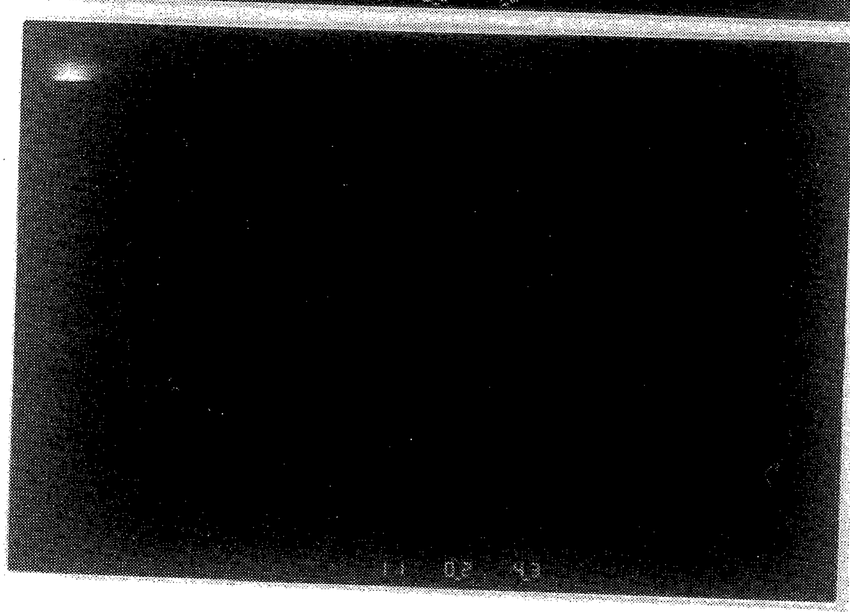

11 01 00

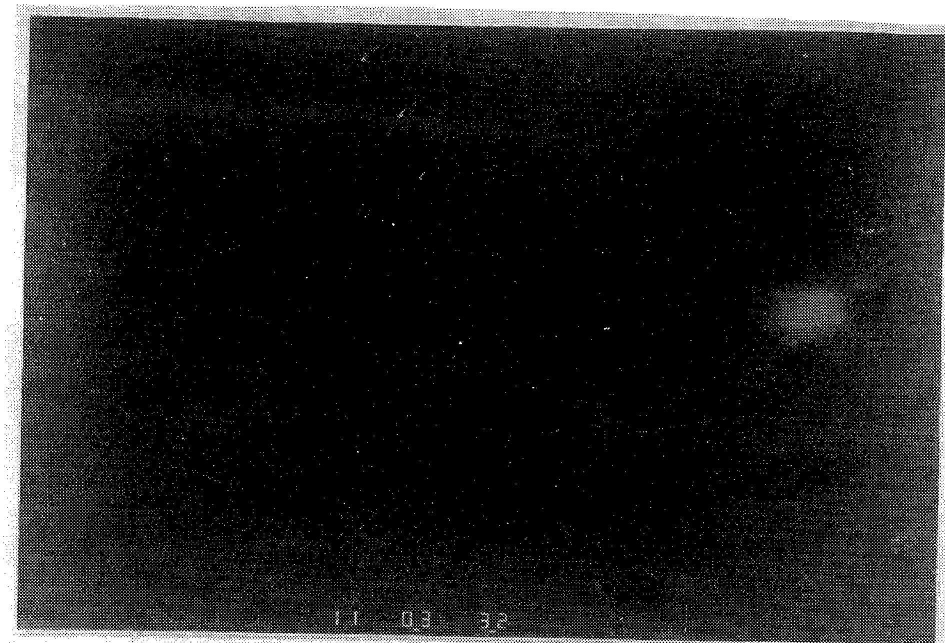

11 01 32


11 01 43

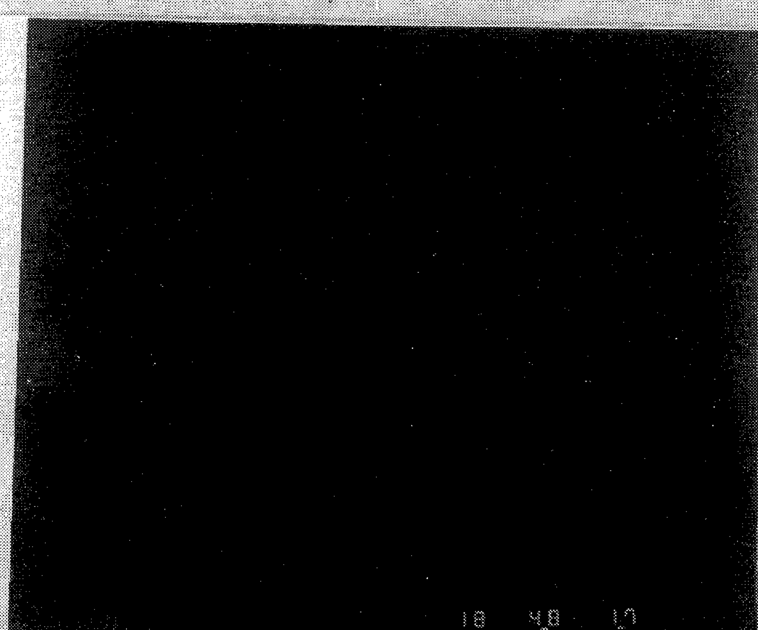

11 01 57

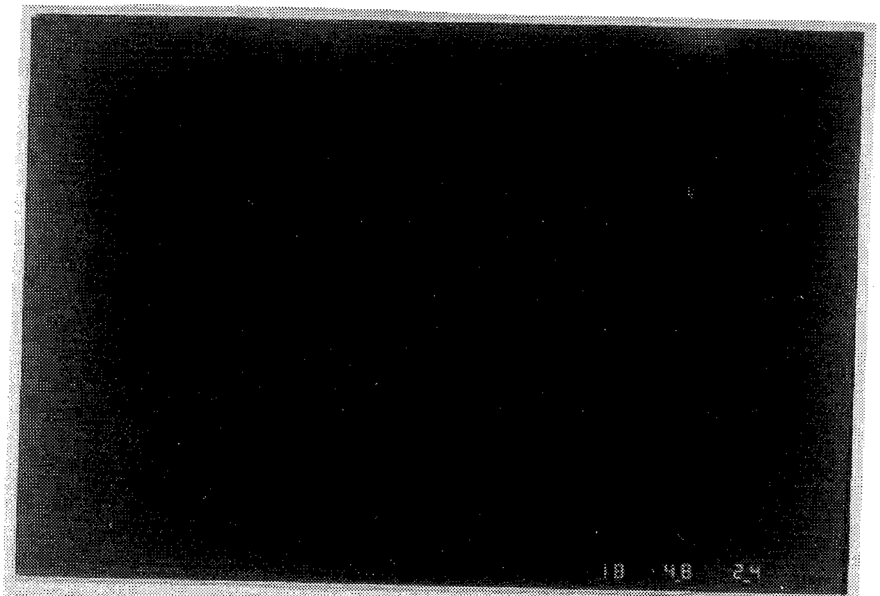

11 02 13

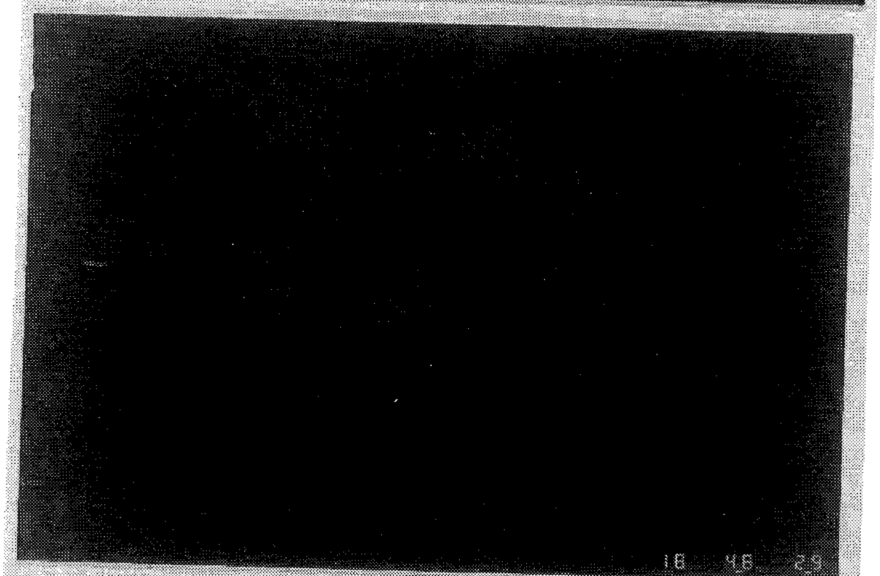

11 02 43


11 03 32


18 47 58


18 48 17


18 48 24

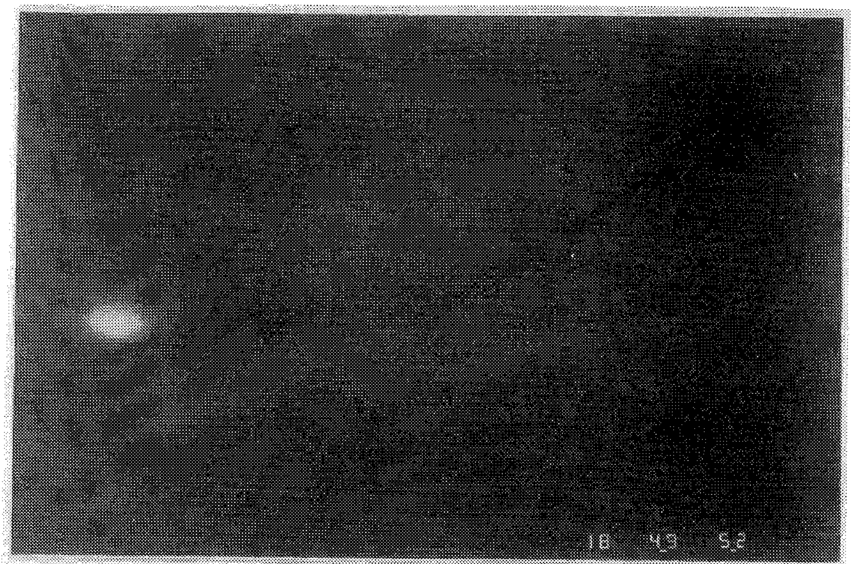
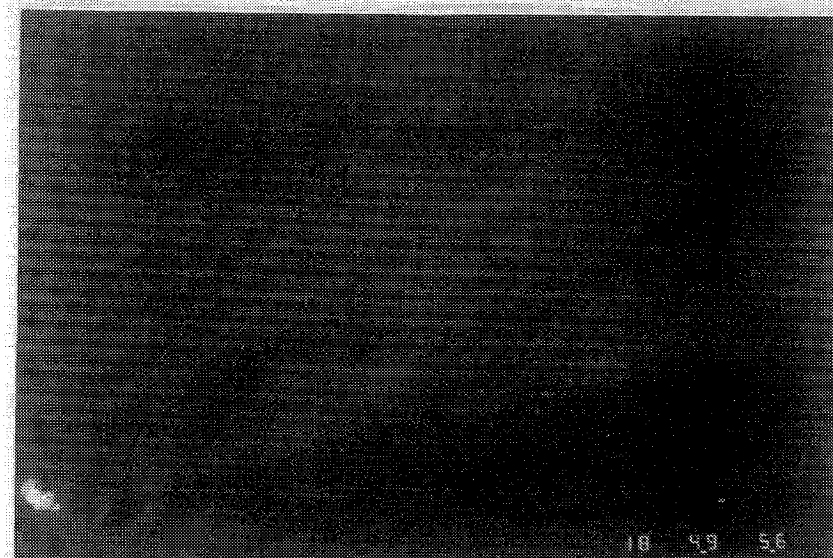

18 48 29


18 49 08

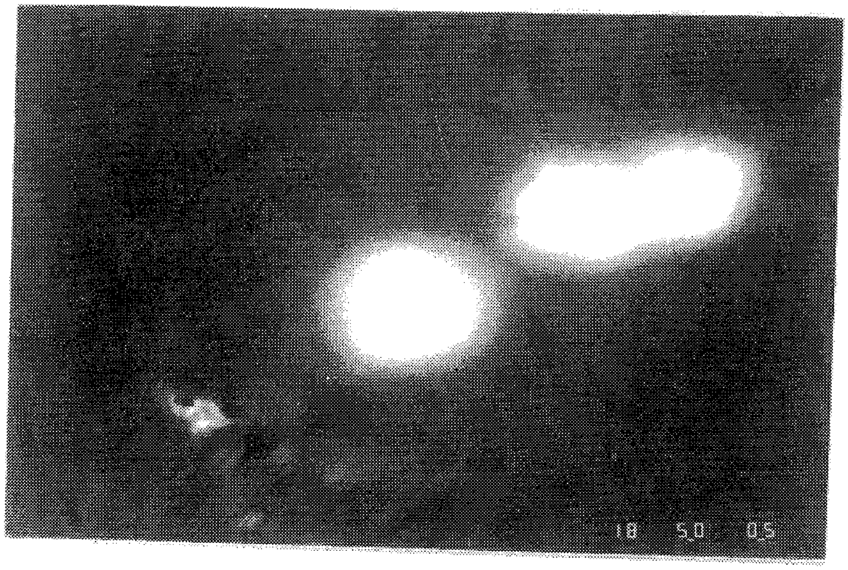

18 49 13

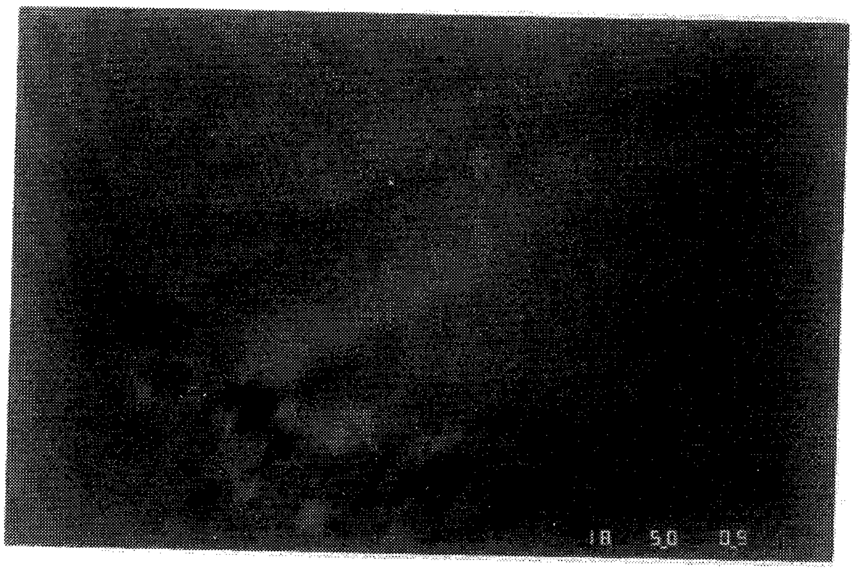
18 49 44

18 49 48


18 49 52

18 49 56

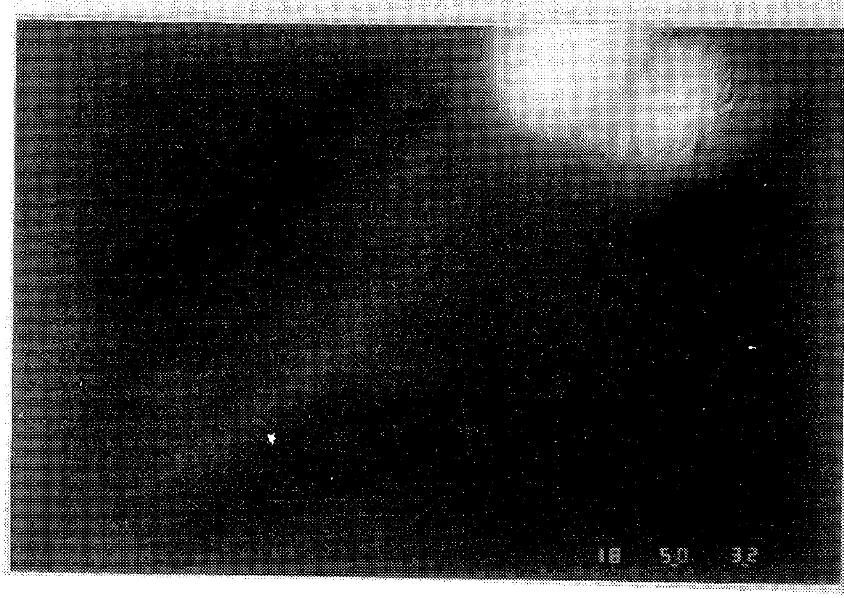
18 50 00

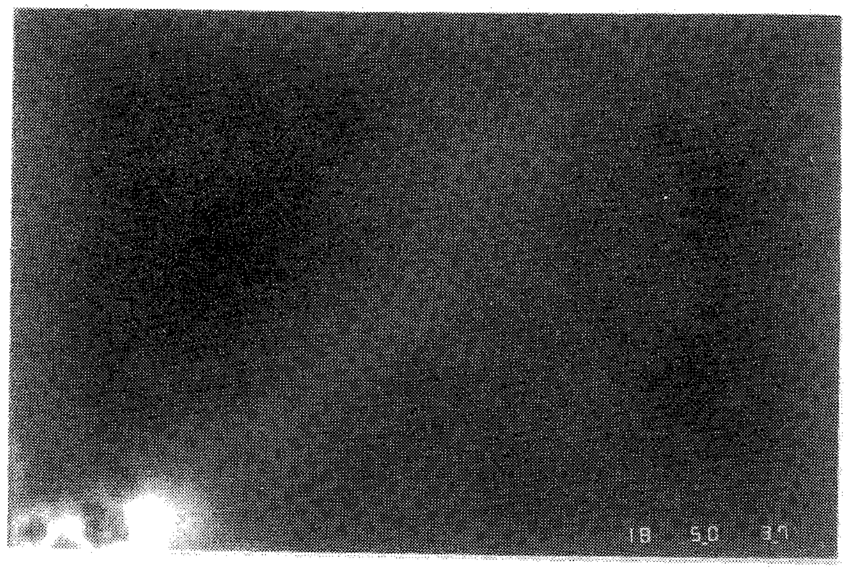

18 50 05


18 50 09

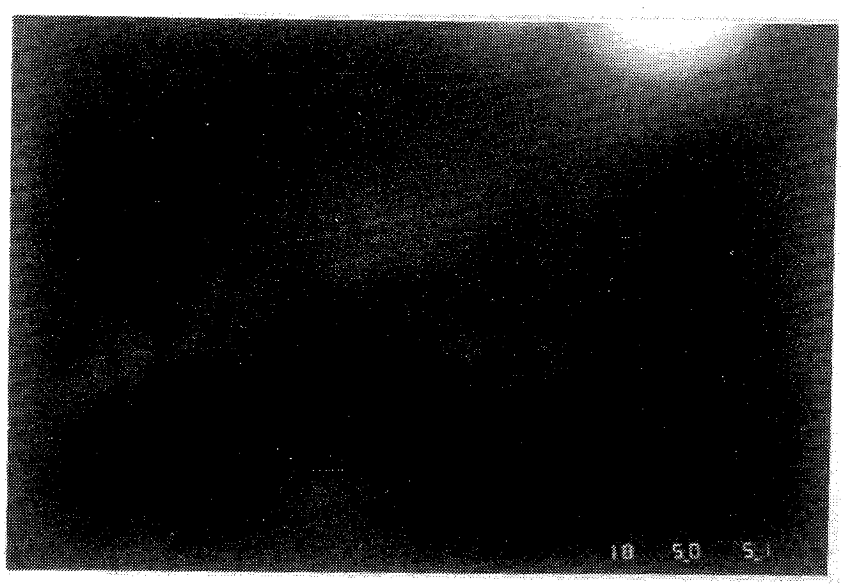

18 50 24

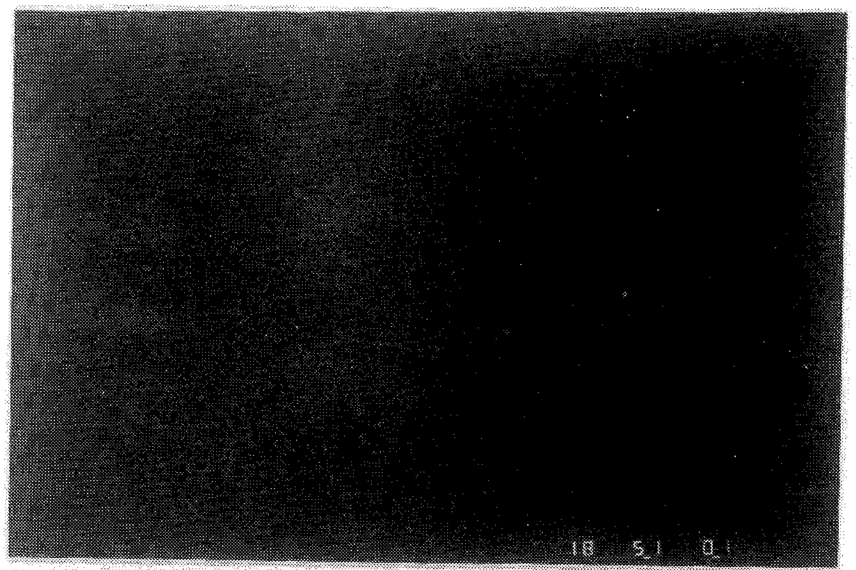

18 50 27

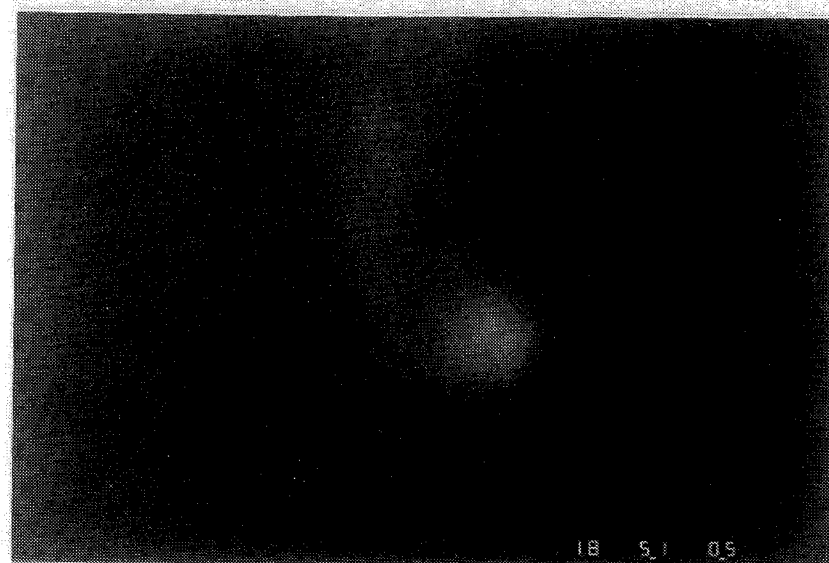

18 50 32

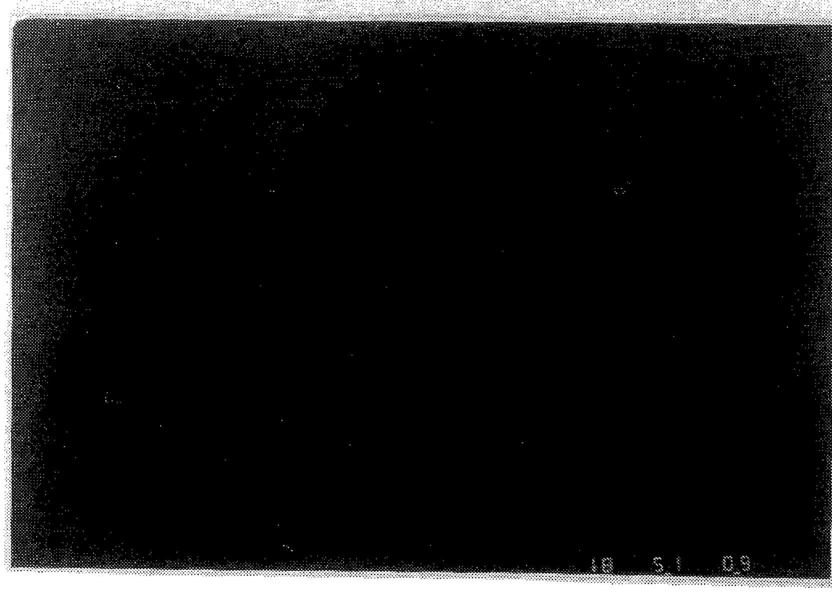

18 50 3.1


18 50 4.1


18 50 5.1



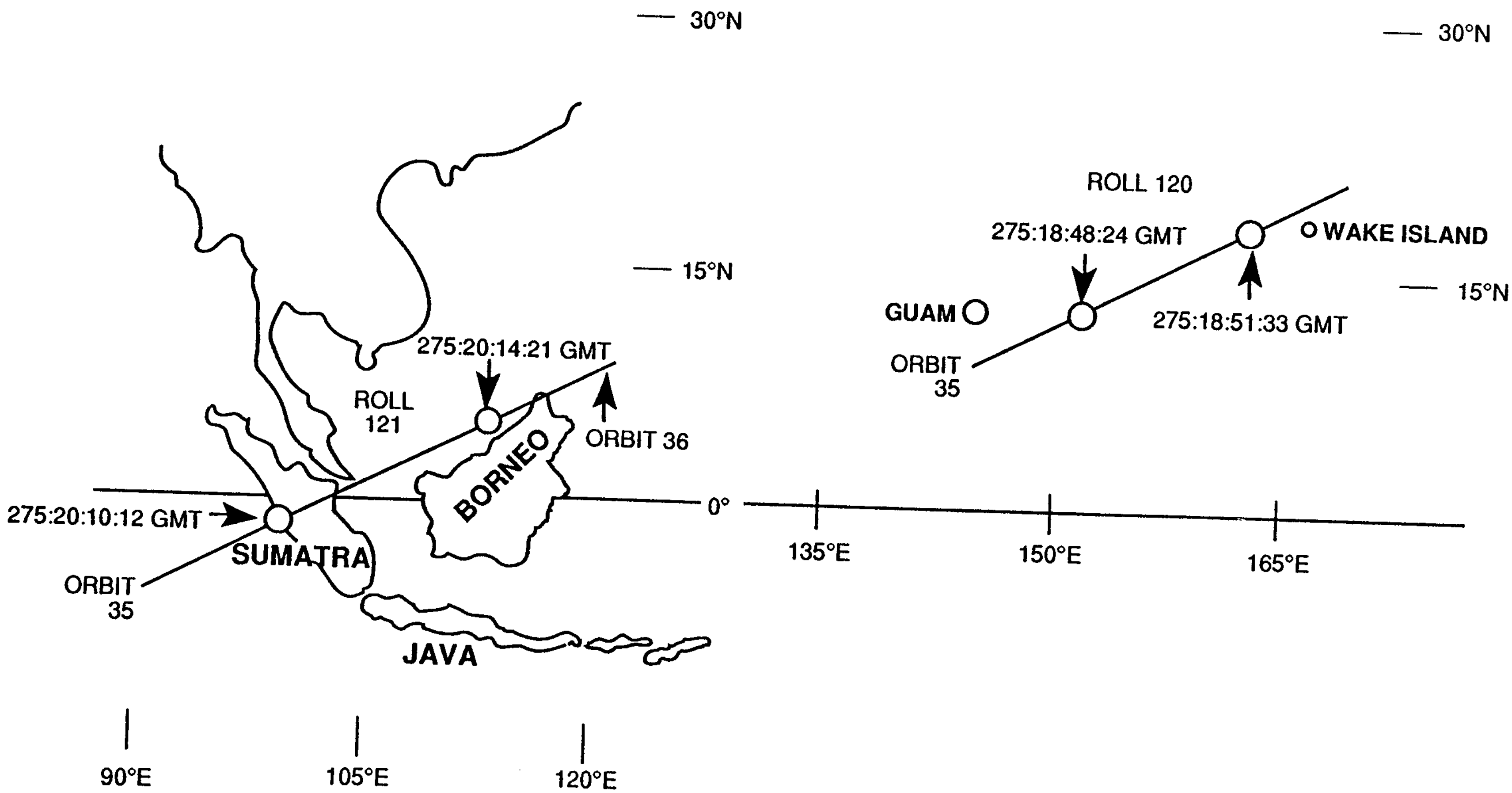




ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

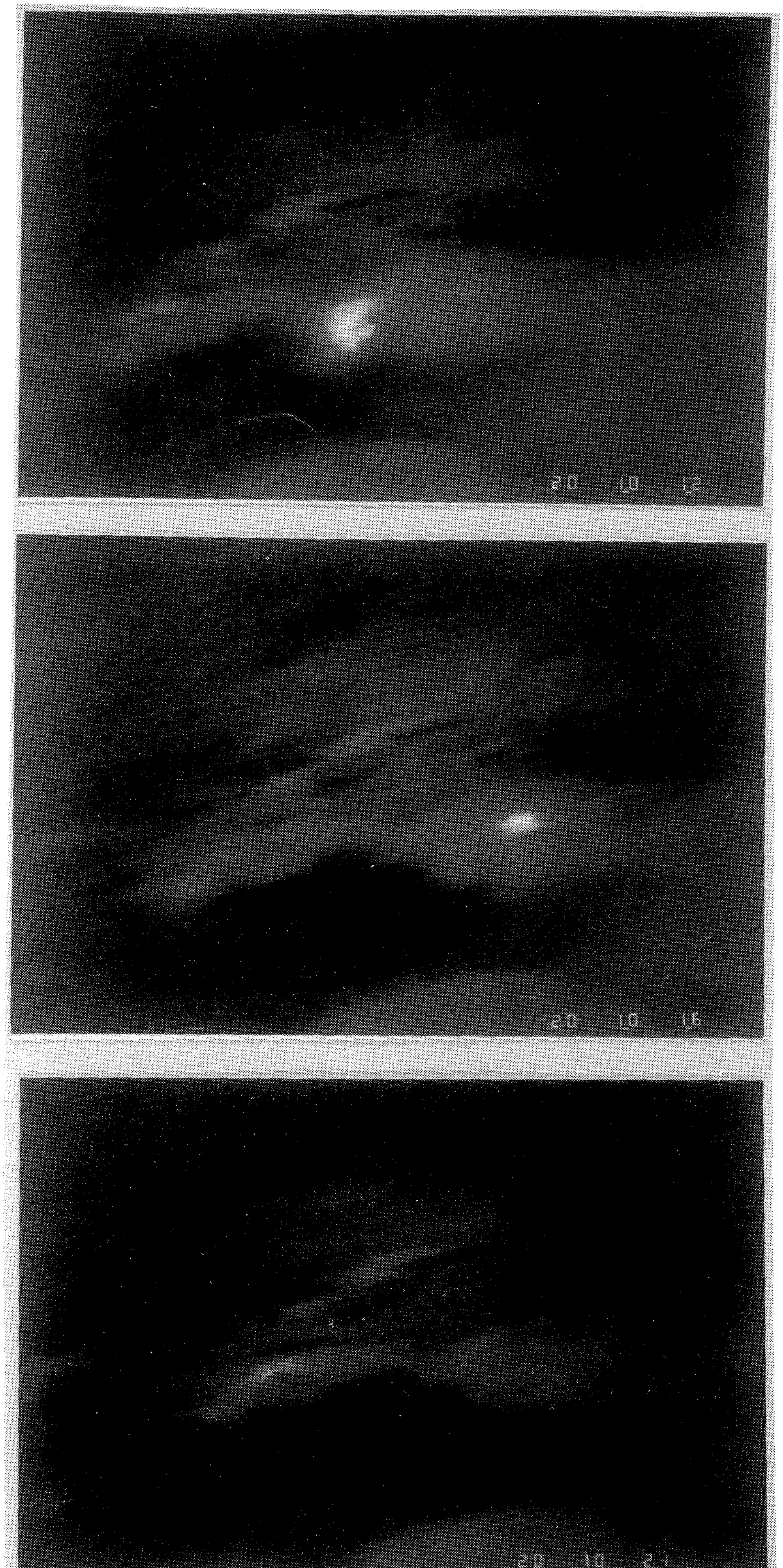
APPENDIX B

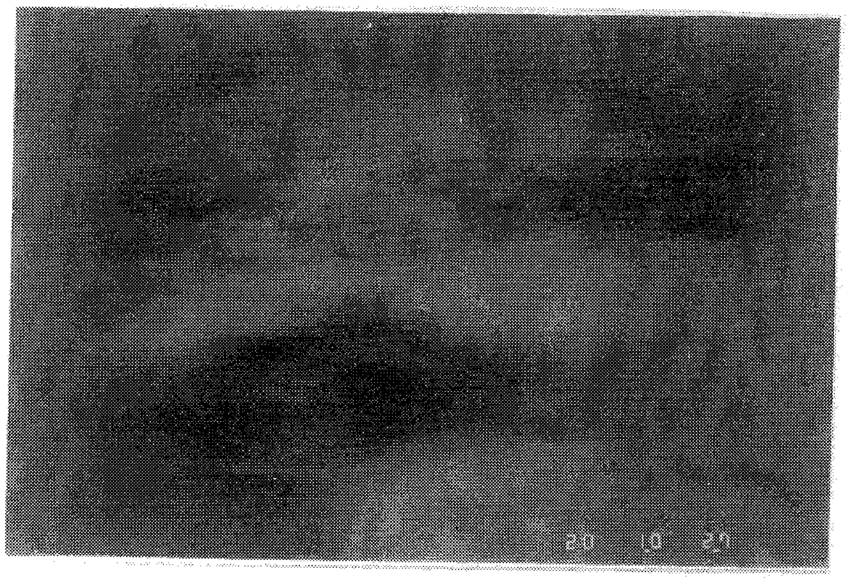
PHOTOGRAPHY OF LIGHTNING TAKEN DURING THE STS-26 MISSION
ROLL 121

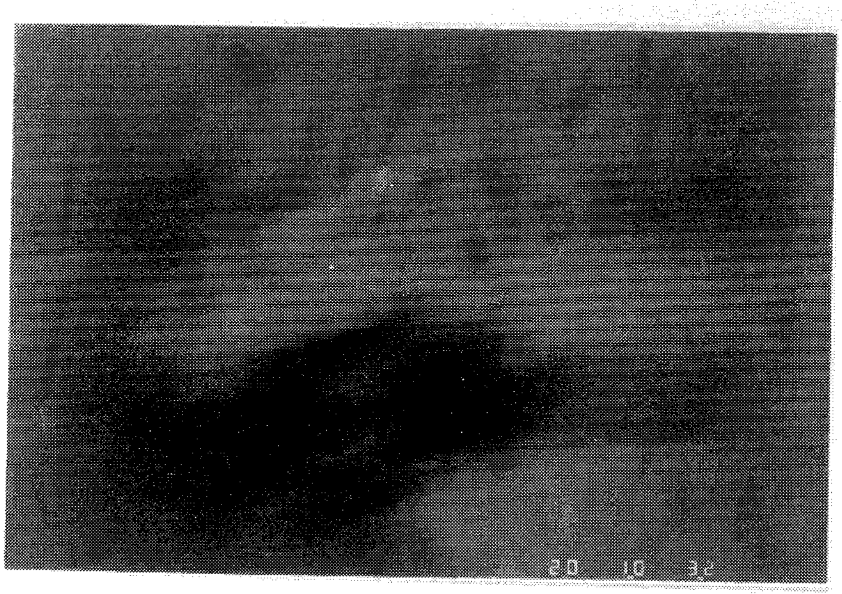


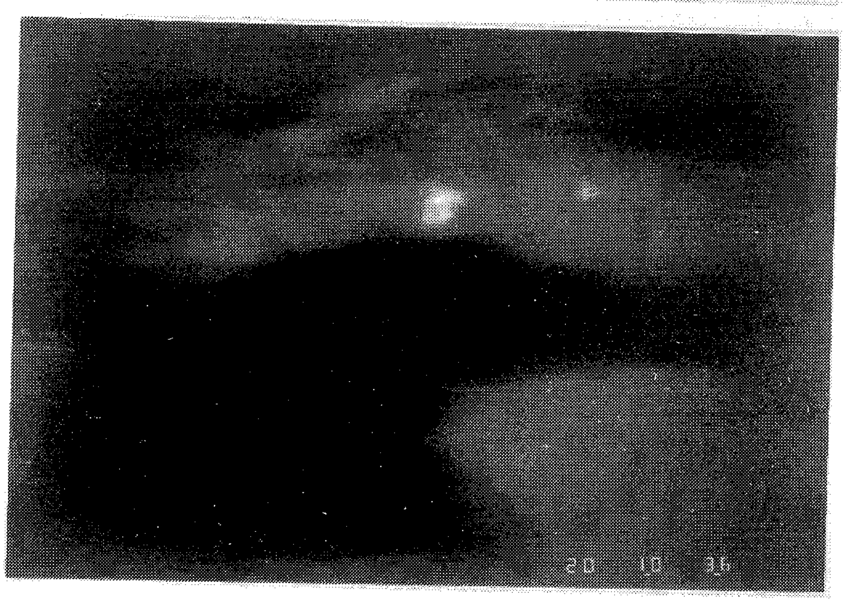
Orbital tracks for rolls 120 and 121, orbits 35 and 36.

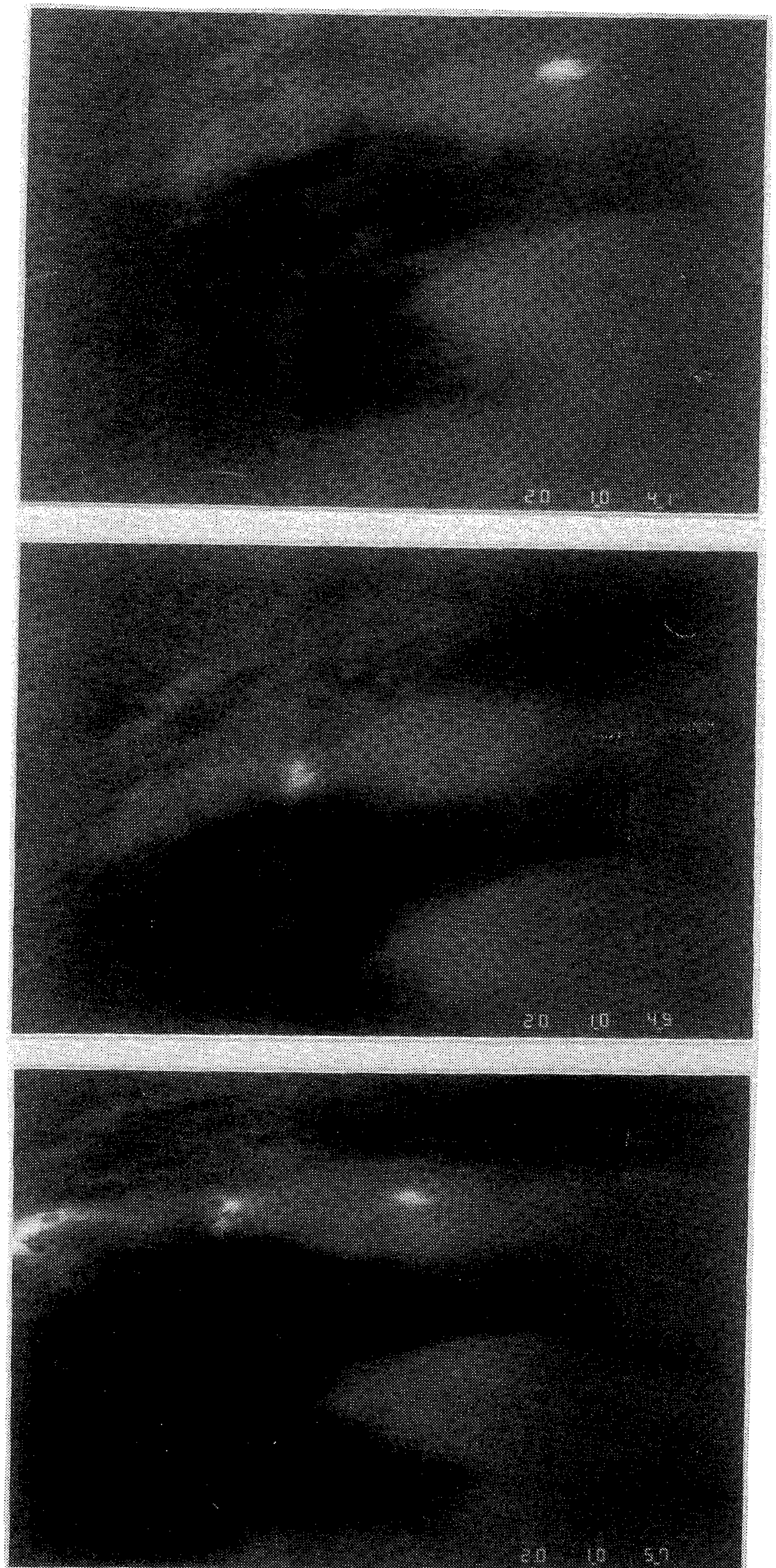
Sequence of films for roll 121, day 275.

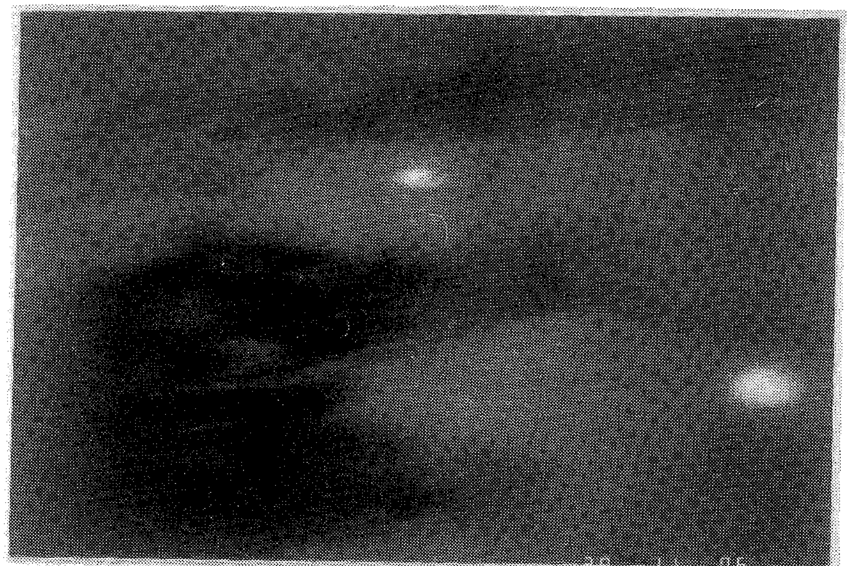


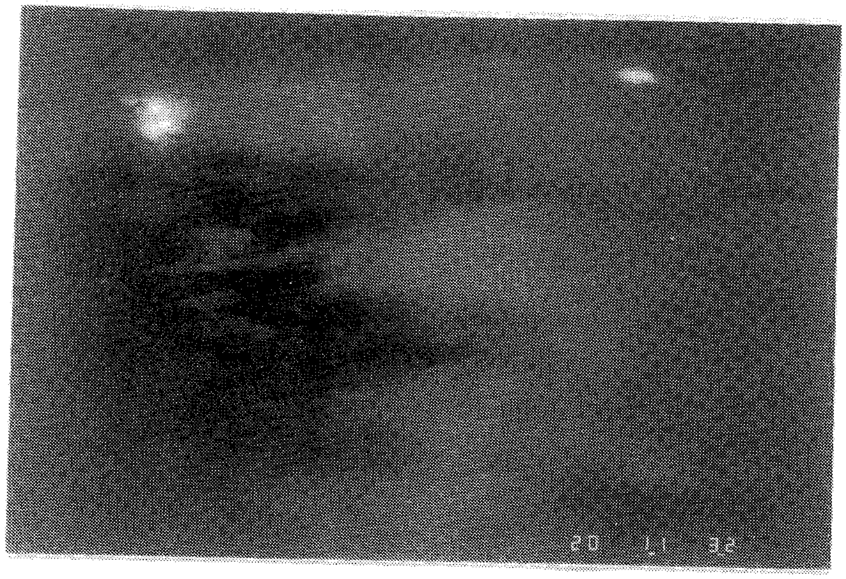

20 10 29


20 10 32

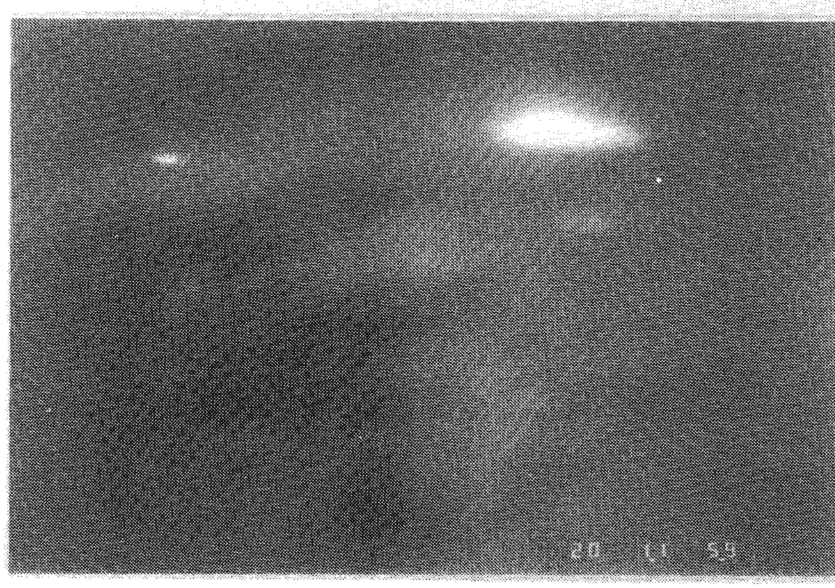

20 10 36

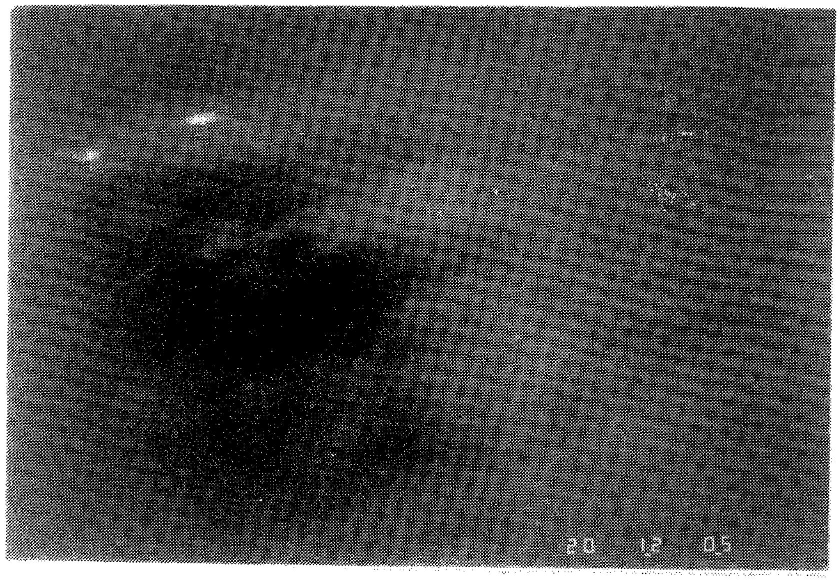

20 10 41
20 10 49
20 10 57

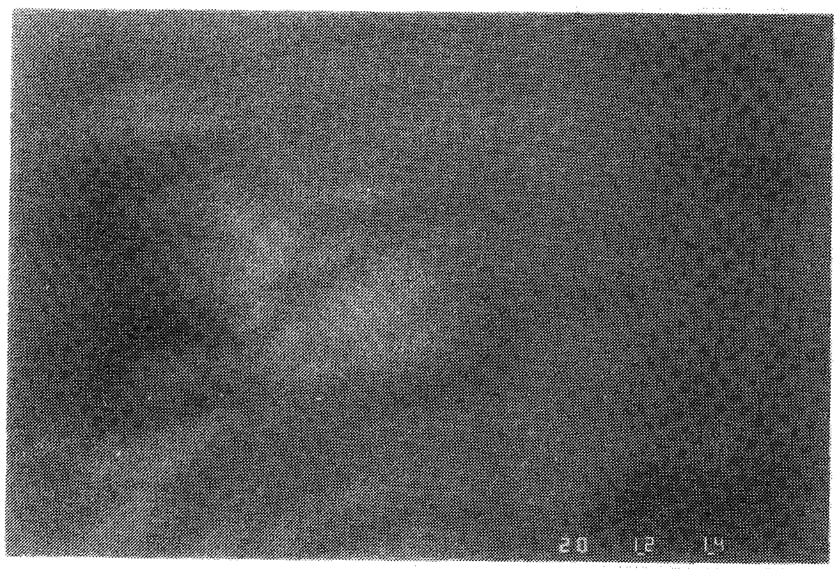


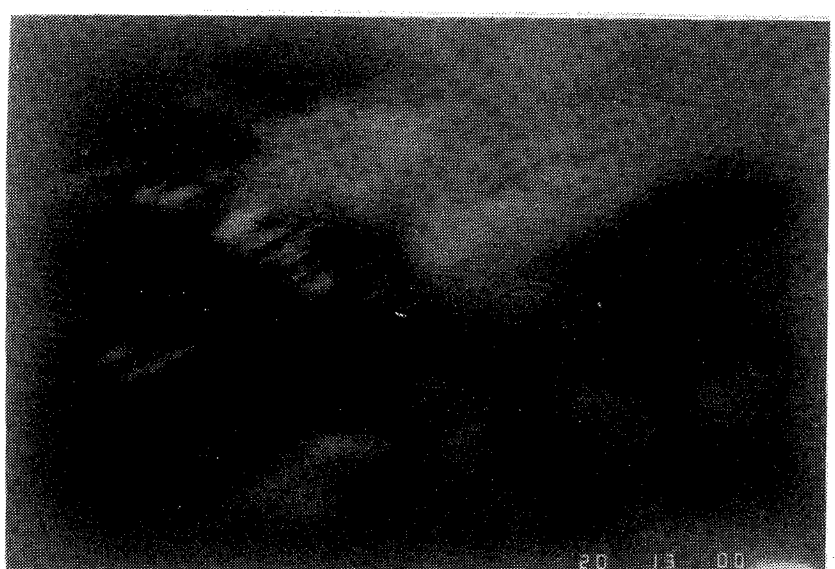

20 11 32


20 11 41

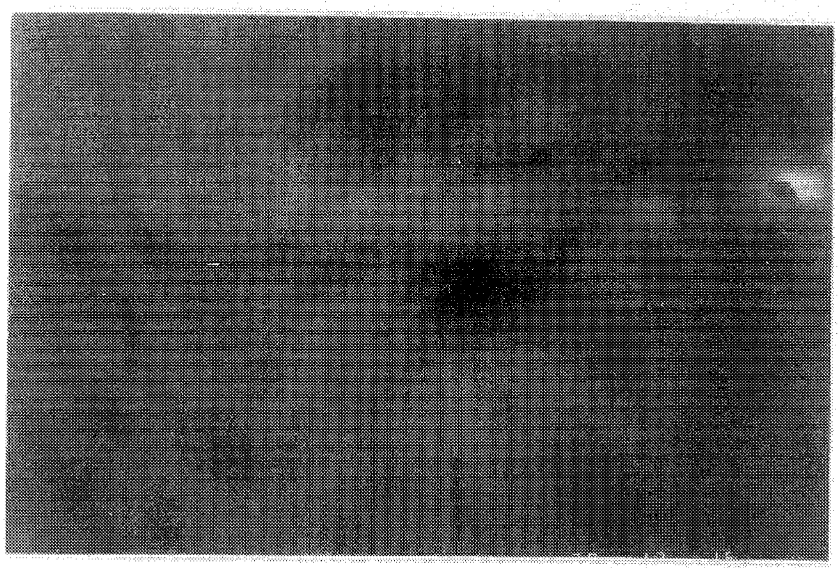

20 11 59


20 12 05


20 12 14

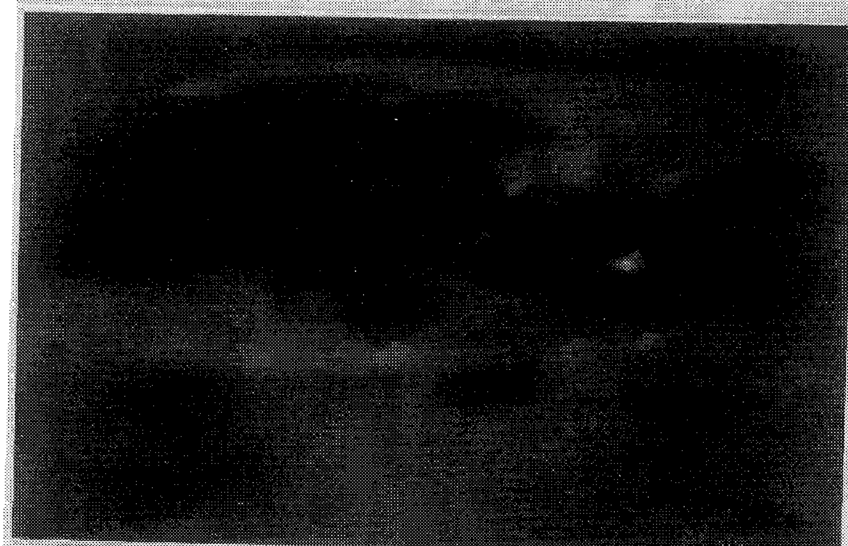

20 13 00


20 13 09

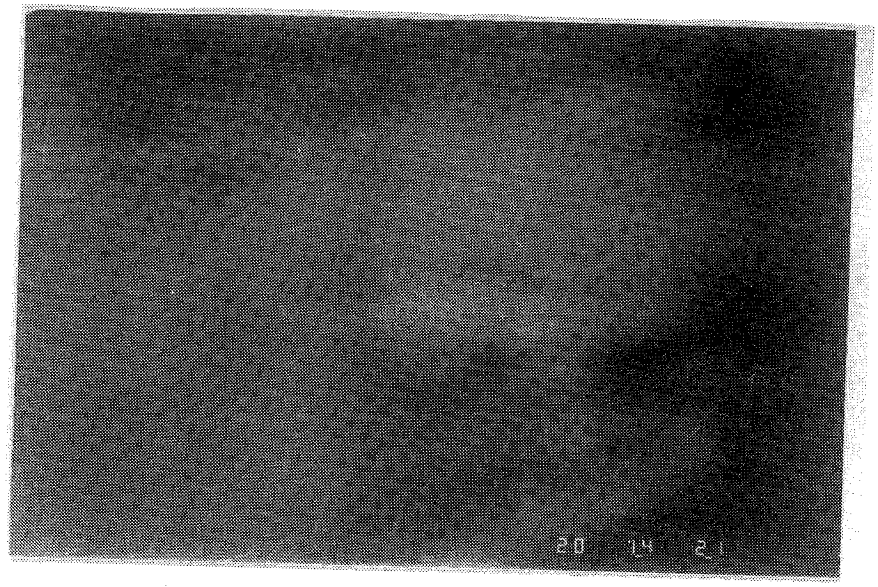


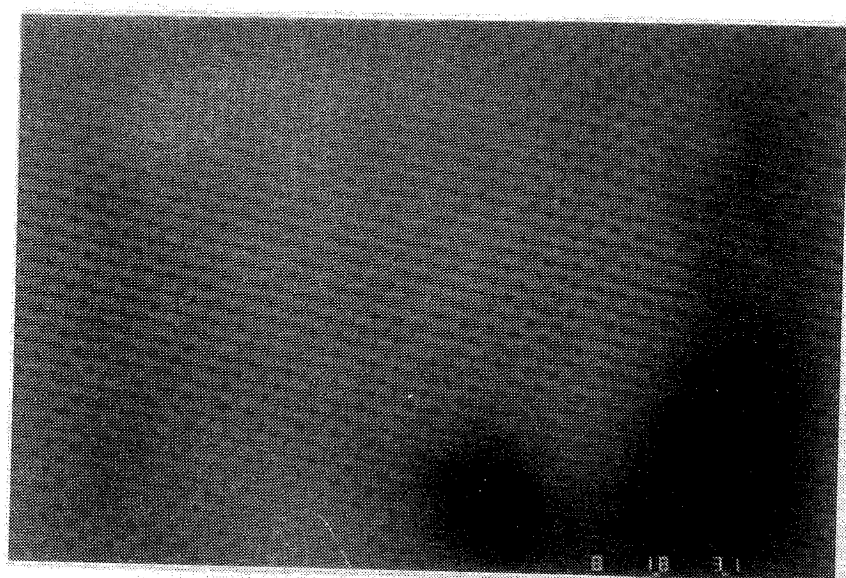

20 13 53

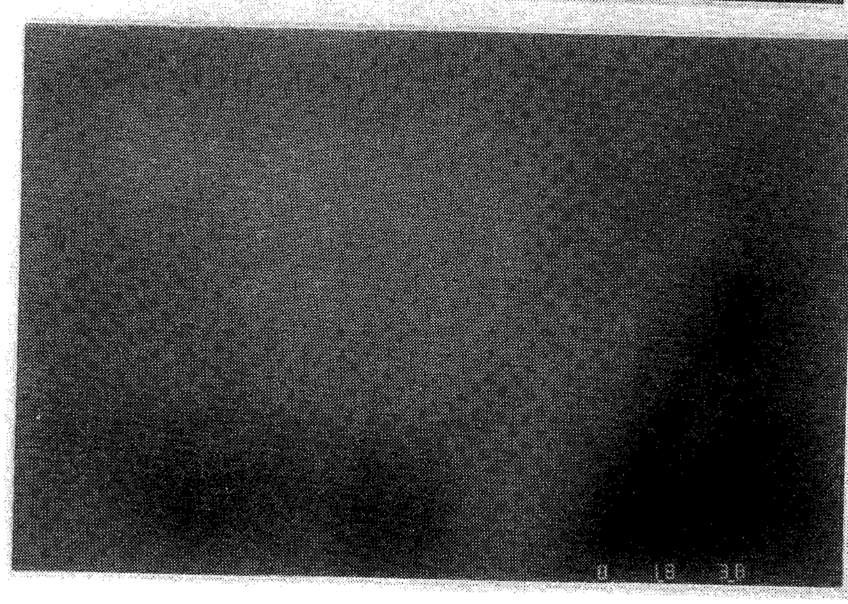

20 13 59

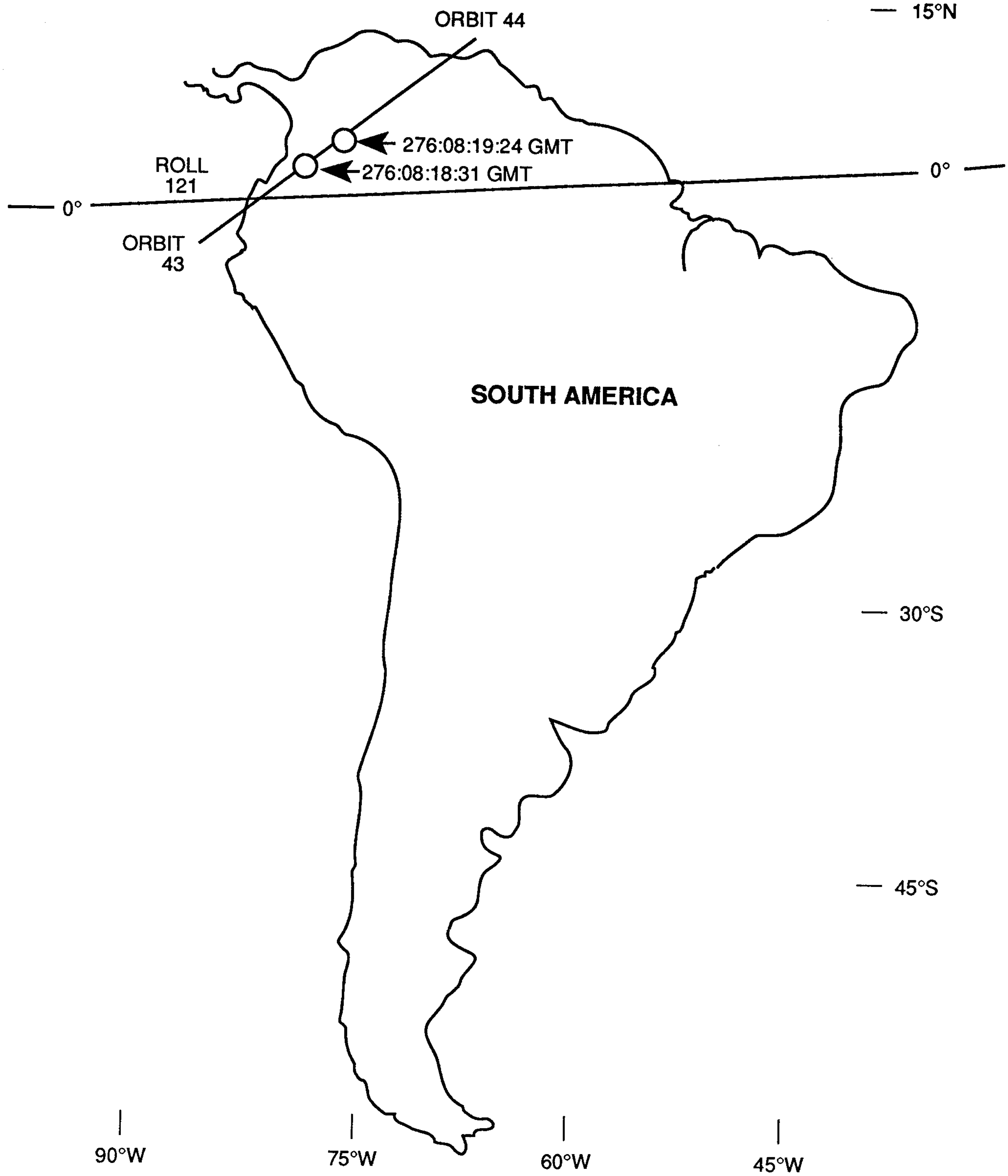



20 14 15


20 14 21

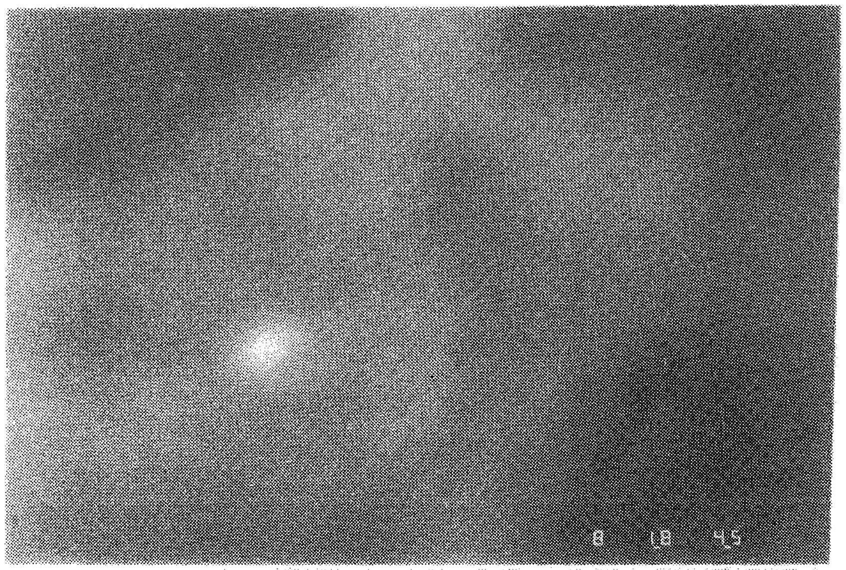


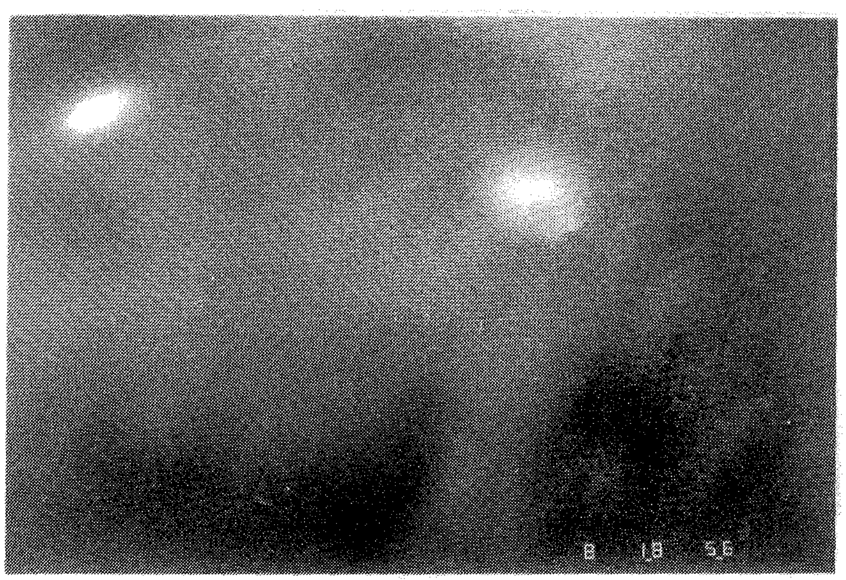


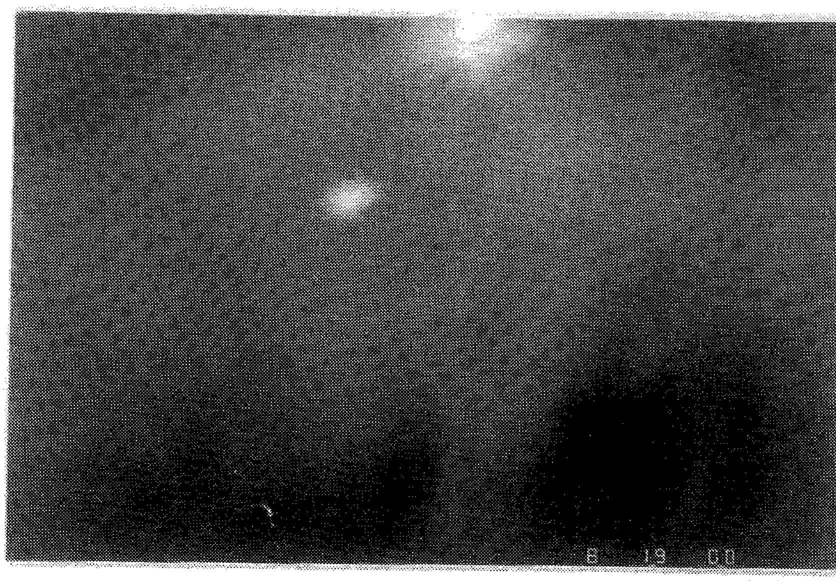


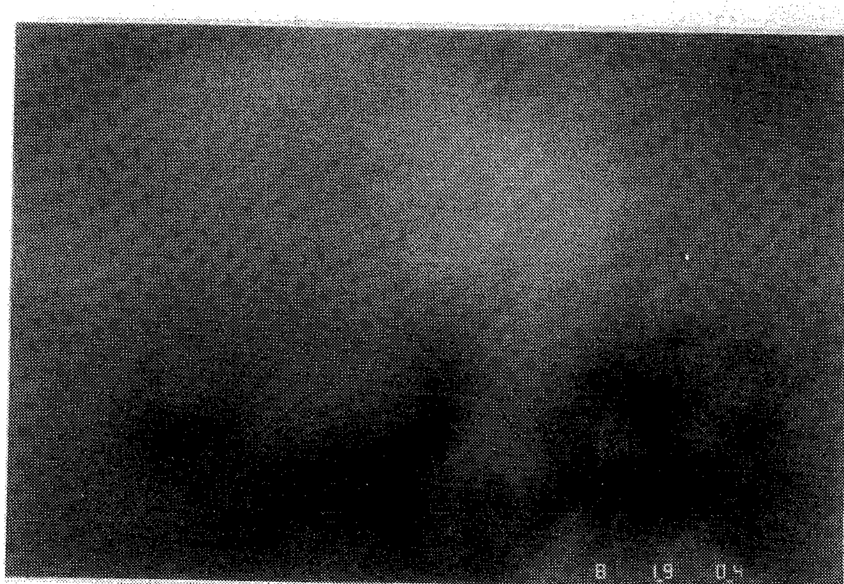
Orbital tracks for roll 121, orbits 43 and 44.

Sequence of films for roll 121.

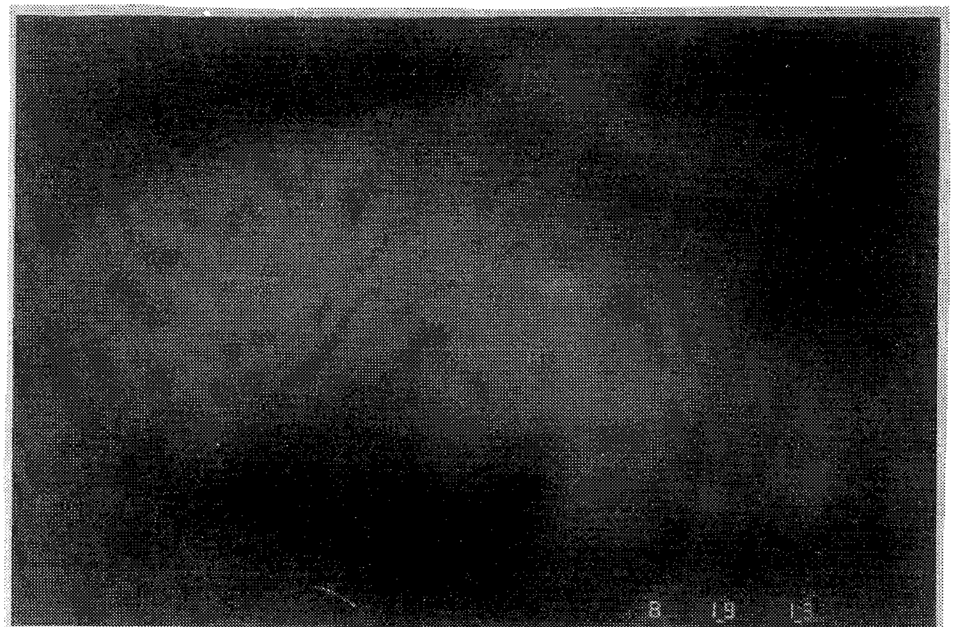


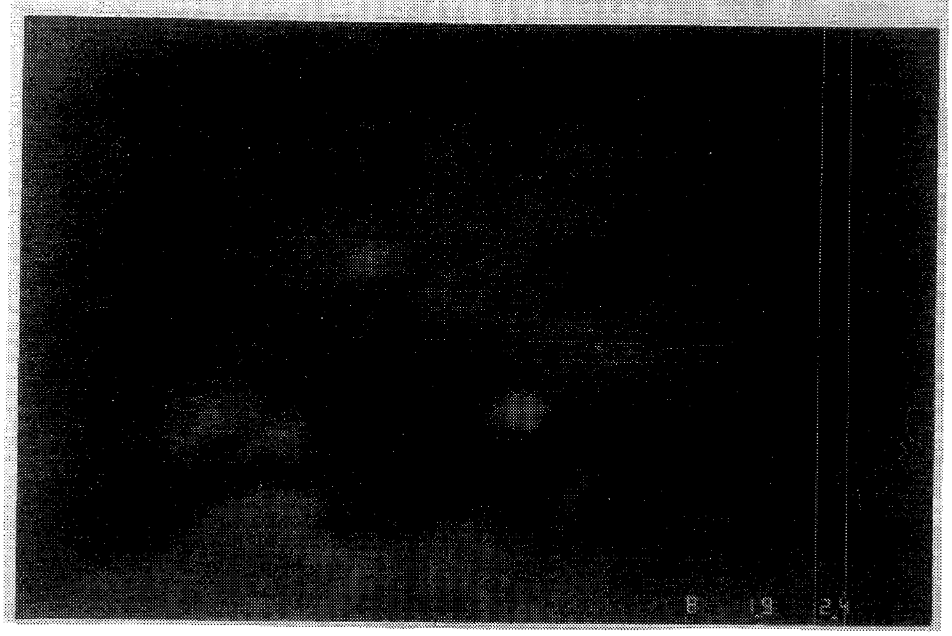



8 19 00


8 19 04

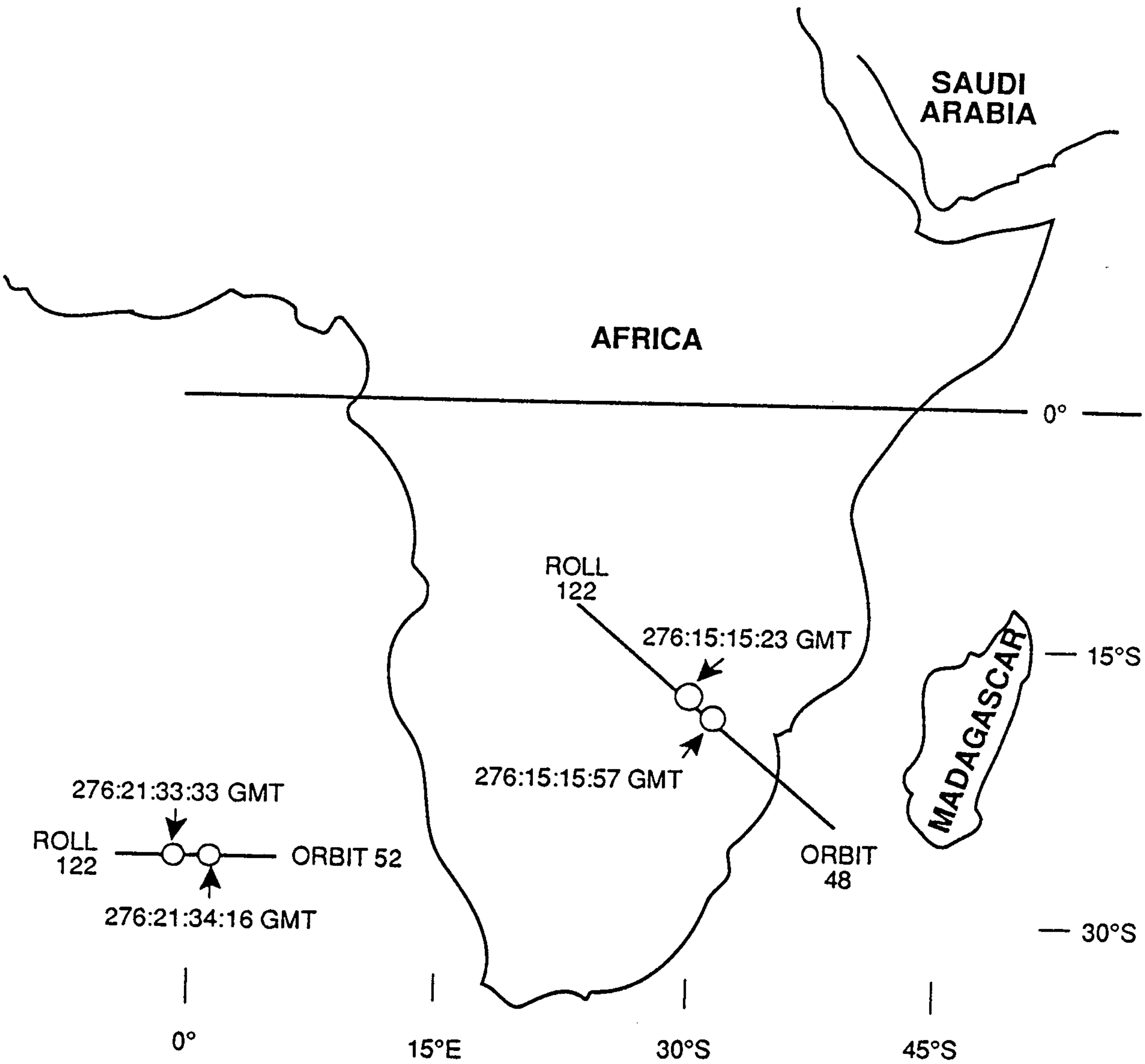

8 19 08


8 19 15


8 19 24

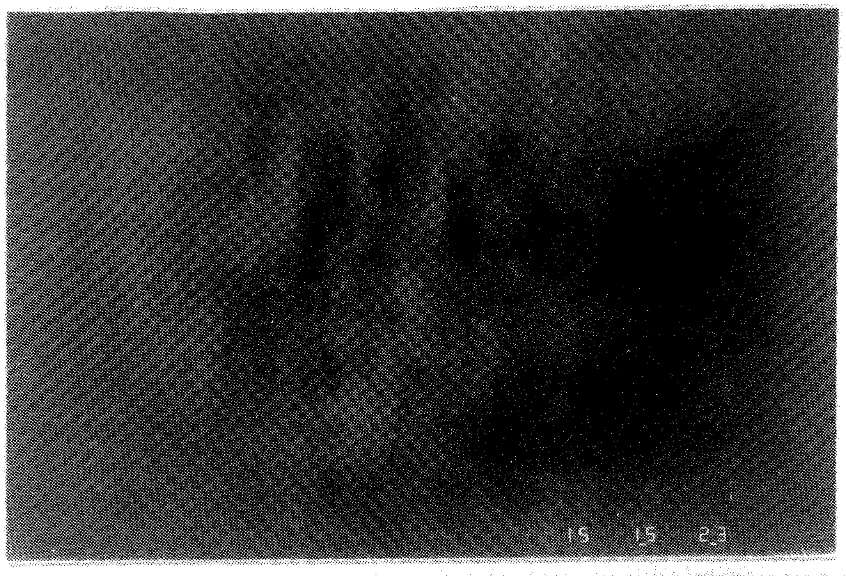
APPENDIX C

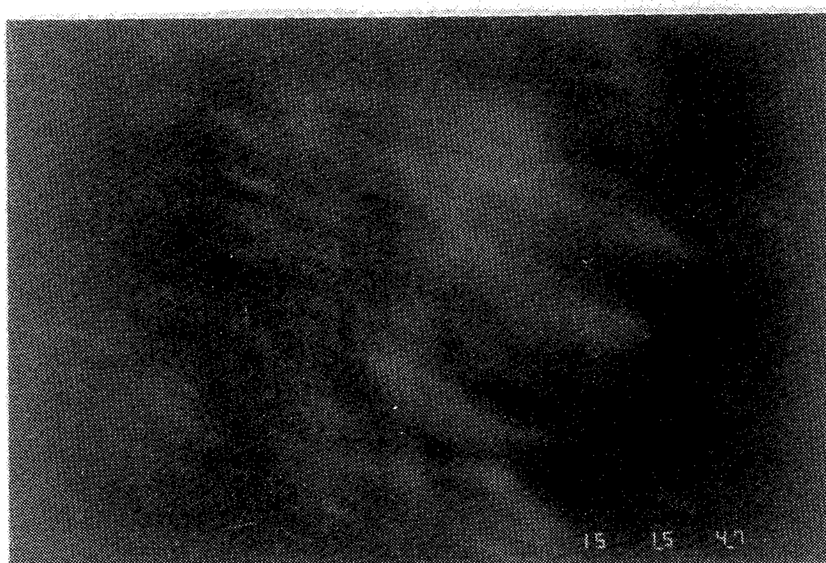
PHOTOGRAPHY OF LIGHTNING TAKEN DURING THE STS-26 MISSION
ROLL 122

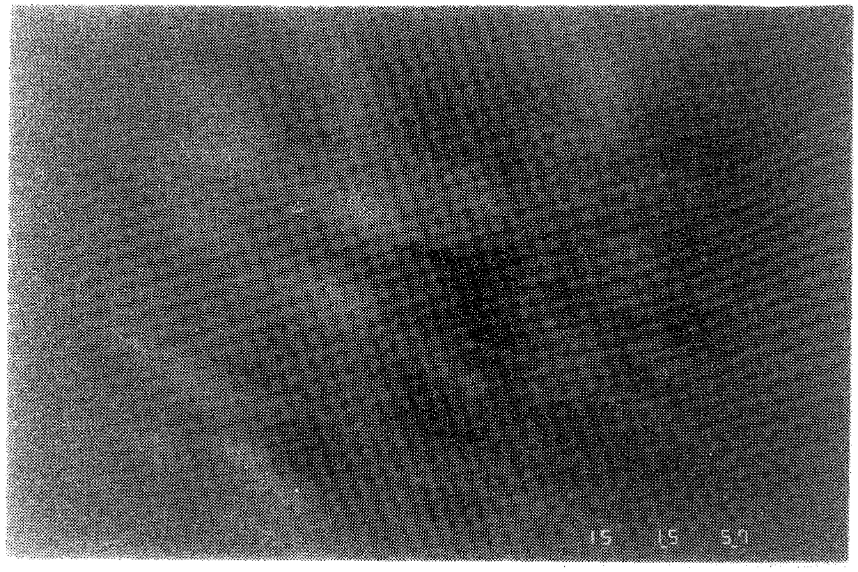


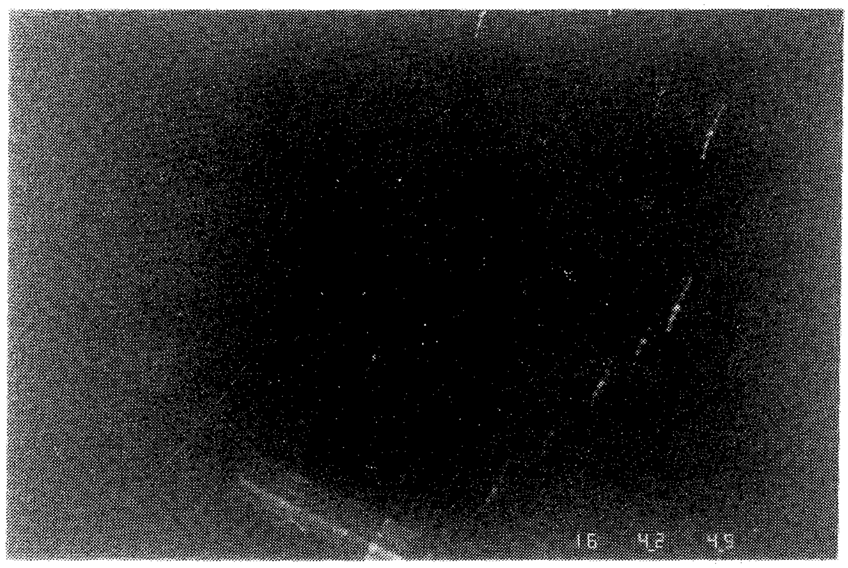
Orbital tracks for roll 122, orbits 48 and 52.

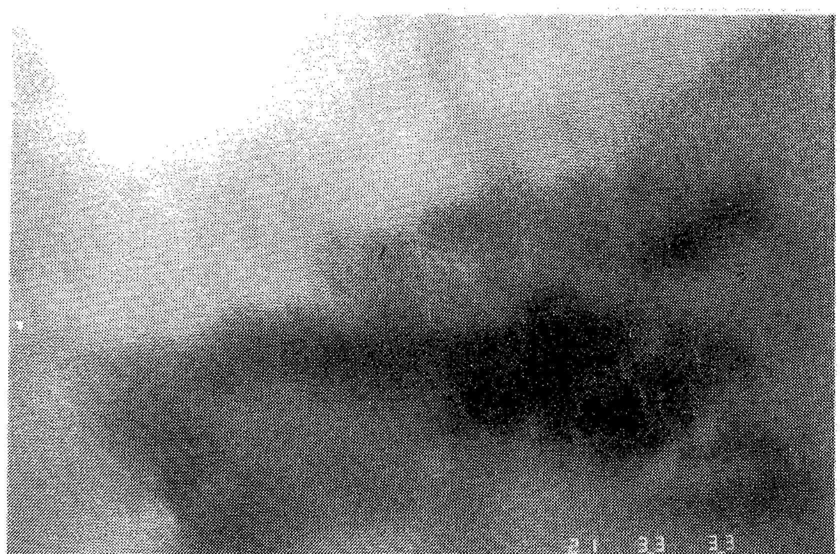
Sequence of films for roll 122, orbits 48 and 52.

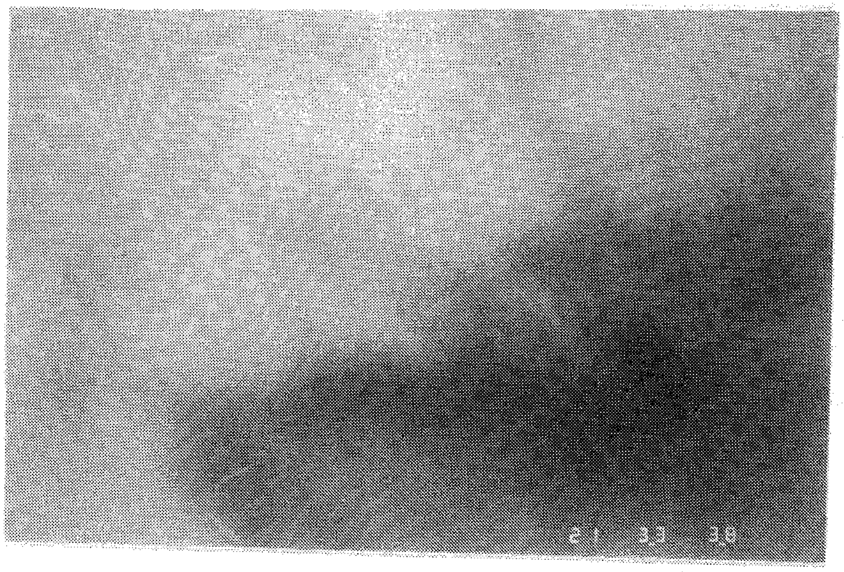


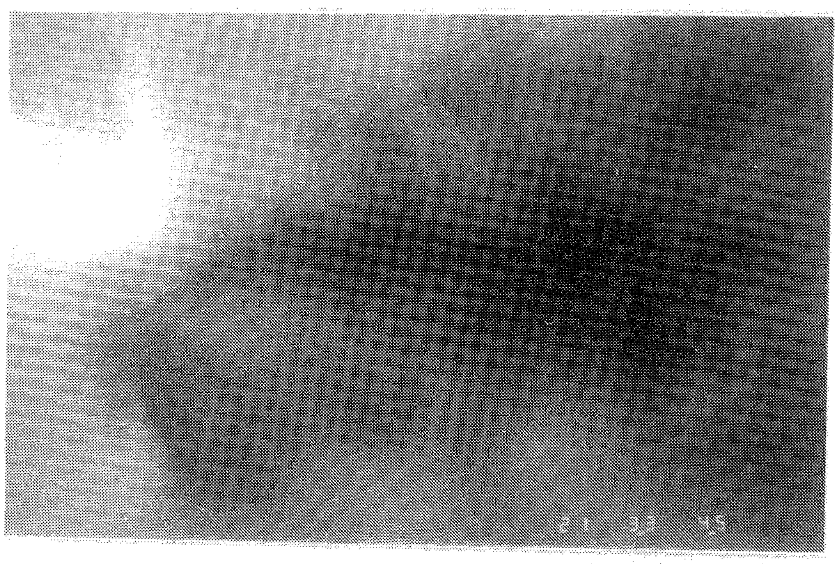


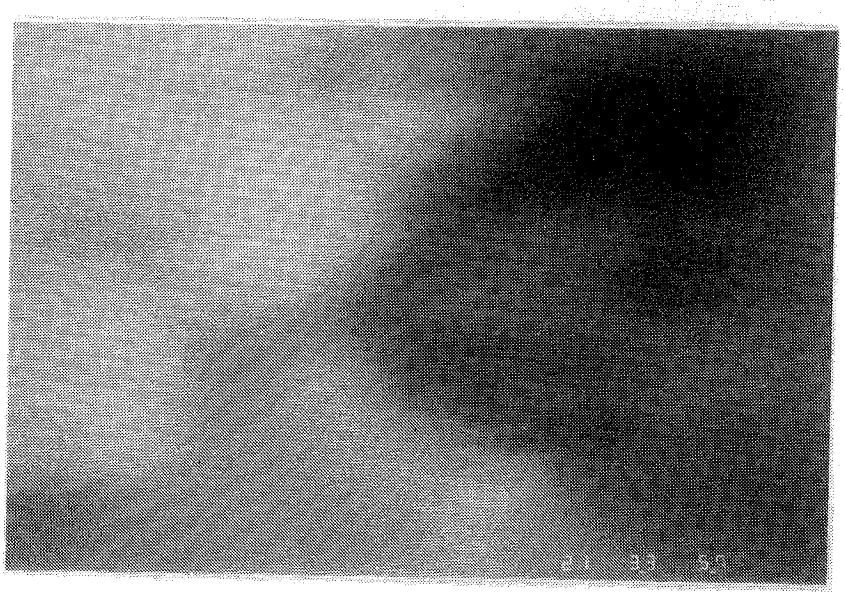

15 15 59

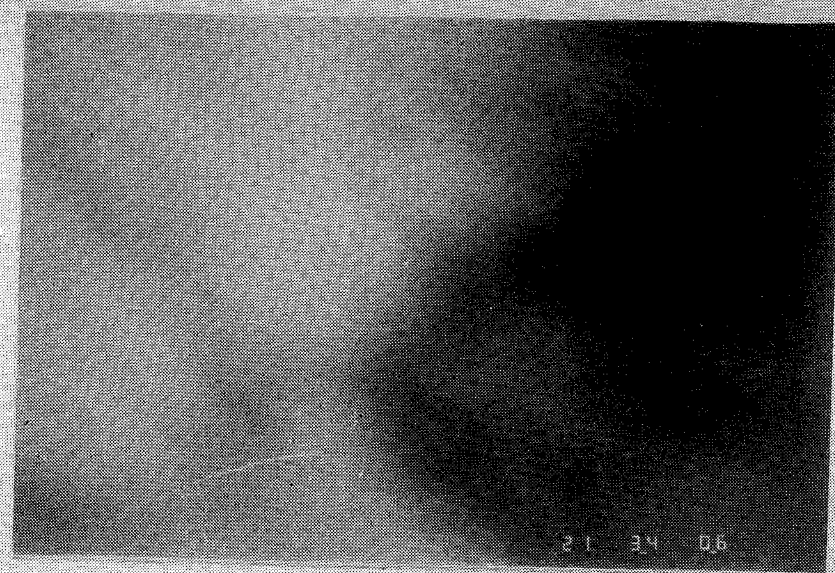

16 42 45

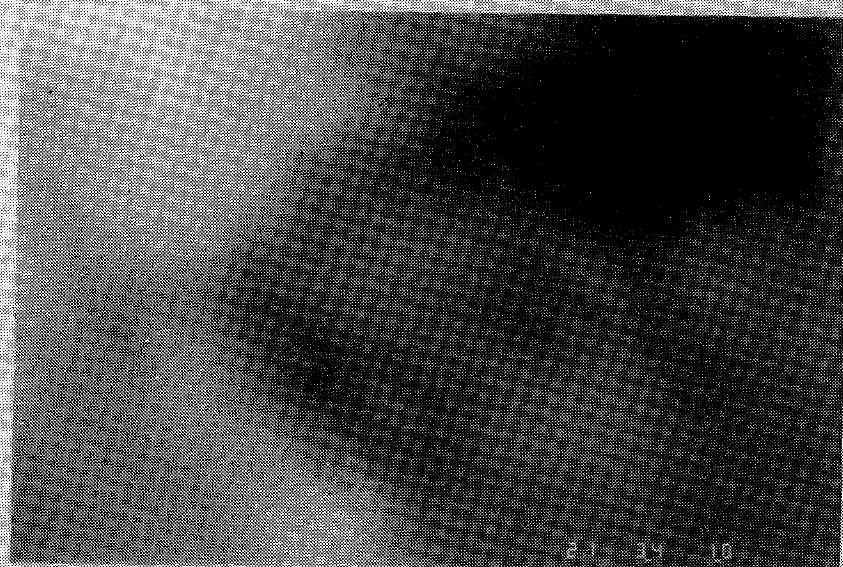

21 33 33

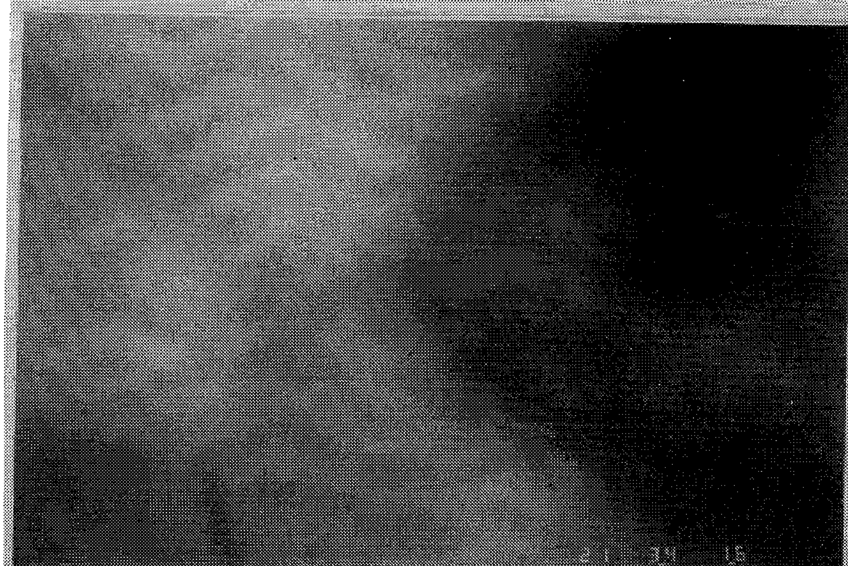


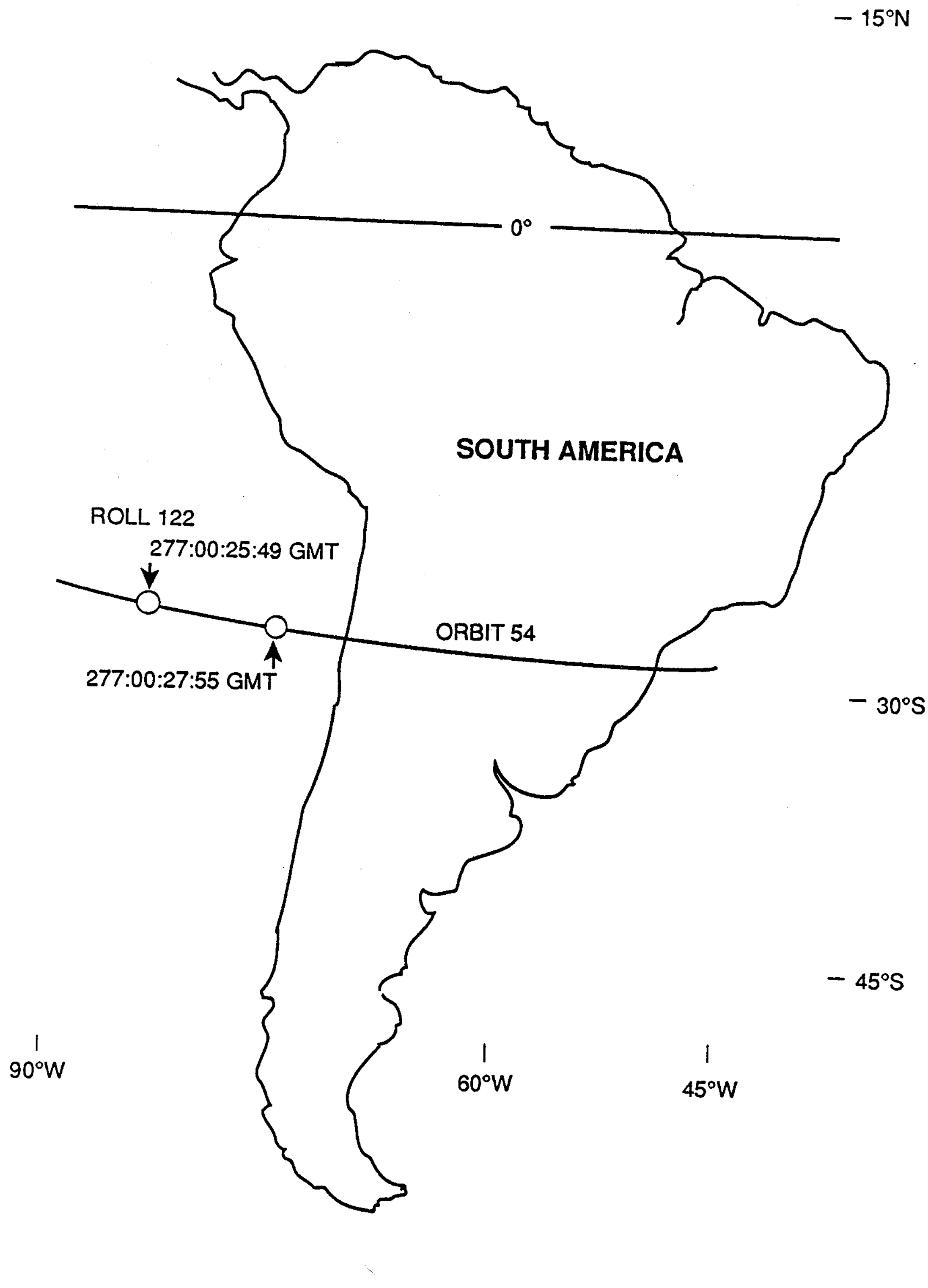





21 34 06

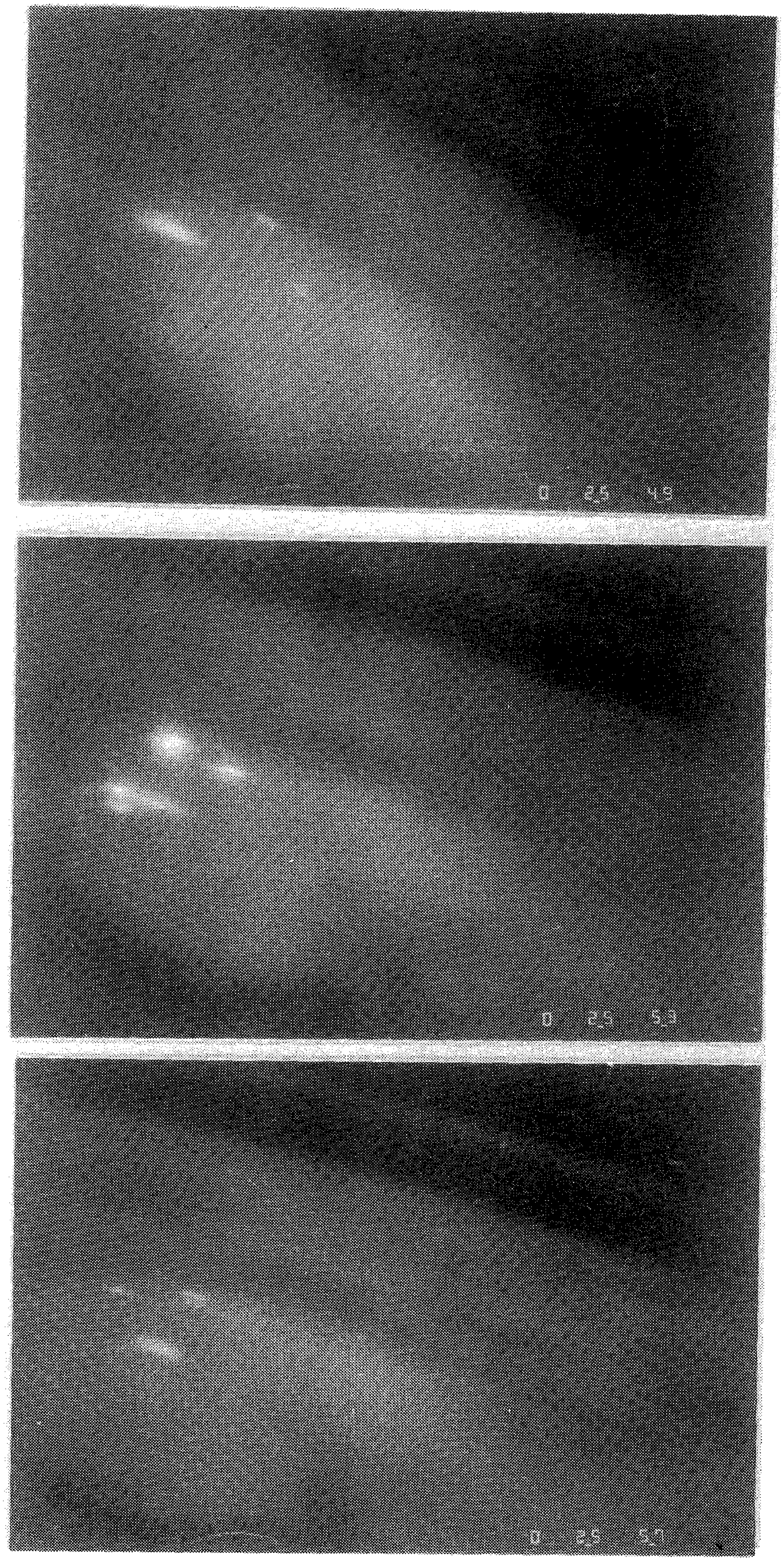

21 34 10

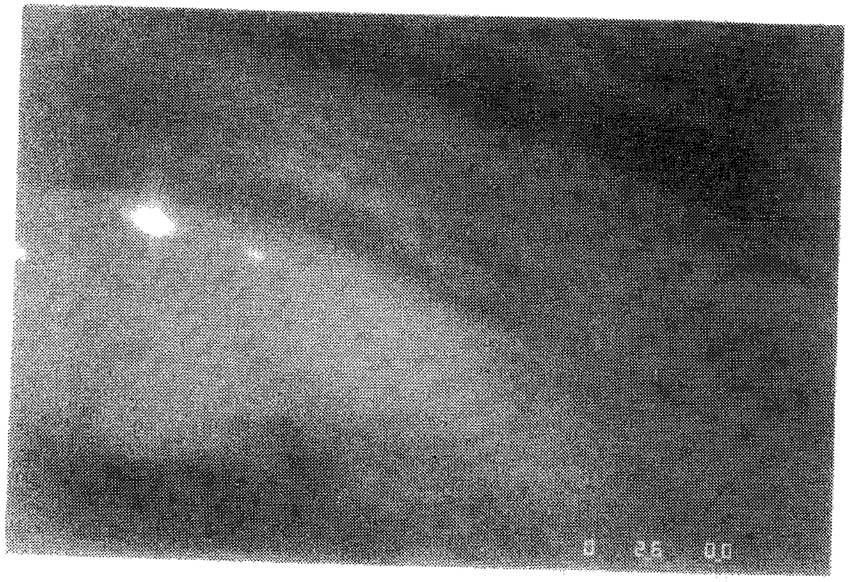

21 34 16

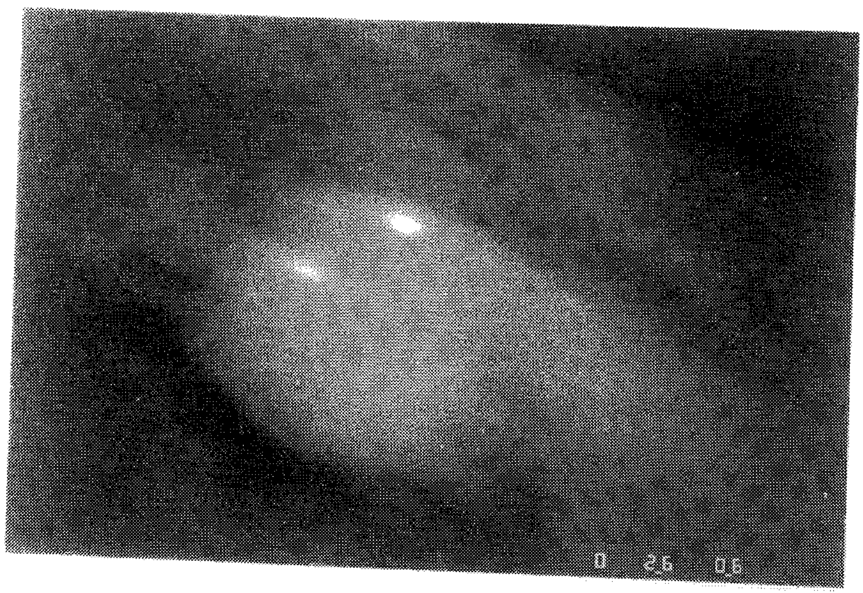


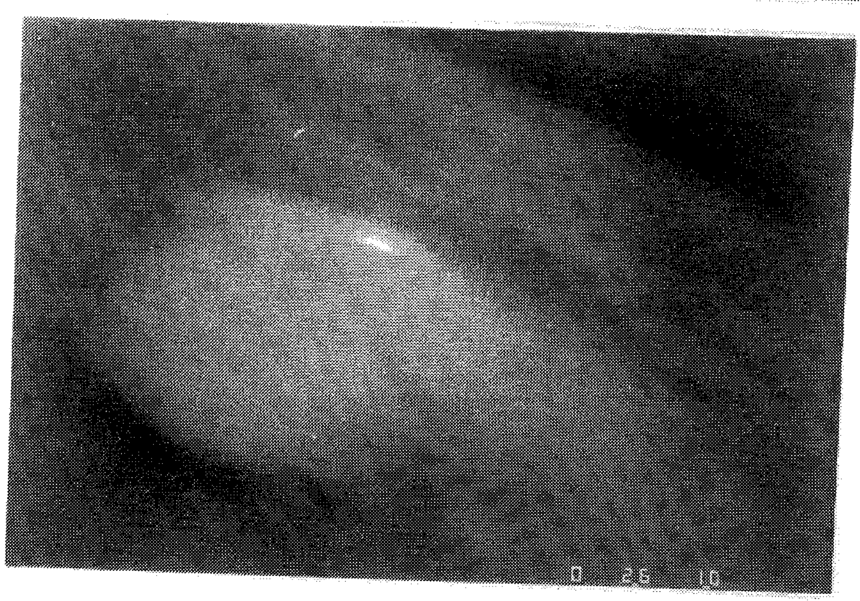
Orbital tracks for roll 122, orbit 54.

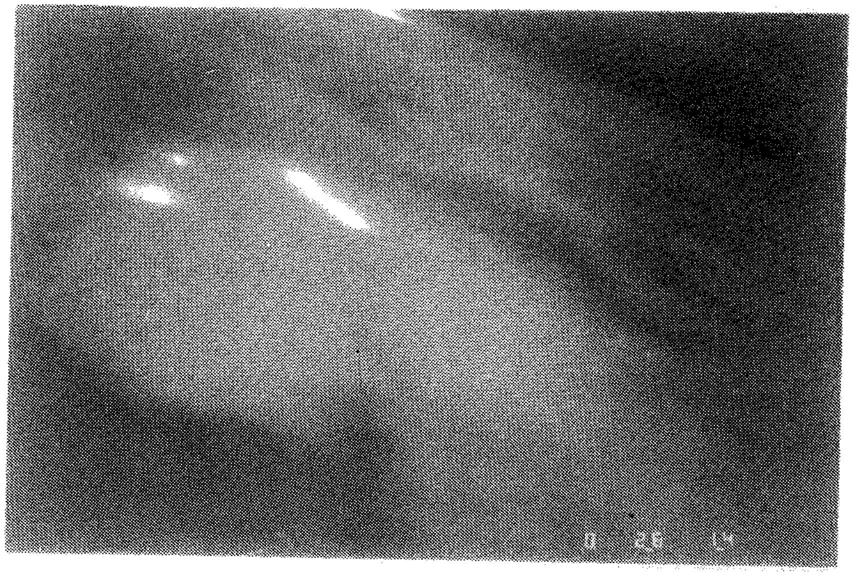
Sequence of films for roll 122, orbit 54.



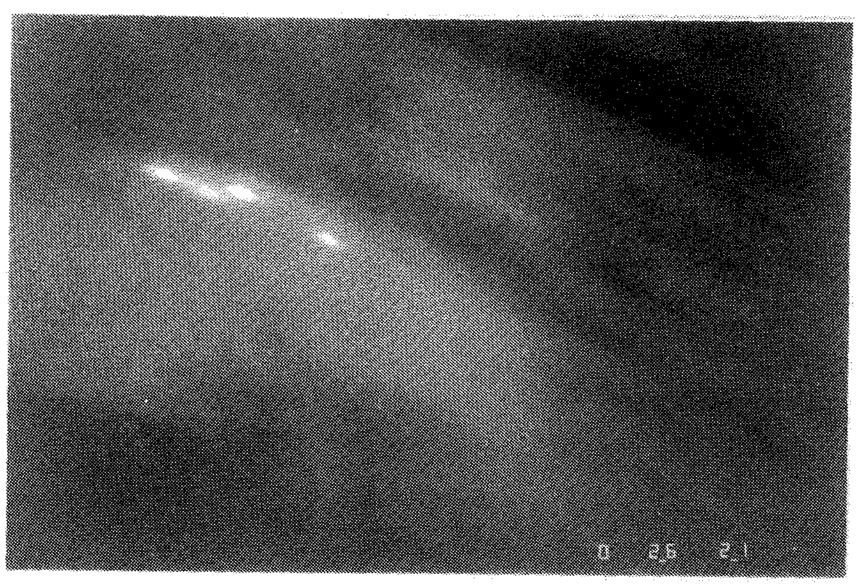

0 26 00


0 26 06


0 26 10


0 2.6 1.4

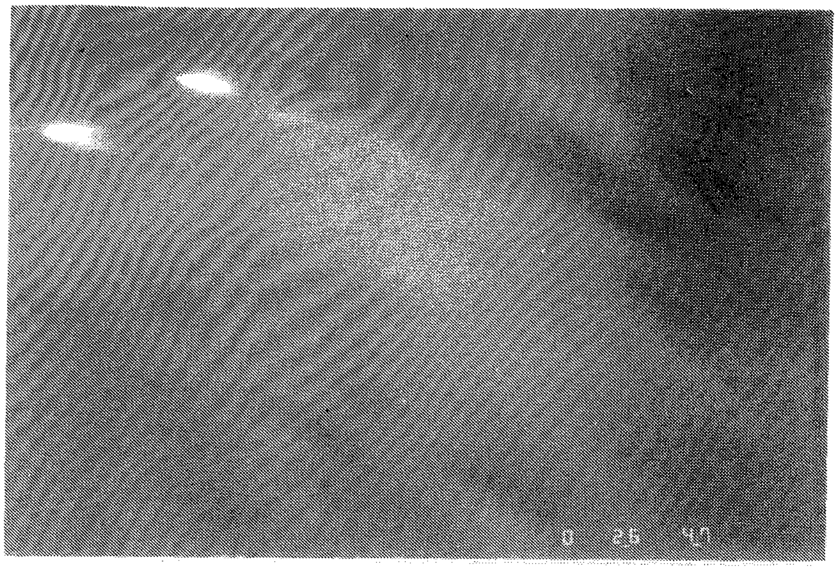

0 2.6 1.8

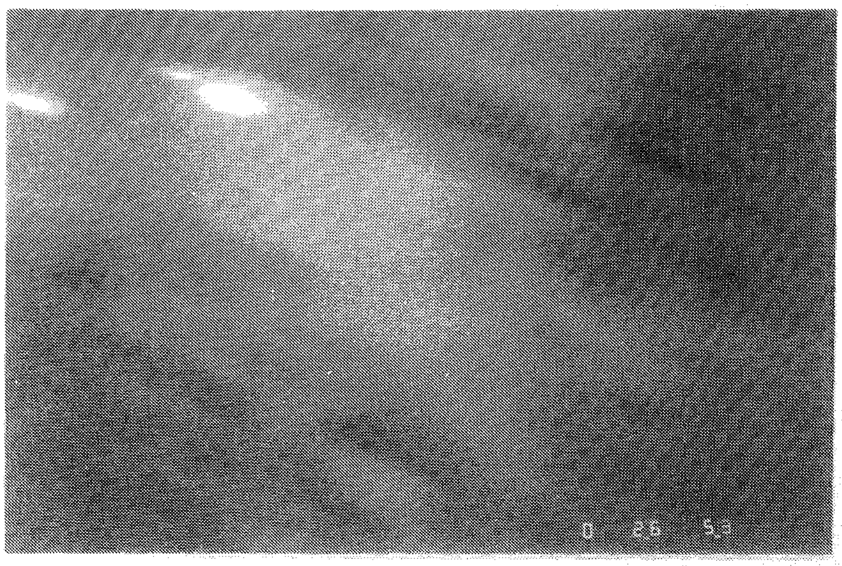

0 2.6 2.1

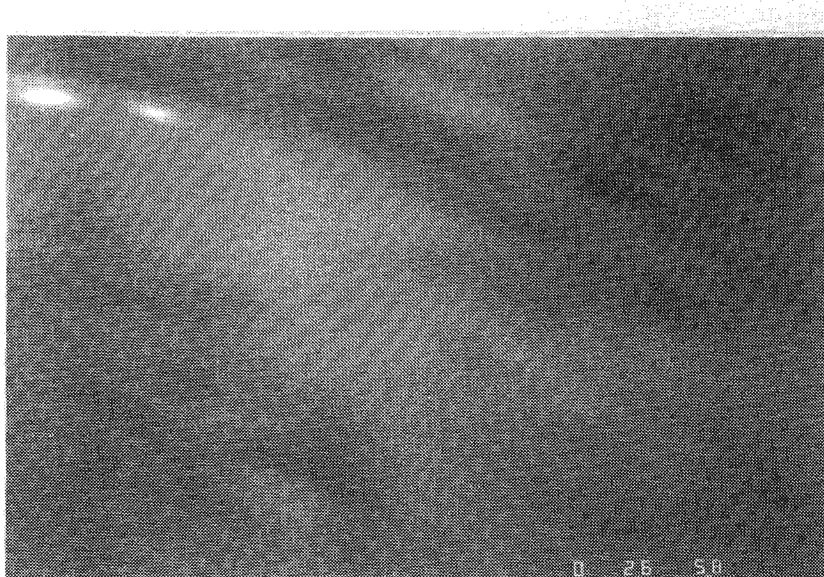

0 26 30


0 26 33


0 26

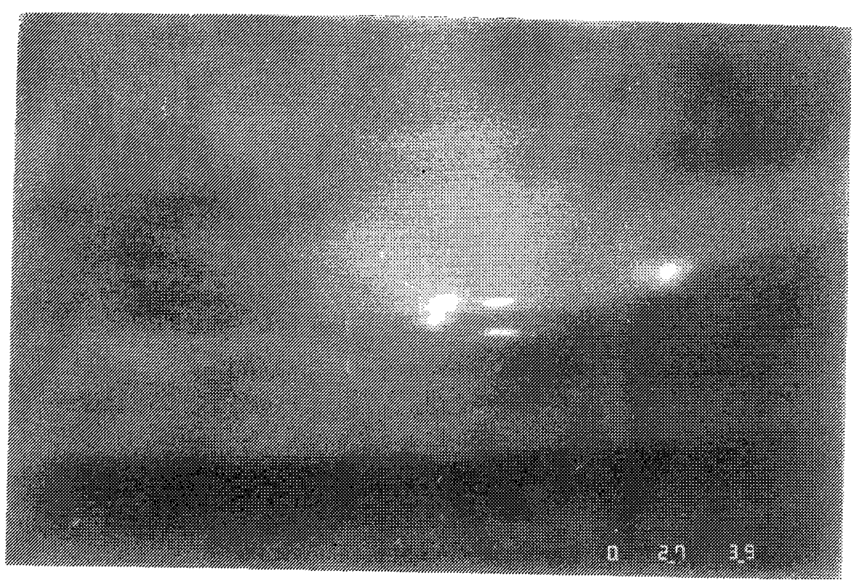


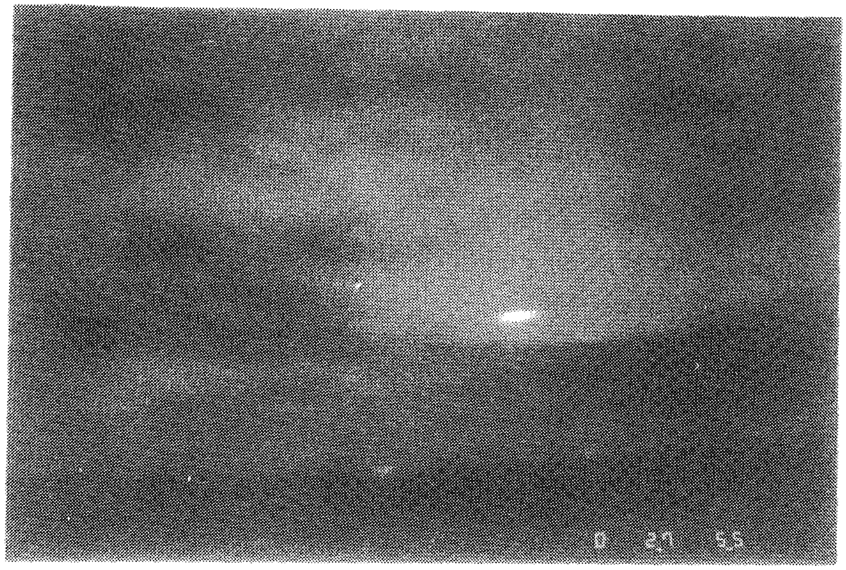





0 2.7 4.9


0 2.7 4.3


0 2.7 3.9



BLACK AND WHITE PHOTOGRAPH

APPROVAL

MESOSCALE LIGHTNING EXPERIMENT (MLE):
A VIEW OF LIGHTNING AS SEEN FROM SPACE DURING THE STS-26 MISSION

By Otha H. Vaughan, Jr.

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

E. Tandberg-Hanssen

E. TANDBERG-HANSSEN
Director
Space Science Laboratory

☆ U.S. GOVERNMENT PRINTING OFFICE 1990-531-081/20249