USE OF AIRBORNE SLAR TO VERIFY OIL PLATFORM LOCATIONS, OFFSHORE NIGERIA*

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ABSTRACT

Offshore well locations in Nigeria have been difficult to verify with multispectral satellite sensors (Landsat TM and SPOT) because of image degradation due to haze, dust, and persistent cloud cover. In 1977 an airborne SLAR radar survey was completed for the Nigerian Department of Forestry across the entire country of Nigeria. While acquiring complete land coverage, the survey recorded between 30 to 50 km of offshore data along the western margin of the Niger Delta. These offshore radar images were valuable for verifying the locations of platforms constructed before 1978 because they were relatively unaffected by poor atmospheric conditions. To integrate the 1977 radar flight strips into Chevron's computer mapping system, the strips were scanned, registered to GPS control points and geocoded satellite images, then rectified to the local map projection. We determined that within an oil field, radar signatures of individual structures were within ± 50 m of their true location. This work demonstrates that older oil fields can have their surface coordinates accurately and economically updated by digitally integrating radar prints into an image processing/computer mapping environment.

1.0 INTRODUCTION

For several years Chevron Overseas Petroleum Inc., Chevron Nigeria Limited, and the Nigerian National Petroleum Corporation have used Landsat TM and SPOT Panchromatic satellite images, with Global Positioning System (GPS) ground control, to verify the location of wells, facilities, and geographic features across the Niger Delta (Figure 1). This effort has been successful for much of the onshore delta despite Harmattan conditions (airborne dust from the Sahara Desert) and persistent cloud cover, both of which degrade multispectral images (Ellis and others, 1989). However, offshore oil platforms are not detected on Landsat TM images (Figure 2) and atmospheric conditions are often so poor that SPOT images (Figure 3) also cannot resolve many offshore structures.

The only visible indicators of offshore structures on TM images are bright signatures of gas flares. These flares oversaturate the sensor, resulting in bright streaks on the images of TM bands 5 and 7. These streaks extend parallel to the scanning direction of the sensor and begin at the flare, providing a very accurate location for the flare (Figure 2). When atmospheric conditions are favorable, panchromatic SPOT (10 m resolution) images provide excellent contrast between offshore, man-made structures and the background ocean (Goodwin and others, 1991).

Discrepancies between Exploration, Production and Facility maps were discovered during a detailed mapping program of an established offshore field (Figure 1). The inconsistencies and

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errors were due to locations in the company's well database historically being derived from multiple and incorrect sources. Multispectral satellite images over the oil field did not provide a solution. A 1977, 1:1,000,000 scale SLAR mosaic of Nigeria was evaluated to provide an image of pre-1978 structures within the oil field, but the offshore area on the mosaic was black and lacked any information. The SLAR contractor reported that the flight strips were mosaiced together and all of the offshore area was masked (R. H. Gelnett, 1991, pers. comm.). The mosaic was masked because the numerous corner reflectors from man-made structures and ships offshore degraded the appearance of the mosaic, which was flown for onshore information. Fortunately, the contractor had all of the flight strips on file and these displayed all of the original offshore information. These SLAR paper prints were an appropriate data source for this application because many of the offshore oil platforms in our field of interest were installed prior to 1977.

This SLAR survey was completed in 1977 for the Nigerian Department of Forestry utilizing a Motorola (APS-94) real aperture, side-looking airborne radar (SLAR) system (see Trevett, 1986). The objective of the radar survey was to acquire onshore images, utilizing E-W flight lines, which paralleled the four vegetation zones across Nigeria. The radar system acquired imagery simultaneously from both sides of the airplane, looking north and south during the survey. While acquiring complete land coverage with the north-looking antenna, the south-looking antenna recorded between 30 to 50 km of offshore imagery west of the Niger Delta coastline (Figure 4).

In order for the SLAR flight strips to be useful for this offshore mapping project, we had to demonstrate that each strip displayed some degree of internal geometric accuracy. This would enable radar signatures of offshore structures (platform risers attached to well heads, production platforms and other structures) seen on the flight strips to be plotted with some degree of confidence into Northing/Easting and Latitude/Longitude coordinate systems.

2.0 DATA PREPARATION

Figure 5 depicts a portion of a SLAR flight strip which was originally plotted onto a 1:250,000 flight strip. Each strip recorded 25 km of data across-track and about 200 km of data along-track (film strip dimensions are about 10 cm wide by 80 cm long). The flight strips were converted from analog to digital data by a scanner connected to Chevron's computer-aided drafting (CAD) system. The flight strips were scanned at a resolution of 400 dpi (dots per inch), resulting in a digital image with approximately 10 meter pixels. This scanned resolution exceeded the nominal 30 m resolution of the original data. Figure 6 shows an example of a scanned flight strip where offshore well platforms, ships, and a jetty are clearly seen.

The digitized flight strips were enhanced using a linear contrast stretch and a 3 x 3 Lapacian edge filter to increase the contrast between the bright elliptical radar signature of the platforms and the dark ocean background. The large elliptical signature of the offshore platforms ranged from 60-180m across-track and 200-400m along-track. The signatures were large because of radar flare (bloom) from the highly reflective metallic structures.

Platforms were assumed to be located in the center of the large elliptical signatures. These elliptical signatures did not increase in size across a flight strip from near range to far range, even though the SLAR beamwidth diverged progressively with distance from the antenna.

3.0 DATA INTEGRATION

The radar images were displayed as raster images and rectified to Nigeria's standard map projection using photo-identifiable GPS fixes and where appropriate, georeferenced TM and SPOT images. The GPS fixes were keyed into the CAD mapping system with the GPS fix represented by a dot centered between crosshairs and a triangle (Figure 7). The registration process consisted of carefully selecting the GPS control point on the CAD map and then selecting the corresponding point on the radar image. The centers of the elliptical radar signatures were used for the assumed location of offshore platforms.

Once the registration was complete, the image was rectified using a first-order polynomial transformation which simply rotates and rescales the image into the correct map projection without internally distorting the image. Root mean square (RMS) error was not more than ± 5 lines and pixels.

4.0 INFORMATION EXTRACTED

Using the center of the bright elliptical signature, Easting/Northing coordinates were extracted from the rectified radar image for each visible platform. The radar-detected structures were compared to other independent data sources such as geo-referenced SPOT and Landsat TM, to determine if these satellite sensors could provide a more accurate solution. In areas where the atmospheric conditions were satisfactory, the panchromatic SPOT images were found to be superior to the radar for locating platforms.

For 24 platforms that were visible on the radar images, Chevron had GPS or shore-based Syledis locational information. These two independent surveys allowed us to verify the accuracy of the radar-determined locations. The differences between the derived radar location and the GPS/Syledis location ranged from a minimum of 5 m to a maximum of 34 m, with an average difference of 19 meters. In the areas with good SPOT images, the difference between the derived SPOT location and the GPS/Syledis location ranged between a minimum of 1 m and a maximum of 7 m, with an average of 4 m. Because there were many of unknowns associated with the internal geometry of the radar flight strips, our work has the disclaimer that the geodetic accuracy of the radar locations is probably ± 50 meters.

After the most accurate location was chosen for each platform (derived from either SLAR, SPOT, or reliable field surveys), the new coordinates were entered into the company's well database. New and more accurate maps were then plotted that eliminated previous inconsistencies and errors.

The globally widespread use of SLAR during the 1960's through 1980's suggests radar images in many areas could be used for verifying the locations of older wells. Mosaics of radar surveys traditionally have offshore areas masked, precluding detection of wells within offshore oil fields. Finding the original flight strips that were used for a proprietary or published mosaic could be difficult for surveys flown 2 - 3 decades ago.

5.0 SUMMARY

This work demonstrates that locations of older, offshore oil fields and facilities can be accurately and economically updated by digitally upgrading radar flight strips from the 1960's through 1980's with image processing/CAD mapping technology. Critical ground control for rectifying the radar flight strips to the local map projection must be obtained. In this project, GPS and multispectral satellite images provided the essential control.

6.0 ACKNOWLEDGEMENTS

We thank Chevron Overseas Petroleum Inc. (COPI), Chevron Nigeria Limited, and the Nigerian National Petroleum Corporation for granting permission to publish this paper. The Nigerian Department of Forestry demonstrated exceptional foresight by initiating this survey in the mid 1970's. Mars Associates Inc. (R.H. Gelnett and D. Anderson) explained SLAR technology and assisted in interpreting the signatures on the SLAR images. Independent verification of platform locations on SLAR was done by Roger Prince of COPI's Nigeria business unit.

Integration of CAD vector maps with radar and SPOT images, and image processing, was accomplished on an Intergraph workstation and scanner. Peter Goodwin, Mike Quinn, Hattie Davis, Bach Dao, Floyd Sabins and Bill Kowalik of Chevron provided timely technical assistance.

7.0 REFERENCES

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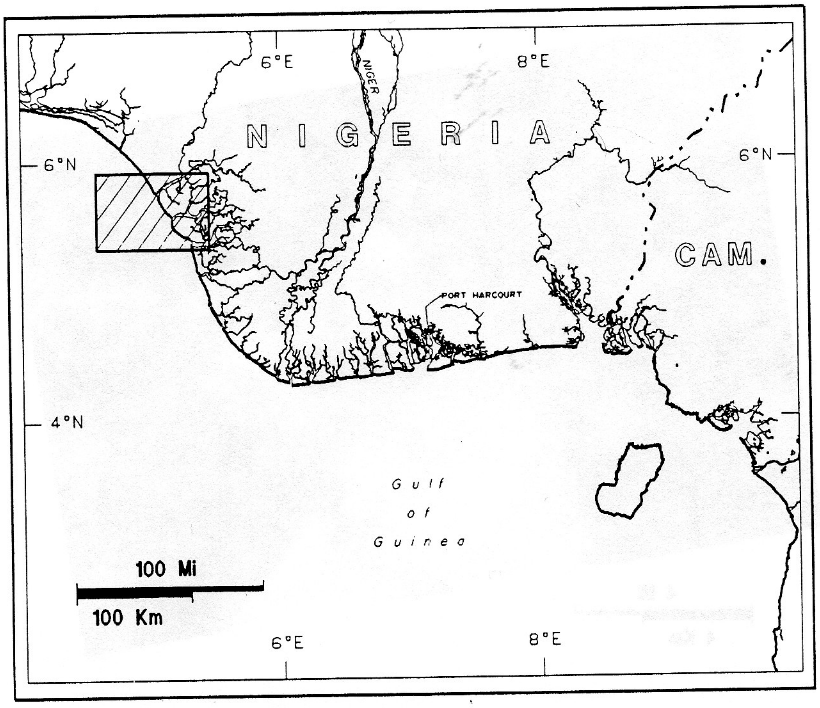

Figure 1. Location map of the Niger Delta. Area of interest shaded.

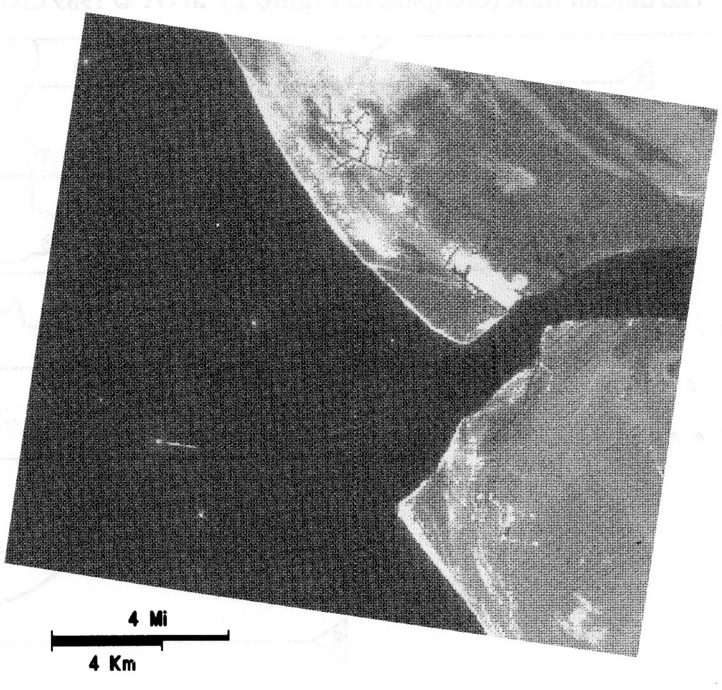

Figure 2. Black & white rendition of color composite (4,5,7) Landsat TM image of shaded area on Figure 1. Image acquired December 1984.

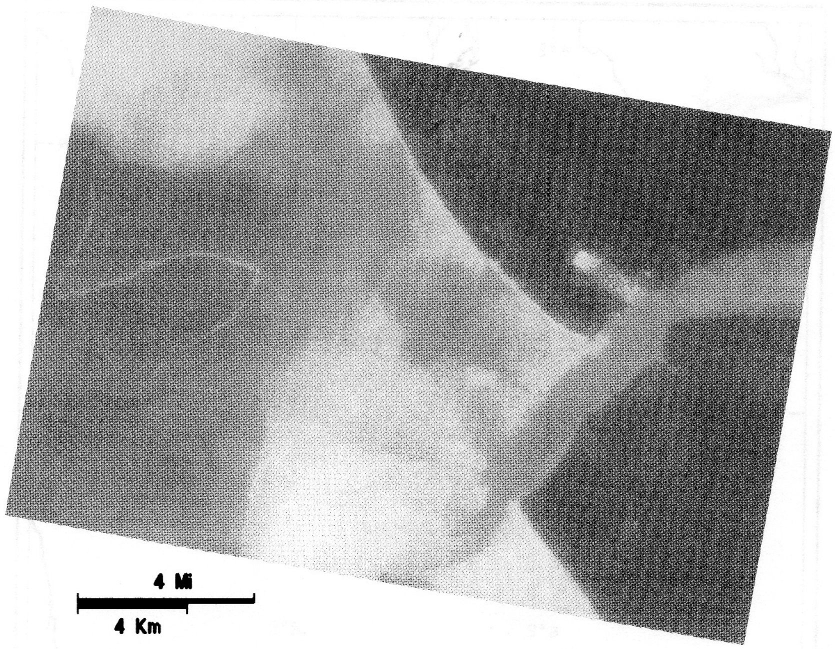

Figure 3. SPOT Panchromatic image acquired February 1989 showing degrading effect of Harmattan dust (compare to Figure 2) SPOT © 1989 CNES

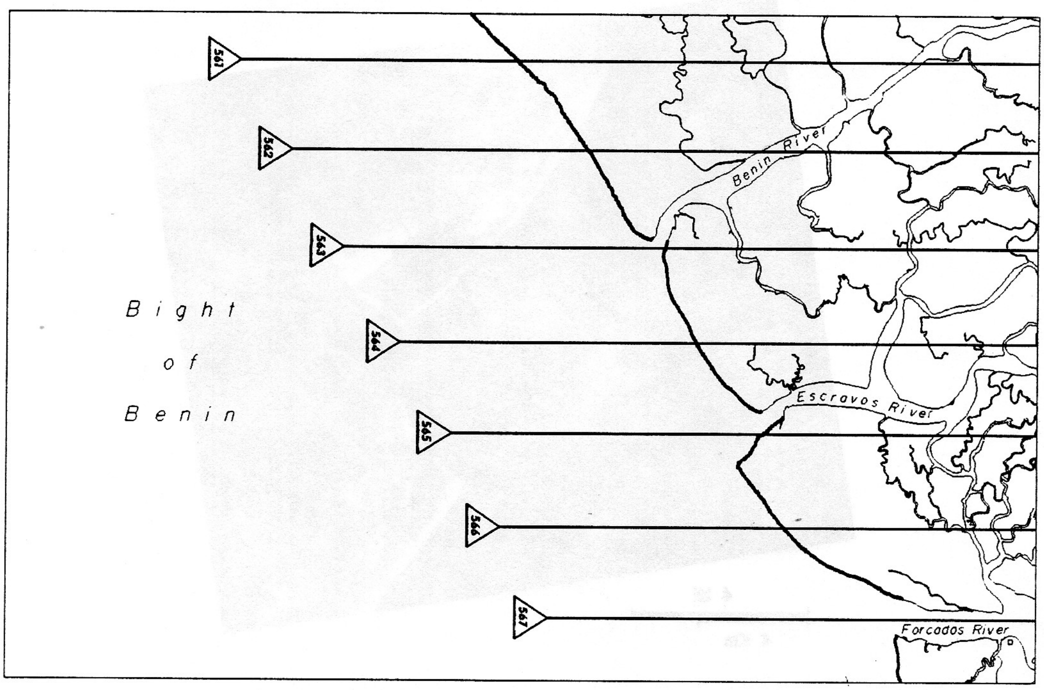

Figure 4. Map showing 1977 SLAR flight lines (courtesy of Mars Associates, Inc.; see Figure 1 for location).

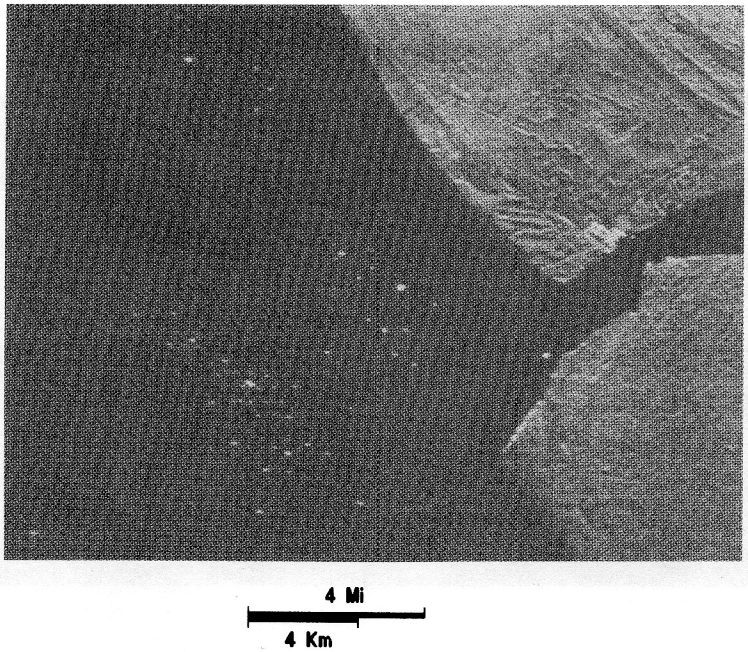

Figure 5. Portion of 1977 radar flight strip No. 565 on Figure 4.

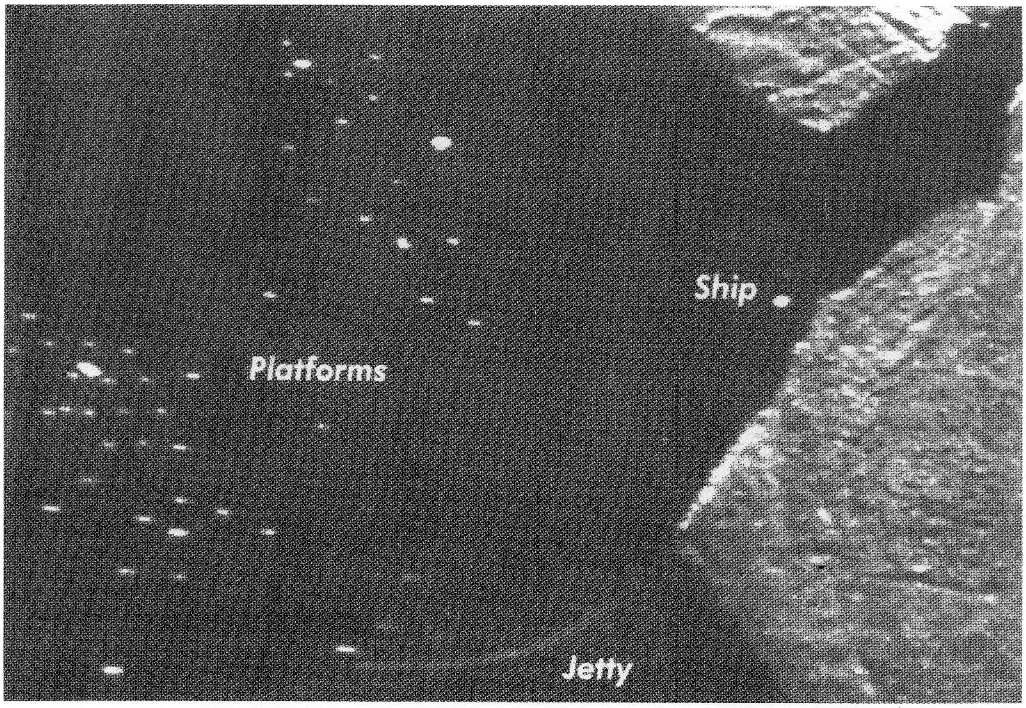

Figure 6. Enlargement of 1977 radar flight strip showing offshore man-made structures as elliptical bright spots. Also jetty and onshore vegetation patterns are evident.

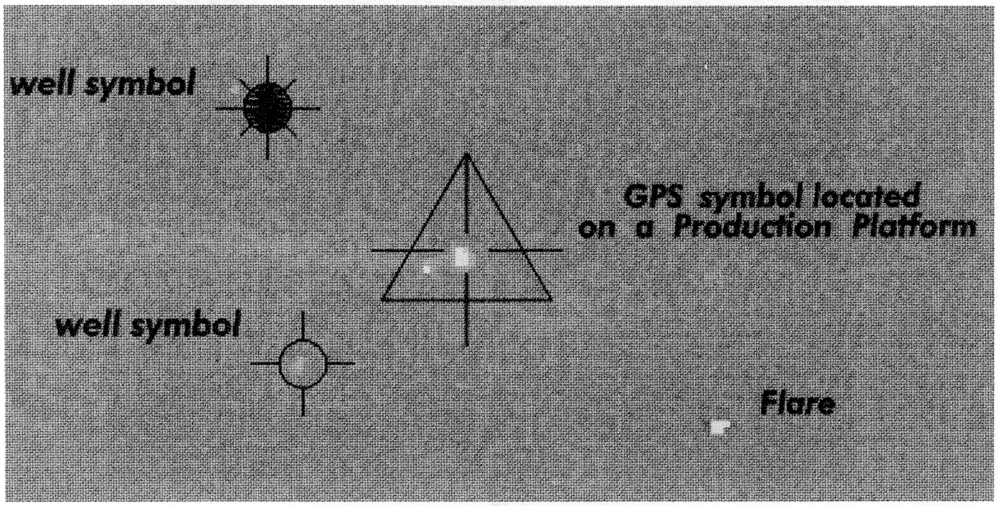

Figure 7. GPS symbol as noted on CAD mapping system

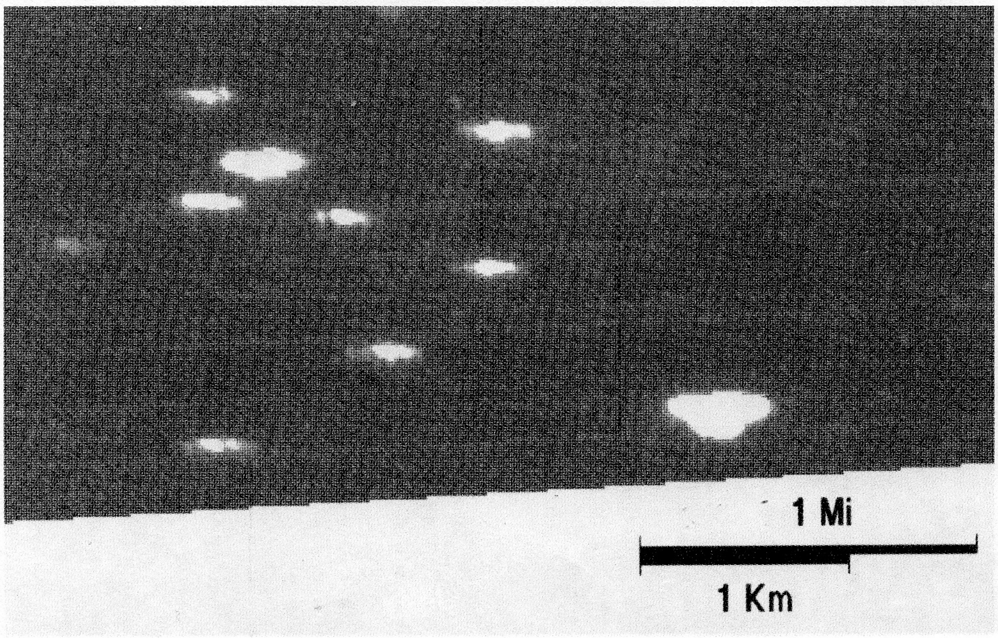

Figure 8. Close-up of elliptical Radar signatures associated with offshore oil structures