EVALUATION AND UPDATING OF OFFSHORE BASE MAPS USING SPOT SATELLITE IMAGES AND GPS CONTROL, WEST AFRICA *

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ABSTRACT

Platform location discrepancies between Exploration, Production, and Facilities maps were discovered during planning for an offshore 3-D seismic program in West Africa. SPOT panchromatic (B&W, 10 m resolution) imagery was used for verifying the location of offshore structures and obstructions. The imagery was digitally rectified to the region's standard map projection using Global Positioning Satellite (GPS) fixes. Locational discrepancies between base maps and registered images were identified and the company's computer-aided drafting (CAD) data base was accurately corrected. The work demonstrates that when SPOT panchromatic imagery is digitally processed and rectified with GPS control, a cost-effective, rapid, and accurate base is generated for updating maps of offshore petroleum fields.

1.0 INTRODUCTION

Platform location discrepancies between Exploration, Production, and Facilities maps were discovered during planning for an offshore 3-D seismic program in West Africa. SPOT panchromatic (B&W, 10m resolution) imagery was evaluated to determine if offshore structures and obstructions could be detected. In particular, petroleum-related structures such as collection platforms, riser platforms attached to wellheads, moored storage tankers, and flares needed to be accurately positioned on company maps so that a planned 3-D survey could proceed safely and efficiently. Of equal interest, however, was the identification of unmapped or incorrectly mapped obstructions.

2.0 DATA PREPARATION

Previous work in West Africa showed that Landsat TM images (28.5 m pixels) could not resolve small-scale offshore structures (Ellis, Caldwell and Goodwin, 1989). We found that the quality of visible-light imagery (TM bands 1,2,3 and SPOT B&W Panchromatic) in West Africa can vary significantly because of clouds, haze, and atmospheric dust (associated with Harmattan conditions - dry hot winds blowing south from the Sahara). Unfavorable atmospheric conditions degrade the spectral contrast between obstructions and the background ocean.

The SPOT imagery was processed to maximize the typical 1 to 9 pixel signature of the obstructions. These techniques included:

1) contrast stretching,
2) high-pass filtering,
3) density slicing and
4) single-band image classification.

Figure 1 depicts a full (60 x 60 km), unprocessed SPOT scene. Extensive onshore clouds can be seen on this image, however the areas of interest offshore are relatively clear. A typical offshore subscene from this full scene is displayed as an unprocessed image (Figure 2). Piecewise-contrast stretching and edge filtering were then used to enhance the brightness and contrast of the obstructions (Figure 3). The range of reflectances associated with platforms, risers, ships, and the surrounding water were recorded before and after processing. In addition, the shapes of the structures were analyzed to ensure that the images were not overprocessed.

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3.0 INTEGRATION OF DIGITAL INFORMATION

Over 110 petroleum-related structures were detected on a single SPOT image (Figure 1) that encompassed 5 offshore production fields. Figures 4, 5 and 6 compare aerial photographs with an enhanced SPOT image of several offshore features (moored tanker, collection platform with helipad, and risers). SPOT imagery allowed differentiation of the superstructure from the main deck on tankers and record individual platforms that were connected with walkways and nested piping.

Individual SPOT images were digitally rectified to a country's standard map projection using at least 6 Global Positioning Satellite (GPS) fixes. These fixes were initially loaded into our computer-aided drafting (CAD) system and digitally transferred as a raster map file to our image processing system. Registration of offshore structures (as seen on the SPOT image) with the correct GPS fixes was done within the image processing system (Figures 7 through 12).

The imagery was enhanced to accentuate the offshore structures (Figure 7). We found that inverting the gray scale was useful for some presentations (black obstructions on a white background) because it could be easily compared with a base map. A catalog of GPS points was reviewed to determine on which structures within the image individual fixes were located. GPS control points are graphically depicted on a surveyor's plat (Figure 8). This location map enables the image processing operator to zoom in on the appropriate structure as it is depicted on the SPOT image and assign the fix's location to the closest 10-meter pixel.

The GPS fix was digitally transferred in the rasterized CAD file as a dot centered between crosshairs and a triangle (Figure 9). The pixel that contained the fix's location on the SPOT image was registered to the dot in the center of the CAD symbol (Figure 10). After at least 6 control points were registered between the image and CAD map (usually a few from onshore and the rest from large, offshore collection platforms), the image was "warped" to the GPS control, which placed the image into the company's CAD base map projection.

For this project a first-order polynomial transformation was appropriate. This transformation simply rotated and translated an image into CAD map space without internally distorting the image. Root mean square (RMS) error between the image and GPS was usually less than +/- 2 lines and pixels. This is very encouraging as only 3 or 4 of the offshore structures in Figure 1 had GPS control associated with them (meaning over 100 of the structures were rectified to the CAD base map without any control except for a line/pixel spatial relationship with the 6 GPS points). "Excessive" RMS errors usually occurred because the operator could not pick out the exact location of a GPS fix on the imagery. Harmattan dust and haze accentuates this problem with visible-light images of offshore West Africa.

4.0 RESULTS

Locational agreement between features seen on GPS-controlled (rectified) SPOT images and original company maps was found to generally range from 0 to 80 meters (Figure 13). However, several errors were documented that ranged from 100 to 250 meters. Within half of one producing field and all of another, significant errors (later determined to be datum-shift discrepancies) were found on the original CAD map.

Based on this study, only wells, collection platforms, and permanently moored tankers that were visible on SPOT imagery could have their locations changed within the company's CAD data base. The SPOT-detected structures had their original and erroneous latitude/longitude coordinates replaced with the coordinates provided by the GPS-controlled SPOT image (Figure 13C). In addition, on the SPOT scene shown in Figure 1, 10 previously unmapped obstructions were identified and posted on company base maps.

After this project, an independent GPS survey was conducted that included all of the structures associated with 2 offshore oil fields in Figure 1. To test the internal integrity of SPOT imagery, and as a check on their updated base map, the CAD group registered all of the new GPS points to the appropriate wells, risers, and moored ships on the rectified SPOT image. It was found that all of the structures depicted on the rectified SPOT image were within 25 m of their new GPS fix and most were within 10 m. This level of accuracy means to our company that offshore SPOT images can be used with confidence to update the location of structures and obstructions with only a select number (at least 6) of well-distributed GPS control points

Because the SPOT images were mostly new acquisitions (1989-1990 data), a very up-to-date picture of shore lines, offshore bars and spits, swamps, onshore culture (roads, villages, well sites, seismic lines, facilities) and vegetation was available for digitizing into the CAD data base. However, although hundreds of offshore structures were identified on the numerous SPOT images we have processed, we know that we are not able to detect "small" obstructions (standpipes, moorings, secondary buoys, etc.), even under the best of atmospheric conditions. In addition, we know that SPOT may not detect "larger" obstructions because of the clouds, haze, and/or atmospheric dust which commonly affects the images.

5.0 SUMMARY

By digitally integrating SPOT satellite data, GPS fixes, CAD base maps, and image processing, we were able to accurately evaluate and update existing base maps of offshore petroleum facilities. Revisions in mobilization planning for seismic crews, as a result of such base map updating, significantly reduced program costs and improved acquisition time. SPOT panchromatic imagery, when adequately processed and rectified with GPS control, provides a cost-effective, rapid, and accurate base for updating maps of offshore petroleum fields.

6.0 ACKNOWLEDGEMENTS

We greatly appreciate Chevron Overseas Petroleum Inc. (COPI), Cabinda Gulf Oil Company Ltd. (CABGOC), and Associates (SONANGOL and AGIP - Angola Ltd.) for granting permission to publish this paper.

Integration of CAD vector files with SPOT images was accomplished on both DIPIX and Intergraph systems. A Terra-Mar system was used for much of the image processing. Technical advice from Chevron Oil Field Research Company's remote sensing group helped us maximize our enhancement of subtle offshore structures. COPI's CAD Drafting group provided cartographic and GPS expertise. Independent verification of the accuracy of rectified SPOT imagery was done by Chuck Clancy of COPI with timely GPS control from CABGOC. Hattie Davis, Mark Choiniere, Robert Bigger, and John Granzella of COPI provided excellent technical support.

7.0 REFERENCES

Ellis, J. M., P. D. Caldwell, and P. B. Goodwin, 1989, Utilization of Landsat TM to improve mapping of the Niger Delta: Seventh Thematic Conference on Remote Sensing for Exploration Geology, ERIM, Calgary, Alberta, Canada, October 2-6, 1989, p. 283-297.

Figure 1. Full (60 x 60 km), unprocessed SPOT panchromatic scene of a portion of coastal West Africa. As is typical for this region, clouds obscure onshore terrain while offshore is relatively cloud-free.

Figure 2. Unprocessed subscene (about 7 x 7 km represented by 700 pixels x 700 lines) of typical offshore area. Bright clouds and haze obscure small offshore structures (seen as subtle white dots).

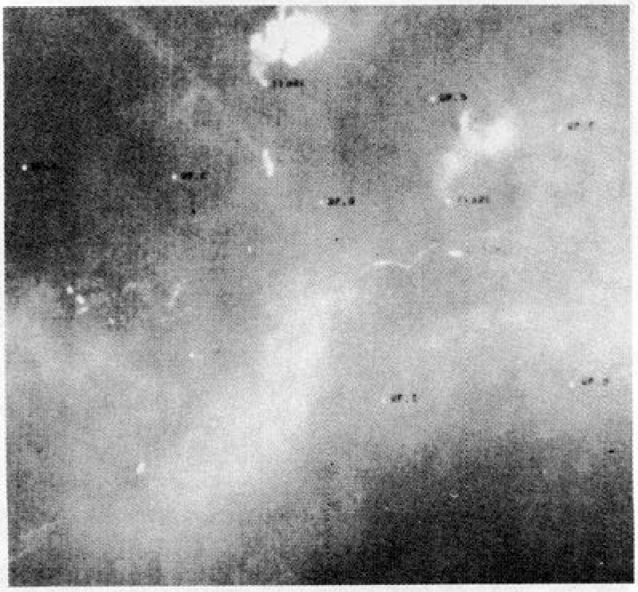
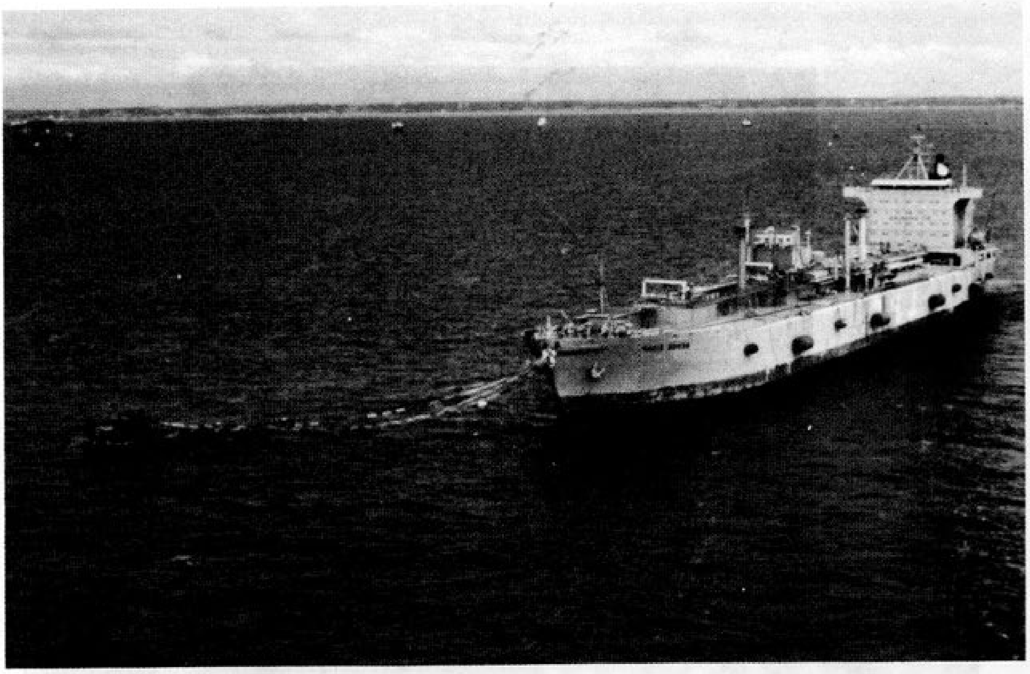


Figure 3. Same area as Figure 2, but subtle offshore structures have been enhanced with piecewise contrast stretching and high-pass filtering. White clouds and haze are still evident. Some structures have been labelled.



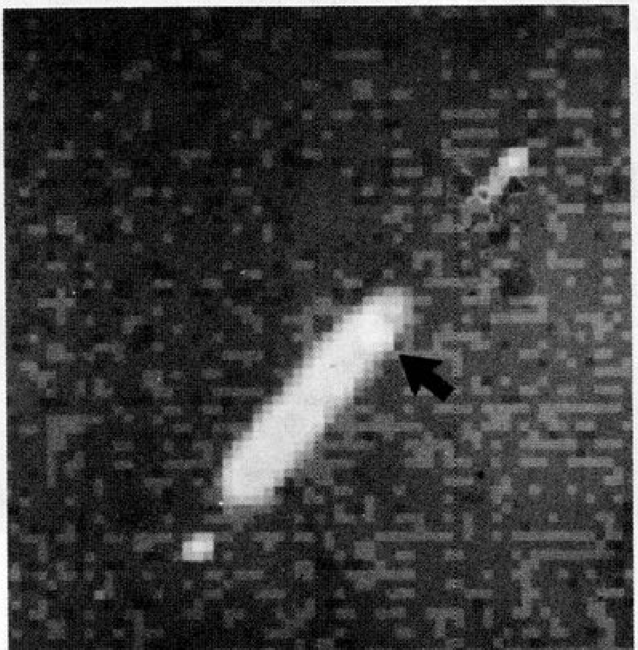


Figure 4. (A) Tanker moored to offshore buoy. View looking toward shore. In background, collection platform (extreme left), risers and flare can be discerned. (B) Moored tanker as seen with SPOT. Ship's bow points toward lower left corner with buoy (?) in lowermost left corner. Superstructure on tanker (see arrow) is brighter than rest of deck. Probable riser visible toward upper right corner. Each pixel represents 10 meters.

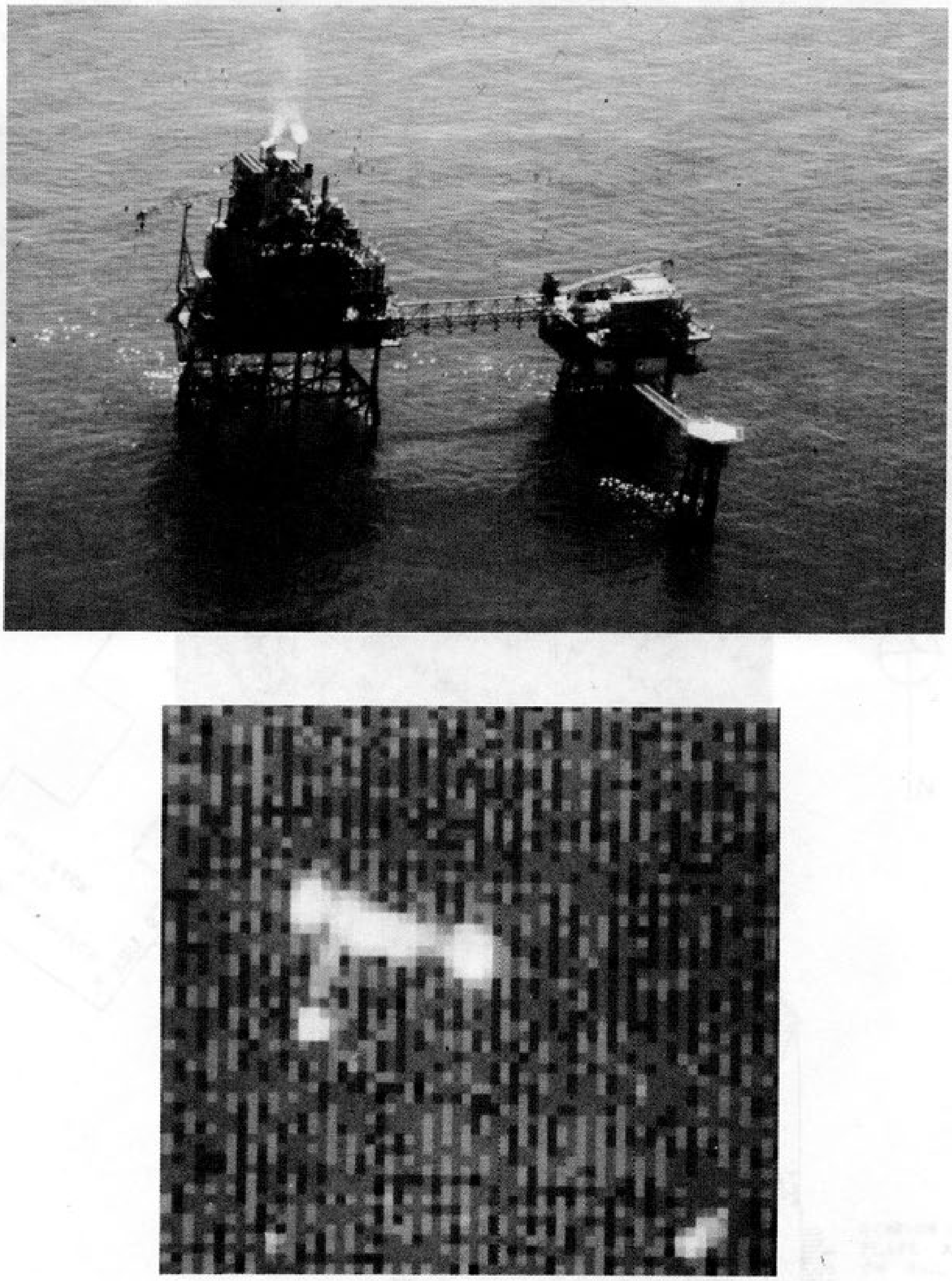


Figure 5. (A) Aerial view of offshore collection platform and (B) same type of structure as seen on SPOT. Shape and components of collection platform can be discerned.

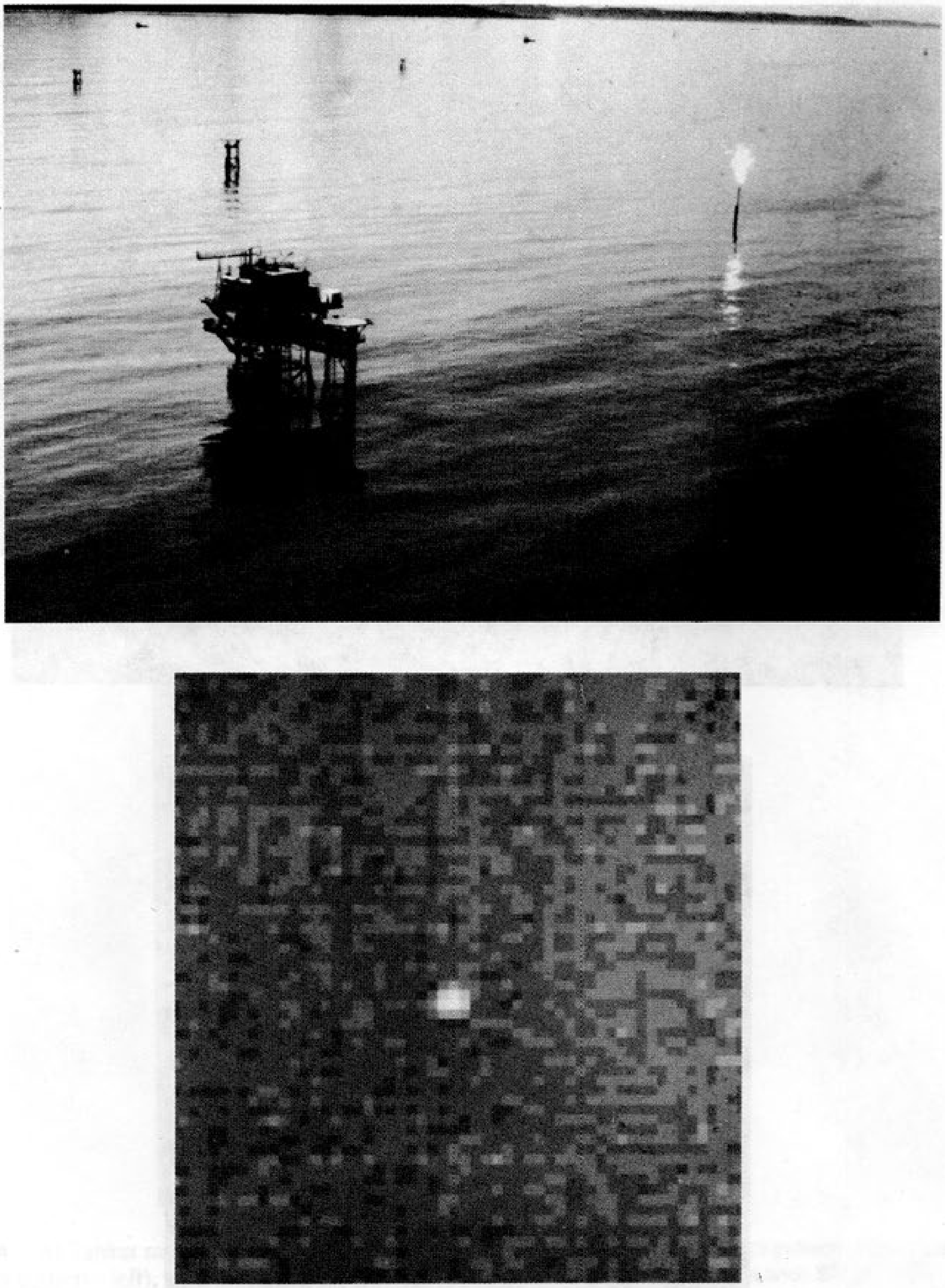


Figure 6. (A) Aerial view of producing field with large collection platfrm in left foreground, a flare to right of center, and risers (see arrow) across background. (B) Close-up of riser as seen on SPOT B&W image.

Figure 7. Offshore producing field (white spots are individual structures). Arrow points to collection platform highlighted in Figures 8-12.

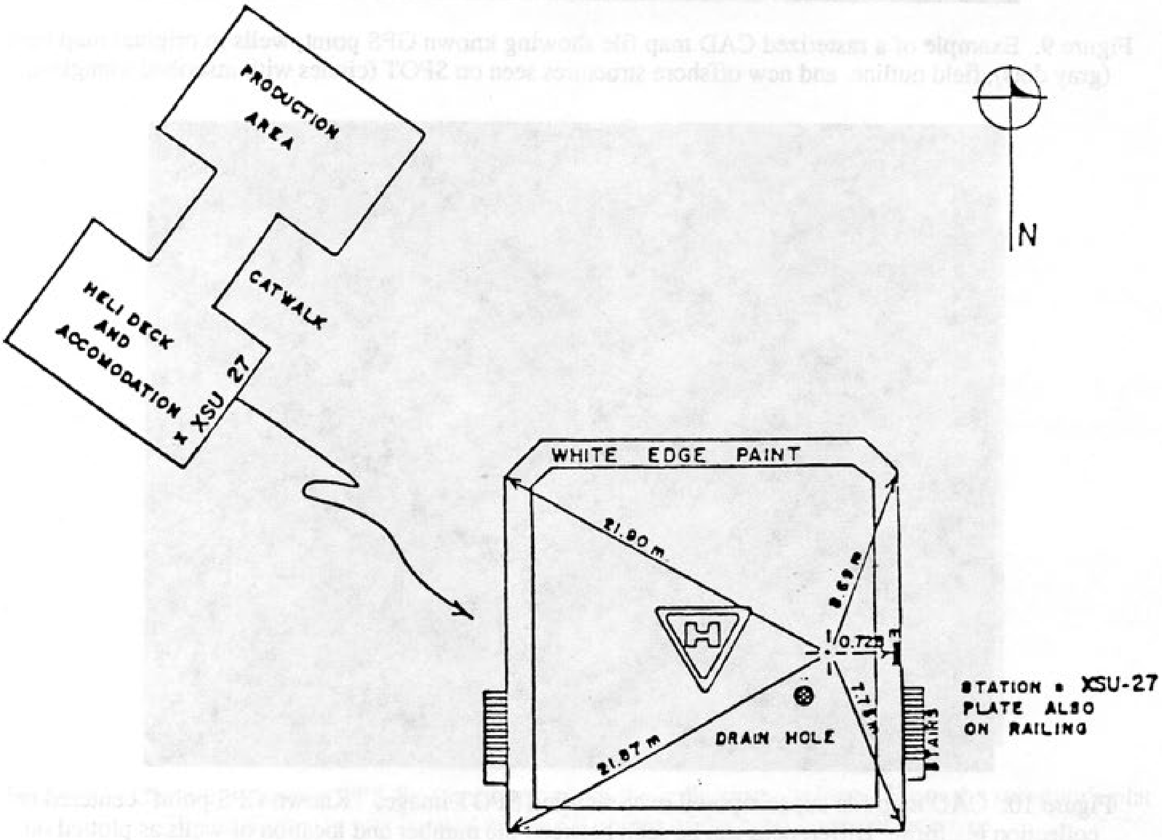


Figure 8. Example of surveyor's plat showing exact location of a GPS fix on an offshore helideck.

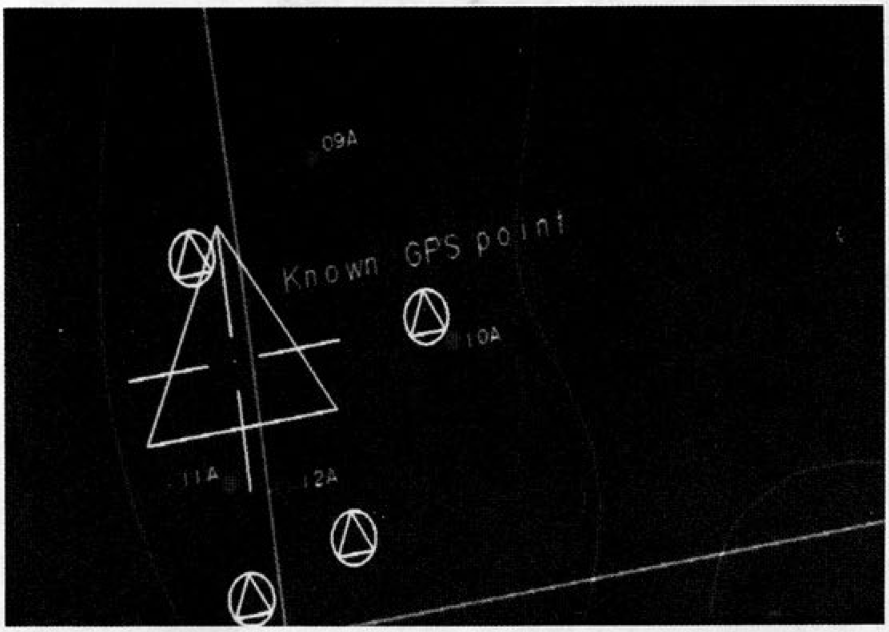


Figure 9. Example of a rasterized CAD map file showing known GPS point, wells in original map base (gray dots), field outline, and new offshore structures seen on SPOT (circles with inscribed triangles).

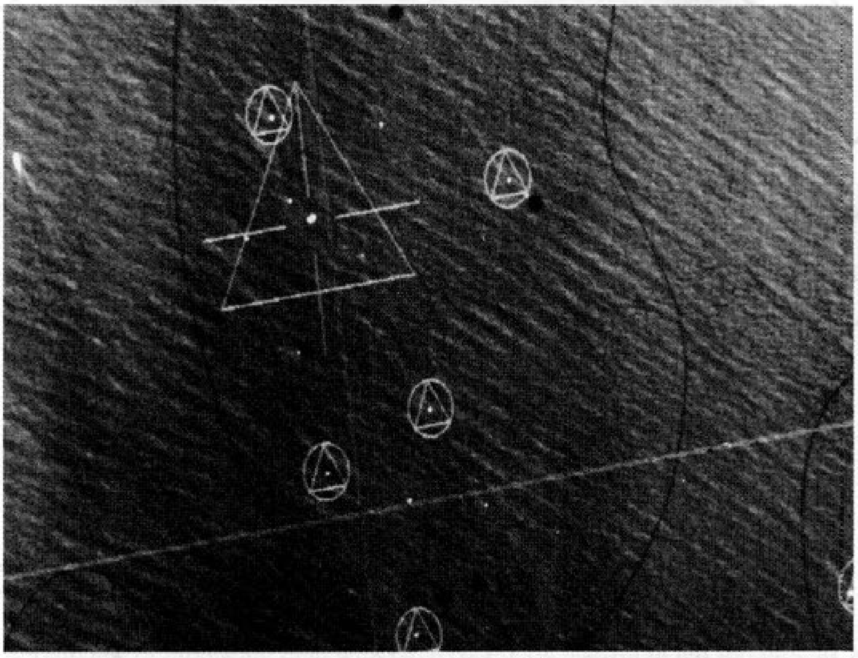


Figure 10. CAD map file superimposed over rectified SPOT image. "Known GPS point" centered on collection platform. Differences can be seen between the number and location of wells as plotted on original map (black dots) and as recorded on SPOT (white dots).

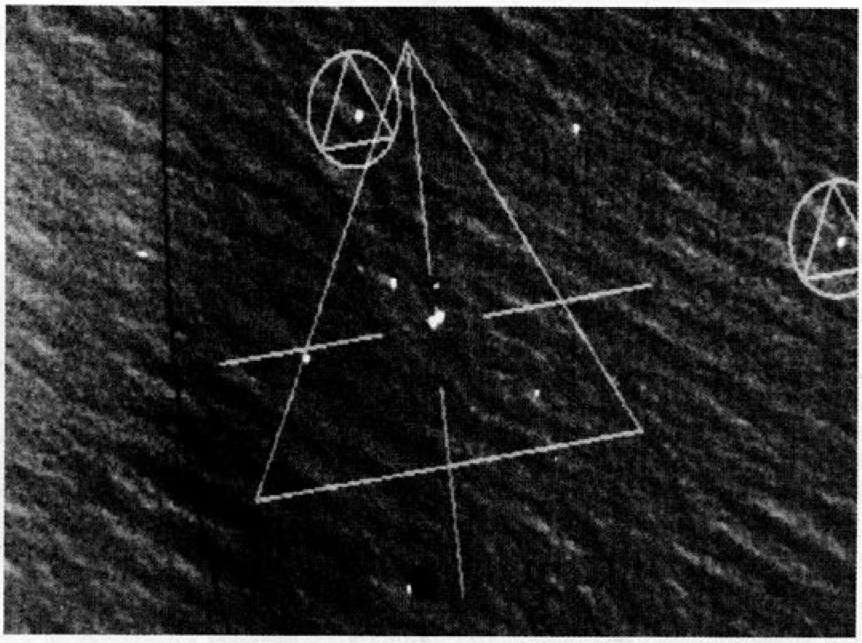


Figure 11. Magnification of GPS control point on collection platform.

Figure 12. Close-up showing GPS fix (tip of arrow) on the collection platform. From the surveyor's plat (Figure 8) the fix was located on the SE corner of the most southern structure.

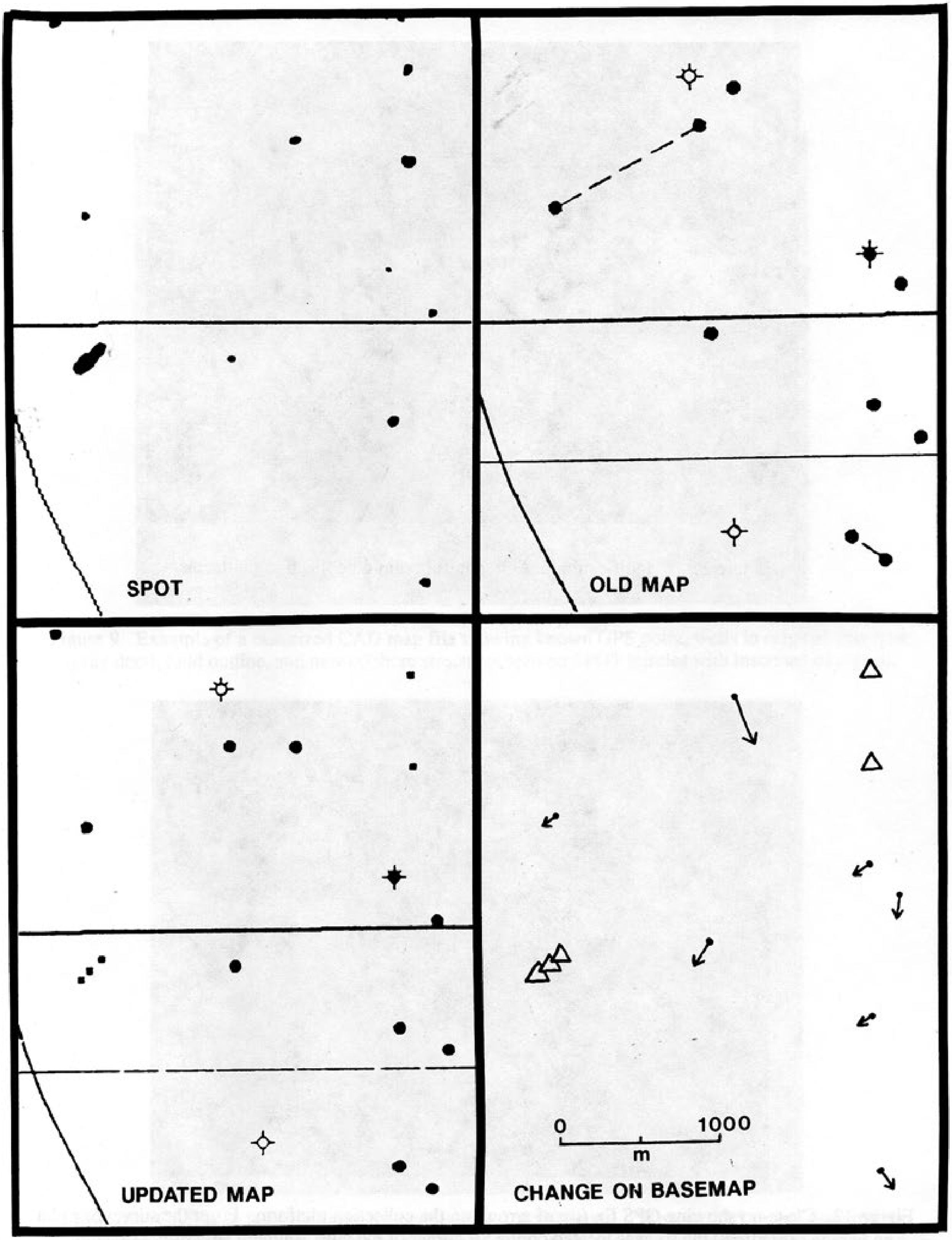


Figure 13. Same-scale maps showing (A) processed SPOT image (gray scale inverted), (B) original CAD map, (C) CAD map updated with SPOT and GPS control, and (D) changes in well locations between B and C (direction and magnitude shown). Offshore structures not on original map shown as open triangles.