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Shipboard Processing and Interpretation

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Abstract: In the fall of 1990, Texaco completed an innovative 4,300 km seismic program which included processing, interpretation of stacked and even some migrated-stacked sections of key lines. One of the new lead areas of complex block faulting was identified, infilled and, after final office-based interpretation of the entire data set, matured into a drillable prospect.

By using this unconventional technology, Texaco saved the time and expense of mobilizing a second survey to mature new leads and furthermore, it allowed the explorationist a chance to begin the block evaluation process months ahead of schedule as good quality (albeit not final quality) record sections were made available hours rather than weeks after data collection.

INTRODUCTION

Ever since the first commercial multichannel seismic digital recorder came into use in the late 1960s with 24 channel capabilities – the DFS-1 by Texas Instruments with support from Mobil and Texaco (Laster, 1985), the huge data acquisition rates of marine seismic vessels have rendered it nearly impossible to achieve real-time processing of seismic data at sea. Modern marine systems commonly employ 240 or more channels at 2 millisecond sampling rates which calculates out to 120,000 amplitudes recorded every second. In the past, any attempts at limited shipboard processing have usually been brute stacks used for data quality control.

In 1989, Texaco International geophysical manager Tom Beyer recognized that a new breed of small but powerful computing systems with interactive seismic data processing capabilities could be used to produce reasonably good quality record sections in the field— sections that could be quickly interpreted and used to make decisions on line locations while the crew was still mobilized. An Indonesian evaluation project with a tight drilling deadline provided an ideal test case for actually using the systems to make decisions in the field based on shipboard-processed data. These was not enough time for shooting more than one round of seismic in a rank frontier basin off the island of Sulawesi if the contract deadlines were to be met. Texaco International explorationist Dave Richards rode the seismic boat, supervised the processing, and analyzed the results. In just a month aboard the ship, he was able to recognize several promising areas for drilling, and to add immediate detailed seismic coverage to those areas (Anonymous, 1990).

Following the Indonesian success, Texaco sent out (author) D.M. Angstadt in the same role to lead a shipboard processing and interpretation team of three to carry out a similar study of sparse data coverage areas of the newly acquired Block PM14 off Pahang, Peninsular Malaysia. While the northeast quadrant of the block was covered by a relatively dense 2–3 by 2–3 km grid of 1981–1983 vintage data shot

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for Petronas Carigali, the rest of the block was covered by only a 10–15 by 10–15 km grid of 1968–1971 Conoco 12-fold lines. The vessel used was the M/V GECO "MY", formerly a German fish-processing boat now converted for seismic acquisition, that would now be processing a different sort of material (Fig. 1).

The following paragraphs describe our efforts to process and interpret seismic data at sea and make a first-pass evaluation of promising leads in the sparse data areas of PM14 so that an infill program could be designed and shot during the same survey mobilization.

PROCESSING

The shipboard processing system utilized two Compaq microcomputers, Advance MicroMax processing software, and OYO and Benson plotters. All the hardware fit comfortably in the recording doghouse on a single desk, with the OYO plotter overflowing onto an empty frozen-food cardboard box (Figs. 2 and 3).

Processing procedures at sea closely resemble a typical flow utilized in a shorebased seismic data processing center excluding some of the more advanced and time-consuming technique such as dip moveout (DMO). After parameter testing is used to tailor the processing flow to the data and design correct filters based on the frequency characteristics of the recorded signal, data are decimated to provide a working data set for the system (Fig. 4). The data reduction was essential if the processing were to keep pace with the acquisition due to memory and

Figure 1: The seismic acquisition ship M/V GECO "MY" served as the floating processing center and interpretation office.

Figure 2: The shipboard processing system placed in the doghouse of the "MY" was built around two Compaq microcomputers and MicroMax (Advance Geophysical) seismic data processing software. A small Benson plotter (between the video screens) which was used mainly for velocity scans and parameter tests and a large OYO plotter (lower right) was used to produce full record sections.

Figure 3: The shipboard processing and interpretation team analyzing a key record section and structure/lead map in the doghouse of the GECO "MY". Interpreter/Mapper/author David Angstadt is flanked by processors Jaroslav Ondrak on the left and Ralf-Dieter Schiebe on the right.

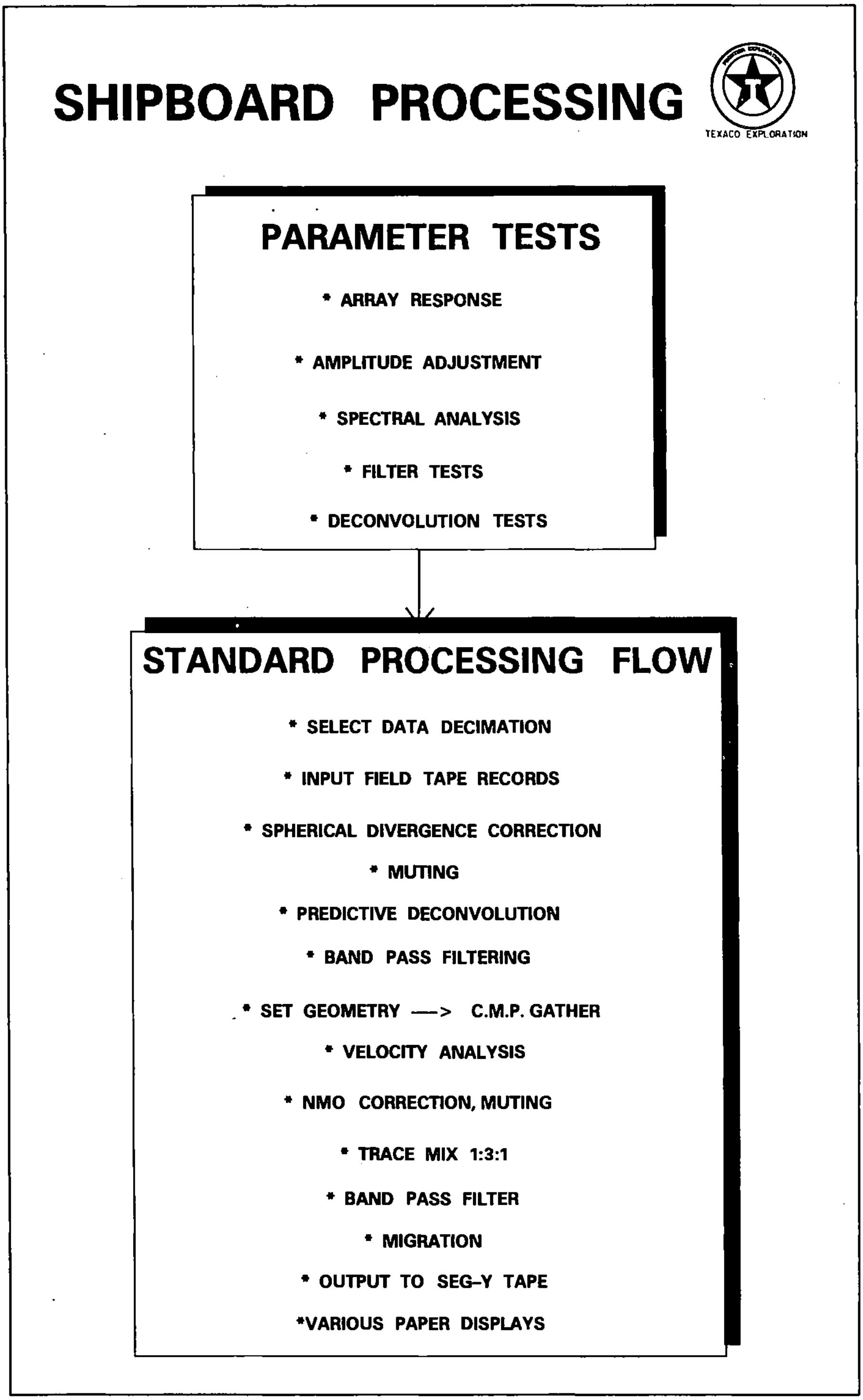

Figure 4: An outline of the processing flow typically used to produce a shipboard-processed section. Migration was used only on key lines because of the excessive computing time required.

speed limitations of the 386-based microcomputers (note: in 1992 more powerful Unix workstation-based machines are available to run interactive processing software). In our case, we resampled to 4 milliseconds to a maximum of 5 seconds, input only every fourth channel. By doing this, we eliminated nearly 90% of the recorded data yet it allowed us to output 30–fold data with 25 mt trace spacing. By contrast, the shorebased processing center produced final sections of 60 fold with a 12.5 mt trace spacing. For our goal of simply designing an infill program, the trade-off of a great increase in processing speed for a small increase in noise and decrease in resolution was completely acceptable.

Next in our processing flow came spherical divergence correction, muting, predictive deconvolution, bandpass filtering, CMP gather, velocity analysis, NMO correction and muting. The brute stack sections at this point contained a fair amount of linear aliasing noise commonly generated in this area when the shot spacing is double the group interval (Chia *et al.*, 1991). This noise was sufficiently eliminated with a mild 1:3:1 trace mix. The data was then bandpassed filtered and output to SEG-Y tape. Although very time-consuming (usually submitted as 7–8 hour "just before bedtime" jobs), migration was performed on a limited number of key lines.

Various paper displays were made to aid the interpretation. AGC scaled sections (Fig. 5) as well as "relative amplitude" section using a single section-wide gain function (Fig. 6) were for all lines. The relative amplitude sections were used to look for bright spots and as an aid for correlating across faults. Figure 5 also demonstrates the quality achieved for a stacked section processed at sea (bottom) as compared with a section processed "state of the art" in the Texaco processing shop in Houston, Texas and displayed (unmigrated) with the same trace spacing and scaling factors. The quality of the shipboard section is nearly as good. During the seven week cruise the "MY" recorded nearly 4,300 km of 60-fold seismic data and the shipboard processing team was able to process 3,200 km of data with velocity analyses approximately every 5 km. This was nearly all of the original reconnaissance program laid out (over 1,000 km was infill based on the shipboard interpretation). In addition, over 900 km of data were migrated before arriving back in port at Singapore (Schiebe, 1990).

INTERPRETATION AND MAPPING

The main reason for instituting shipboard processing and interpretation was to allow Texaco to add detail program in areas of interest where thick Tertiary section was known from aeromagnetics and a loose grid of late 60s and early 70s data but where this data was too sparse to locate individual structural or stratigraphic leads. The preliminary shipboard interpretation was used to identify the more obvious leads. In the circumstance of a virgin frontier basin with no geophysical data, such a program might be used to establish whether a sufficiently thick sedimentary basin for the maturation of hydrocarbons exists at all by first shooting and processing a loose rake of lines. If the answer is "no", much money could then be saved by perhaps eliminating the rest of the program. If "yes", a tight grid could

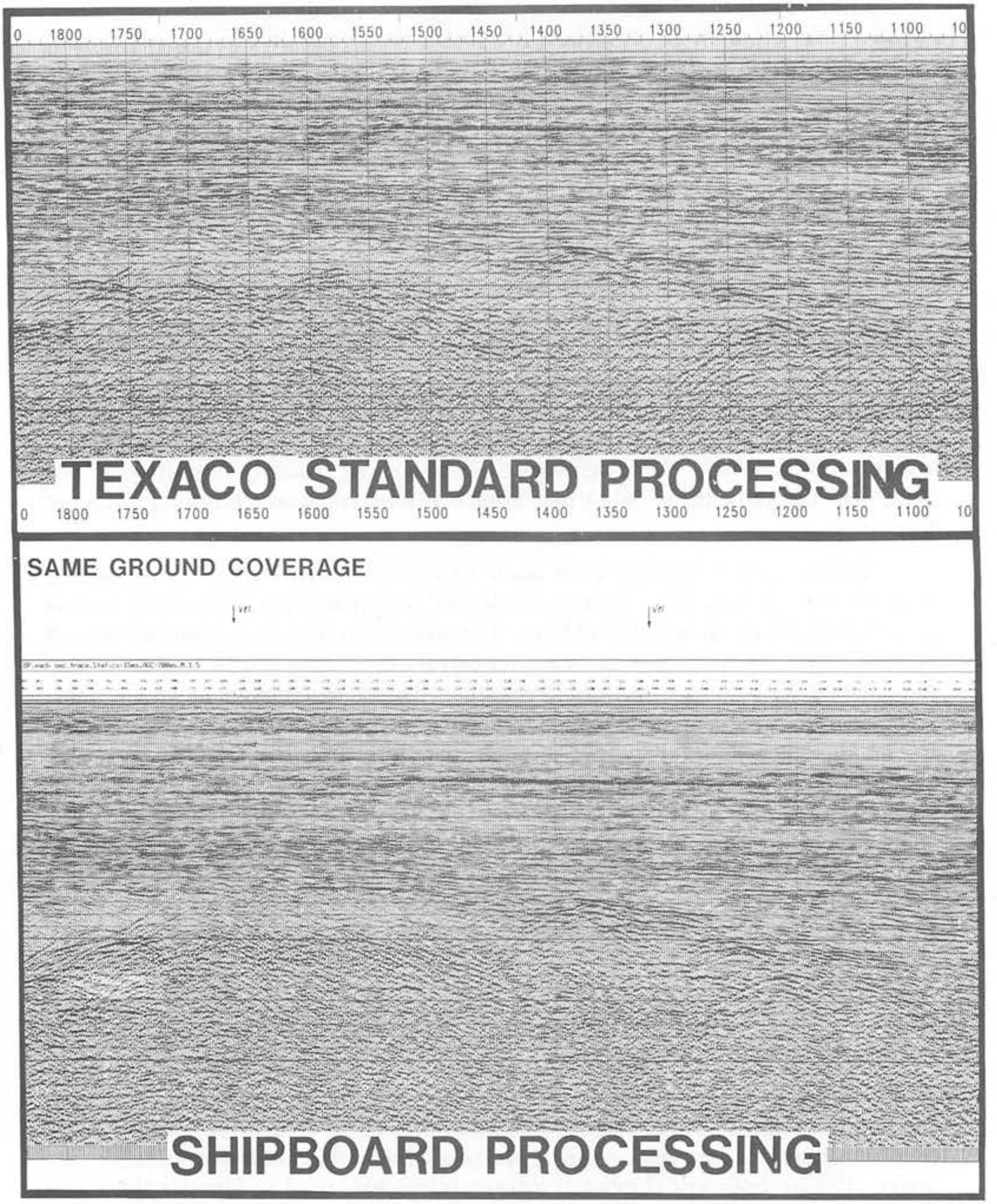

Figure 5: The upper panel shows a section of a 1981 line shot between the only two well penetrations of the Penyu Basin prior to Texaco's award of Block PM14 in 1990. The line was reprocessed at Texaco's processing center using state of the art techniques but displayed using the same trace spacing and scaling as the 1990 shipboard processed sections.
The lower panel shows a record section processed on the ship with the same ground coverage as the upper section as the line was reshot in 1990. Although the highly-faulted basement reflector (about 2/3 of the way down the section) is imaged slightly better in some locations in the onshore processed section the quality of the shipboard processed section is felt quite high. Both sections were Automatic Gain Control (AGC) scaled and are unmigrated.

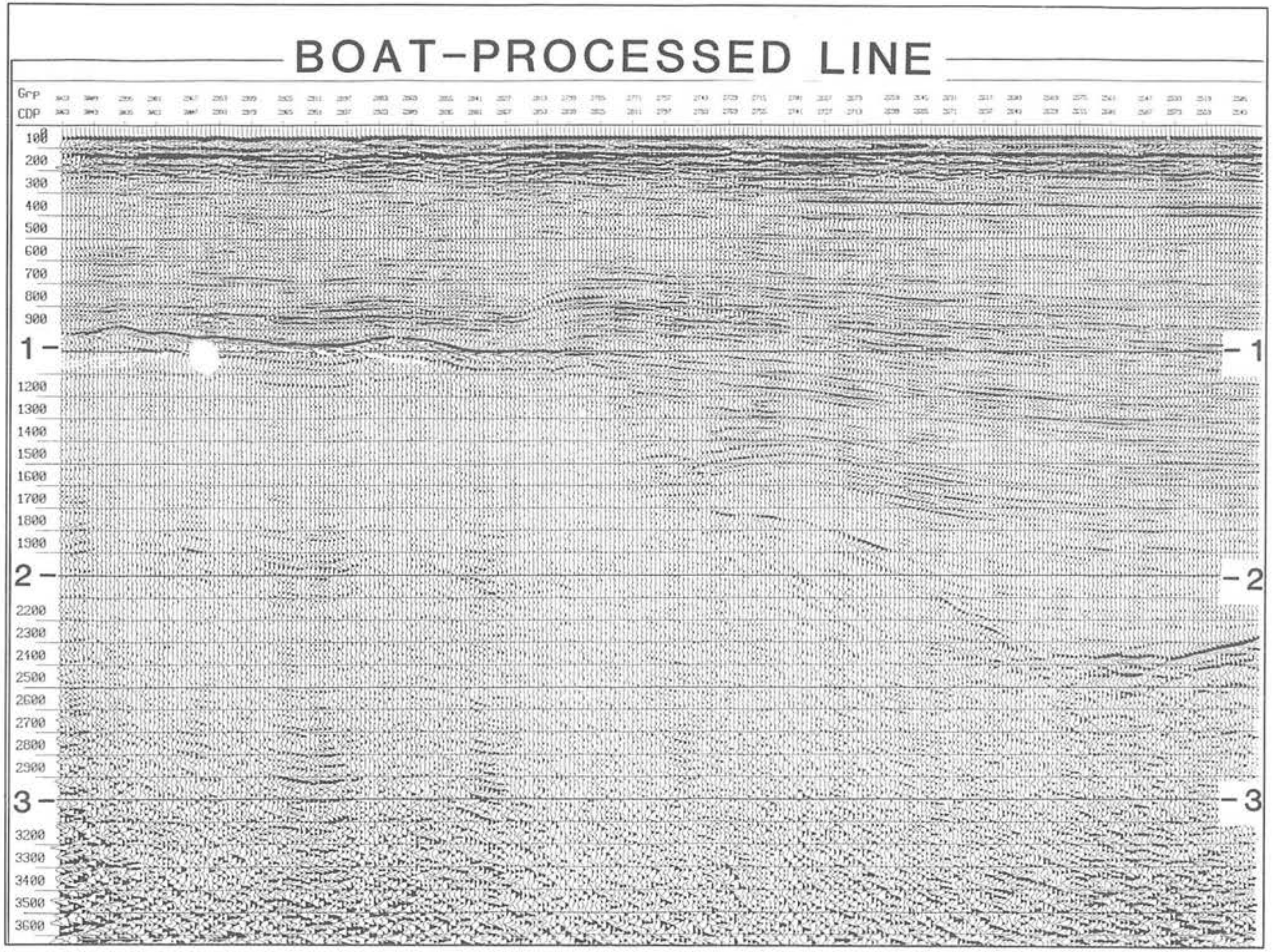

Figure 6: A relative amplitude section scaled with a laterally unchanging gain function. The strong reflector on the left half of the section at 1 second is the granite basement of the Singapore Platform. Halfway across the section it is downfaulted to form the Penyu Basin with approximately 2.5 seconds of Oligocene-Recent sedimentary fill on the right half of the section. A small fold can be observed where the basin bounding fault was reactivated by Miocene wrenching or compression.

be shot to infill the more prospective areas. An additional advantage of the onboard processing is that during the course of any type of survey, processed lines can be used for achieving better quality control. For instance, several times during our PM14 survey attempts to ward off ships passing over our hydrophone cable were unsuccessful and a decision had to be made whether or not to reshoot the line. Engine and propeller noise could be seen on the monitor strips in several channels but by observing that nearly all of the noise was removed during the 60-fold stack we could avoid reshooting the line segment.

Before the interpretation of lines could really begin a shotpoint location base had to be constructed so that line crossings could be located on sections and structural contours, faults, and other features could be mapped. Seismic line track charts (no shotpoints of course) were made on shore with closely-spaced latitude-longitude ticks. As the lines were shot, shotpoint location printouts supplied by the ship's navigator were used to spot shotpoint locations and numbers on the track charts. Record section interpretations were constantly updated as more lines were shot and processed, more crossings were provided, and the three dimensional aspects of the geology became more clear. A structure/lead map resulting from this procedure is shown in Figure 7. This map shows faults, structural contours (in 2-way travel time), and possible leads. It is important to note that in no way was the shipboard interpretation used as the final say in evaluating the block or picking drilling locations. During shorebased processing higher quality record sections were produced utilizing the entire data set to achieve the full 60-fold. More powerful computers also allowed more advanced processing routines (e.g. DMO, several types of migration, etc.) to be used and these proved necessary to properly image the highly-faulted pre-Miocene section of the Penyu Basin in block PM14.

The interpretation resulted in the delineation of three areas of interest for which three structure/lead maps were produced onboard.. The maps were used to design an infill program of over 1,000 km. Eventually a prospect was matured in one of the three areas as a result of the infill program designed onboard. Although that prospect was drilled in late 1991 as the Merchong #1 dry hole (the next well drilled was the 6050 BOPD Rhu discovery), the shipboard processing proved its merit by providing good quality brute stacks that sped up the evaluation process. Future speed and miniaturization advances in computer hardware will give the exploration community even greater opportunities to get a good first look at the geology of their properties in the very early stages of their permit evaluation program.

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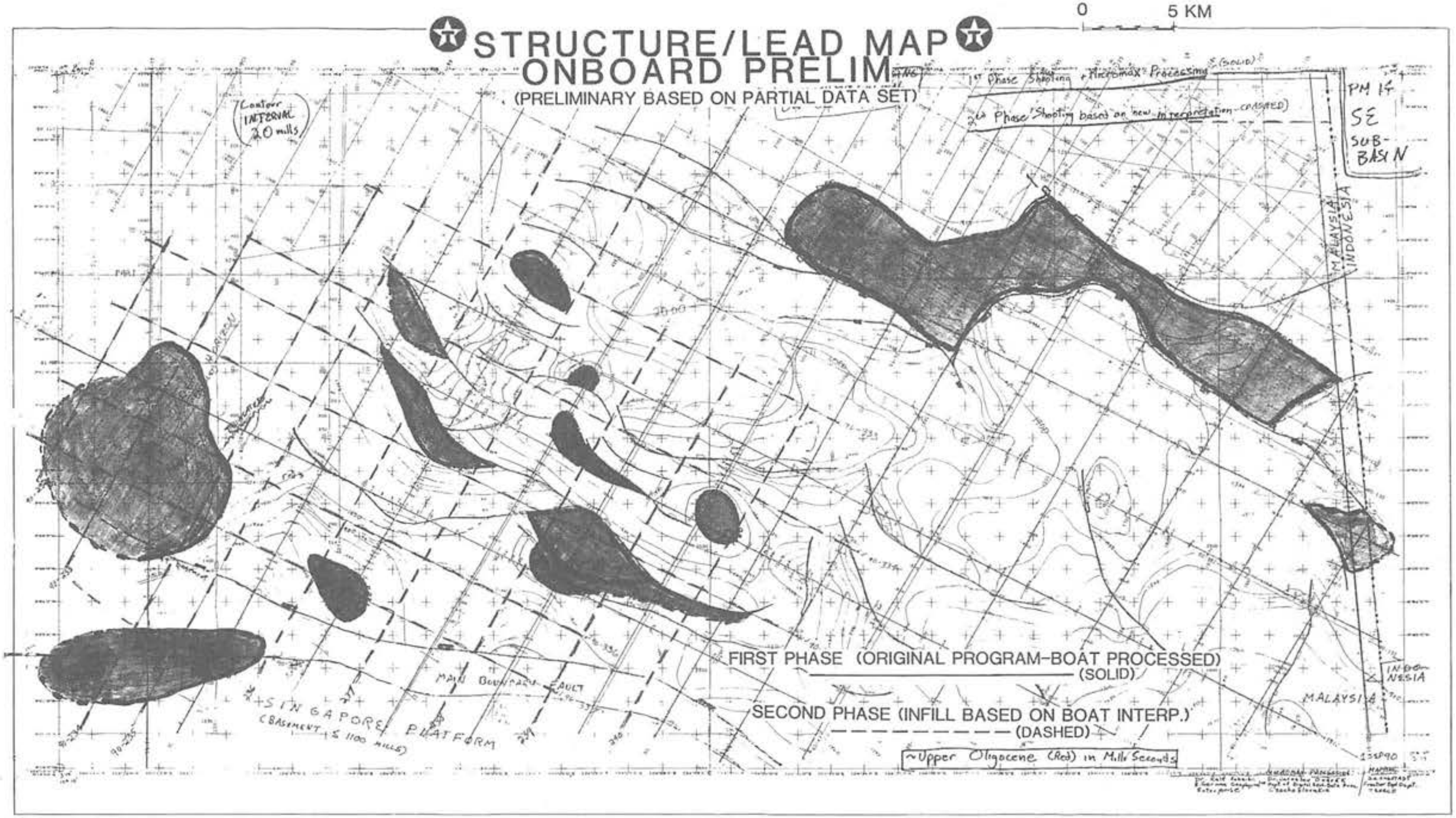

Figure 7: One of the three structure/lead maps produced during the seismic survey. The map shows tentative leads (dark shaded) as well as structural contours (in time) and faults. Solid lines show the first phase seismic lines on which this map is based and the dashed lines show infill lines added based on the preliminary interpretation.

16 hour days gazing at their rolling video screens and to the geophysical acquisition party of the GECO "MY" for their helpfulness in setting up the processing system even though their precious doghouse space was being invaded. Special thanks go to Thomas Beyer for conceiving the use of shipboard processing as an exploration tool and David Richards for working out many of the technical details as well as providing a useful critique of this paper and greatly improving its quality.

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