JOINT INTERPRETATION PROJECT
LING GUO DEPRESSION, JIJI AREA

FINAL REPORT

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INTRODUCTION

Landmark Graphics had the opportunity to participate in a joint interpretation project in the Ling Guo depression, China. Those involved in the project included people from each of the following groups: the Bureau of Geophysical Prospecting-including the interpretation center, the Ren Qui Oil Field, the Zhi Da University, and Landmark Graphics. The scope of the project centered around the Landmark III workstation located in the Zhi Da University, and included training, transfer of technology, and demonstrating the use of a workstation in the search for oil. Data available for the project came from each of the participants and included regional gravity and magnetics, and local well, seismic and velocity control. There were 51 seismic lines used in this interpretation both on the work station and paper plots. Dr. Brad Macurda was involved in the first two weeks of the project helping set out the stratigraphic framework.

The project had originally been set to analyze the following seven points:

1) Differentiation of the volcanics and the conglomerates
2 Extend the definition of the volcanics and the conglomerates to the northeast
3) Study production from the volcanics in well 12
4) Understand why there were only oil shows in the sand bodies in front of the fans
5) Identify the onlaps in the area
6) Unravel the heavily faulted Tertiary fault blocks on top of the Buried Hills
7) Resolve the arguments about faults between the Buried Hills.

Upon arrival in China the following 10 objectives were assigned the team:

1) Determine the paleogeography of the Oligocene
2) Study the conglomerates within the Oligocene
3) Map the thickness and changes in the conglomerates
4) Study changes in the porosity of the conglomerates
5) Identify sources and extent of the volcanics
6) Find high porosity zones in the volcanics
7) Look for top and bottom metamorphism associated with the volcanics
8) Determine the time of the igneous intrusions
9) Study faults in the conglomerates and volcanics
10) Identify potential hydrocarbon traps.

The project took almost 4 months to complete and was presented to the Oil Fields on July 7, 1987.

REGIONAL GEOLOGY

The Ling Guo depression is located just south of Beijing in the Bohai Basin. This area is part of the Eastern China oil and gas province that has some of China's largest fields. This area, the Eastern China Platform, has been under the influence of the tensional stresses as the Pacific Plate has been subducted under the Eurasia Plate. The Bohai Basin is part of one of two generalized spreading zones found in Eastern China that trends from the Songliao Basin, through the Bohai Gulf Basin, down to the Beibu Gulf Basin. The other zone passes through the East China Sea and influences the eastern offshore China Basins. (Li, 1986)

The Bohai Basin is a pull-apart, rift basin that has formed half-grabens in the paleozoics. These "Buried Hill" structures have provided a significant amount of oil, and form the primary reservoirs for many of the big pools. Mr. Li Desheng describes four cycles of rifting and subsidence, but of main interest to this paper is his third stage, during the Paleocene and Eocene. He labels this as the 5th episode of the Yanshan orogeny that developed until the Oligocene depression, which he sets as the first episode of the Himalayan orogeny. The Oligocene depression period contains the infill of conglomerates that make up the Shahijie formation (hereafter referred to as the Sha formation). These conglomerates were the main objective of this project and their stratigraphy will be discussed later. After deposition of the Sha, there was a period of uplift and erosion, with the next period of deposition being the Neogene river deposits which sit unconformably on the Sha. Present day alluvium consists of sands and conglomerates, not that much unlike the rocks seen in the cores taken from the Sha, except that the Sha appears to have been a lake deposit versus the present day alluvial fans and braided river systems.

I was most impressed with the number, and quality of cores taken in this area. Most of the wells had been cored, and the cores covered not only the intervals of potential production, but shales, tight sands, volcanics, and areas needed for pure scientific study. Then very detailed analysis had been done on each core and tabulated for easy use by the geologists that needed the information. I had the opportunity to go to the Oil Field and review four of the cores and found the descriptions to be accurate and reliable. The visit also left me with a greater understanding of the Geology involved. My findings from the cores will only be generalized here, but there were several things which stood out in each of the cores that will help the reader to grasp the rest of the stratigraphy a little better.

Each of the conglomerates showed similar characteristics, namely: 1) They were clast supported with a mudstone matrix. 2) There was poor sorting with little or no obvious grading. 3) The clasts were usually sub-rounded to rounded although there were many clasts that were angular with minor rounding. 4) The clasts from the deeper (older) conglomerates were sourced by the younger surfas paleozoic limestones with the younger conglomerates being sourced by the older Cambrian, and Pre-Cambrian rocks. 5) There was a noticeable lack of fossils in the shales or surrounding units. 6) The matrix was predominately mudstone and the shales were organic rich and showed the potential for good source rock. 8) Many of the shales were sitting at up to 30 degrees dip to the lower and upper beds/ and well bore.

Each of the conglomerates had a scour base that usually had 1 to 3 cm of fine grain sand with some small pebbles that preceded the massive conglomerates. There were some flame structures at the base, but no other obvious features consistent throughout. Clast size ranged from coarse sand to small boulders/cobbles with no obvious sorting.

Of special interest in the cores were several igneous bodies that have bothered the seismic interpreters. These volcanics were apparently low temperature intrusives, very homogeneous fine-grain mafic bodies. I did not get to see the contact zones but other core descriptions describe the expected metamorphic effects on the surrounding shale with some foreign clasts in the intrusive. Well 12 had some minor production from this zone but it is in the 1 to 10 meter thickness range.

There were over 20 wells that penetrated the Oligocene in the Jiji area, and most of the wells had a full suite of logs run on them. Twelve of these wells had been digitized for input to the computer, and most of the 20 wells had paper synthetics already calculated. Of these 12 wells, 9 were chosen to have complete suites digitized for display purposes, with the display including the lithology log, the Sonic, Gammay Ray, Resistivity (Dual Induction), and the Self Potential. The lithology logs were input as seismic traces on 3 lines defined for the purpose of these displays. The remaining logs were then put in as overlays, allowing the interpreter the ability to have complete control over the display.

Three of these wells had production out of the conglomerates, with the best production coming from well 34. There were two zones of production in well 34 - the first from 1506-1535 meters flowing 63.5 tons oil/day with 3532 m**3 gas/day, and the second from 1542-1549 meters flowing 174 tons oil/day with 6863 m**3 gas/day. The other two wells were down dip and flowed less oil with water. There were offsetting wells within 600 meters that found no equivalent conglomerates in the same zone.

Another well of interest was well 36 which penetrated 257 meters of massive conglomerates. The log characteristics showed minor sorting that could be used to break this unit into 9 to 10 meter sub-units, but there were no major shale breaks in this interval. This well was proximal to the main fault and will be discussed later.

ANALOGS

There were two main analogs used in modelling the basin geologically. They had no production and thus were used mainly to help explain the depositional history as appeared in the wells and on the seismic. The first example comes from a study of the fans in the Wollaston Forland, Greenland done by Surlyk in 1981. The conglomerates there had the same basic characteristics as I saw in the cores as just described. Surlyk described the lacustrine fans with massive breccia deposits at the base of the slope of the major fault that regionally graded to braided middle fan facies out to distal shales and thin sands with sands lapping on to distal fault blocks similar to the Buried Hills. The production from well 34 seems to match the middle fan facies very well.

The second analog comes from a series of papers done by Wescott and Ethridge (1983) on the lower Eocene Wagwater and Richmond formations in the Wagwater Trough, eastern Jamaica. They described both the fan-delta and the submarine fan deposition in the Yallahs Trough and the paleo equivalent in the Wagwater Trough. The current deposition of the Yallahs delta into the fault bounded Yallahs basin closely resembles the paleo setting for the Jiji area. Their facies closely resemble Surlyks and the Jiji stratigraphy. Both current and paleo deposition consisted of an uplifted block with a sharp rifted fault scarp bounded by a lake/sea into which massive conglomerate deposition occurred. At the base of the scarp were proximal, or slope, conglomerates (Surlyk's slope breccia) that graded into alternating conglomerates and shales in the proximal submarine fan (Surlyk's middle fan channel deposits) grading out to interbedded thin sands and shales in the distal submarine fan facies.

REGIONAL GEOPHYSICS

The seismic grid that was loaded into the workstation consisted of 52 recently reprocessed seismic lines of varying vintages and folds. Most of the lines were either 12 or 24 fold CMP processed, migrated data. This was shot hole data of good to excellent quality processed as a 2D grid. The lines were shot in four directions with most the lines being dip lines (NW-SE), or strike lines (NE-SW). Several lines were shot N-S and then E-W thus oblique to the formations. This, combined with the 2D migration and the steep dip of many of the formations, led to many severe misties. Migrated data was interpreted because of the complex structure, but final stacks were available on paper, and often used to clear up mistie problems. The processingwas structurally oriented with the final stacks being low frequency (dominate frequency =20-30 hz) and heavily scaled. There were several types of reprocessing involved and were discrepancies on lines that were within 50 meters of each other. There was a problem with many of the lines that had crossing reflectors, not knowing if one set were multiples or the crossing reflectors from over-migration. The geology did not help, rather the seismic often left much debate as to the potential depositional models. This report assumes that the flatter lying reflectors were multiples, due to both well control indicating the probability of shales and no obvious flat reflectors. The processing was an ongoing process and the last line was received only 3 weeks before the presentation of the project. The work-station made integration of each of the new lines a simple task as they came. Maps were instantly updated and no redrafting was required.

The velocity control came from the Interpretation center and consisted of a single velocity function that was drafted on mylar and taped to the back of a ruler. That same function was input into the computer and used to convert time maps to depth. The overall fit seemed ok, but there was no real effort to tie individual wells to the seismic and develop a regional velocity function. Modelling has shown some potential problems with this approach and may be the source of so many of the problems encountered in the three months it took to interpret the structure.

Mel Carter of Landmark had taken this function and the stacking velocities of 5 lines from which he did a velocity study. A copy of his results are attached to this report for a detailed study of his processes and results. His basic findings showed that the stacking velocities were not done in enough detail to get a consistent or reasonable velocity function. A detailed velocity study might prove beneficial as all depths were converted to time based on the single function that had to fit a radically changing geology.

STRUCTURE OF THE JIJI PROJECT

Over three-quarters of the project was spent on working out the structural framework of the area. Both the fault pattern and the horizon picking was changed many times until a satisfactory result was obtained. The 2D nature of the data with the complex structure made the work go slowly as there were many different hypothesis's that are still plausible.

The fault pattern is based on the regional patterns and several known faults. The major bounding fault to the north west is the Da Xing fault, and its footwall consists of the Tai Hang San uplift region, the hanging wall side consists of the Burried Hills distally with the Oligocene conglomerates deposited on the scarp face. This fault trends NE-SW and is well delineated by the gravity and magnetic maps. The fault is often at a low enough angle to get reflectors from the scarp face and easily map. The Buried Hills are recognized by the very low frequency and high amplitude that often characterizes the Paleozoic limes and bedrocks. The Buried Hill in this area is bounded on the west and south by the Tomba fault. South of the Buried Hill on the south side of the Tomba fault is a growth faulted structure we named the Pagoda due to its resemblance to the large stone structures easily viewed from our window. The Pagoda consisted of a thick wedge of sediments that were dipping slowly down to the north east, but fairly flat in all other directions. Except for the growth faulting that seemed to symmetrically enclose a ridge of sediments with strike of faults and platform going NE-SW. The remaining faults around the Buried Hill looked to be enechelon faulting similar to other rift basins with minor strike-slip or rotational movement. (Lovell, 1985) The major faults appear to be part of the continuing rifting of the Eastern China Platform (Li,1986) while sediments filled the depression during the Oligocene. The soft sediments were subject to the natural growth faulting, and when the subsidence was finished there was an uplift causing parts of the Sha-1 thru Sha-3 to be eroded. This was then overlain with Neogene to present deposits.

For structure map purposes, we carried around four major horizons. Namely the T-2 or Base of Neogene, the T-5 or Base of Sha 2, the T-5-2 or middle of the Sha 3 and based on a shale unit in the wells, and the TG-1 or Top of the Ordovician. Maps and Isochrons were made based on each of these horizons.

The structure map on the base of the Neogene, the T-2, shows only minor structure with dip generally to the south west. The southern portion of the area shows a slight low where the pagoda is located. The higher portion to the north west is over the paleo uplift and much thinner than to the west.

The next major horizon is the T-5, which marks the base of the Sha 2. The Sha 1 can be seen as you move further downdip to the west but was not involved in this project area. The Sha 2 sits unconformably under the Neogene due to having been uplifted and eroded. There is also a mappable high down south at the Pagoda due to the growth faulting on both sides. This high matches the lows in the Gravity and Magnetics and displays a very thick section of sediment.

The T-5-2, or middle of the Sha 3, shows the complexity of the structure in the area. The T-5-2 goes from approximately 700 ms against the Buried Hill to the north dropping down to 2200 ms beneath the Pagoda, and then down to 3200 ms in the south-east portion of the study area.

The T-G-1, or Top of Ordovician, is the lower limit of the conglomerate deposition. There are a dozen major faults at this level that are associated with continued subsidence through the Oligocene. The high in the northern part of the survey is the half-graben rift block that forms the Buried Hill in this project area. There is a smaller, deeper structure at the base of the western delimiting fault that caught the interest of the interpretational team and deserves further study. There have been several wells drilled into this Buried Hill, but no production found to date.

The isochrons show the same general characteristics in varying degrees. The Oligocene is delineated with the T-G-1 to T-2 isochron. This shows the deepest portion of the lake to be where the Pagoda now is with the portion between the Da Xing fault and the Buried Hill to be shallower and narrower than down south. Stepping through the isochrons shows the depocenter to gradually move from south to north-north-east. We eventually see the Sha 2 and Sha 1 to the northeast just beyond our project area.

STRATIGRAPHY

During the two weeks that Dr. Macurda was in China we set out the major stratigraphic units of the area. As it turned out the structural boundaries ended up following these areas so that the structural horizons also became our mega-units. Although not a perfect one to one overlay they are close enough to use almost interchangeably. There is the obvious erosional unconformity at the base of the Neogene, and an amplitude/frequency difference between the Sha 2 and the Sha 3. The Sha 3 also downlaps/onlaps on the Sha 3 making the T-5 relatively straight forward to pick.

The T-5-2 is not as obvious or definitive on the paper sections, but when the data is shown as instantaneous phase and especially instantaneous frequency in color, there is a fairly pronounced difference between the lower and the upper Sha 3. The upper zone has a higher frequency content than the lower and continuity is not a obvious. We noticed this after having picked the T-5-2 and this might be used in the future for a fast method to regionally check the horizon.

The T-G-1 was picked as the lowest mega unit boundary as it delineated the base of the Oligocene. There are several other possible boundaries that might have been picked, but the structural complexity of the data made this very tedious.

After working with the conglomerates in both the wells and the seismic, and reviewing the analogs several times, several major zones seemed apparent on the data. They were most apparent on the workstation by playing with the color bar on the amplitude sections so that certain amplitude levels stood out. By whitening out the section and using a marker to highlight only certain amplitudes several anamalous characteristics seemed to stand out. The first was a series of high amplitude, spacially short reflectors that seemed to lie about the same distance from the major Da Xing fault all the way up and down the fault scarp. These reflectors were surrounded by low amplitude/frequency zones in the data that helped them stand out. After reducing the amplitude displayed on the color bar, another zone would become more apparent that lied between the fault and the previous zone. This zone had a relatively high amplitude, but was chaotic,and locally moundy looking. The last zone carried out past the high amplitude zone with low amplitude concordenant reflectors that went up to the erosional truncatation.

The Three zones matched the concepts of the three facies as defined in the previously mentioned analogs. By using the fault picking mode on the workstation to pick each of these characteristics on the lines, we were able to do a stratal interpretation on the work station. Each valid reflector was picked as a fault (vector list) thus maintaining the stratigraphic character of the line. When these picks were displayed in cross sections, the fans and different facies became apparent. The moundy, chaotic reflectors near the fault became the proximal fan breccia and massive conglomerates as seen in well 36. The short high-amplitude reflectors in low amplitude/frequency data are the middle fan braided stream channels and middle fan conglomerates interfingering with shales similar to well 34. The concordenant lower amplitude reflectors become the interfingering thin sands and shales in the distal portions of the submarine fans.

Our approach at this point was regional due to the lack of time remaining until date of presentation, and the long time taken in working out the structural picture. We chose seven lines surrounding the existing well control and picked each line with the stratal approach as mentioned above. The lines chosen were (dip lines from N to S) 1357, 1351, 539, 1339, 535, and 520 (a strike line), and an E-W line 571 which crossed the key wells 36 and 34. After picking each line and defining sub-units as possible fans, we brought the data into FMAP for the ability to review the data in 3D and in cross section mode. After assigning each segment to one of the three facies or as a volcanic, we made perspective views to compare the relationship of the lines and the stratigraphy. The data was defined so as to display the findings as three units which had the geometry of large fan complexes. FMAP gave us the ability to display one fan at a time or all three simultaneously. This gave us the ability to relate the fans to each other, and see their individual geometry.

We then went back to the seismic and used regular horizons to envelope the middle fan environment in each of the three fans. These horizons were then used to generate isochrons of the middle fan facies. When the three maps were overlayed one could see the depositional meandering of the fan bodies as they filled the holes created by the previous deposition. Then individual horizons were mapped to show each conglomerates extent.

In order to check our theory, and gain a better feel for the deposition, we flattened the seismic lines on the T-5-2 and then displayed the stratal interpretation on each of the lines. The only real surprise was the thickness of the middle fan environment in relationship to the near fan slope deposits. If the fan shapes were correct, the bulk of the deposition came over the breccia and was laid down in the middle fan environment. The study in Greenland showed this as a possibility as the breccia there was deposited over by stream deposits.(Surlyk 1981). If not correct then the fans will need redefining and should be done on flattened sections.

The volcanics were also picked in the stratal interpretation with several things coming out. The volcanics as interpreted never came higher in the section than the T-5-2. They also cut across the bedding planes of the conglomerate fans. These two considerations lead one to believe that the volcanics are either older than the T-5-2 or never found a pathway or gained enough pressure to come above the T-5-2. Since the pressure in the subsurface would be decreasing as it got shallower, I do not place much faith in the second assumption. The volcanics also seemed to come out of deep seated faults. Just below the area with the volcanic intrusives were several large mounded reflectors which were interesting both as potential deep fans or else as the deep sources of the volcanics. It will take a lot more work to feel comfortable with either.

There are several characteristics about the volcanics that seem to differentiate them from the volcanics in small ways. First, the volcanics are more homogeneous and provide a better reflection than the conglomerates. The density of the volcanics and the conglomerates is different and this also helps. The volcanics also were intrusive and did not follow the bedding planes consistently, but seemed to follow weak zones in the rock instead. Some of these things seem to explain the results of the amplitude with offset study that was done.

AMPLITUDE WITH OFFSET STUDY

With the above differences in mind, it seemed appropriate to look at the changes in amplitude on the offset records where the differences between the two rock types should be maximized. The big advantage of using the workstation verses record by record analysis is the ability to see the results in a map format along with all the horizon, fault, and processing techniques available to the interpreter.

We only had one line with trace data over both volcanics and conglomerates, line 546- a north south line going through the production area. The line was loaded as a 3D survey with the line direction being shotpoints and the trace direction being the offset traces on each shotpoint. The line was then processed for each of the attributes and displayed. Due to the quality of the data an AGC was applied with a 3.6 second window to normalize the amplitudes trace-to-trace. The horizons for line 546 were brought in on the appropriate shotpoint/traces and then interpreted down the offset direction. The amplitude was extracted and then displayed as a raster horizon.

In viewing the results in map form there was a difference in the response of the volcanics and the conglomerates. The volcanics amplitude carried to the far traces and the conglomerates amplitude decreased with far offset. Keeping in mind that this was a single line test, we found the results encouraging. We expect this phenomenon is related to dispersion of the seismic energy by the conglomerates at low angles of incidence. It will be something to consider in further studies.

MODELING

There was not much time left for modeling so only first passes at two models were attempted. The first was using GEOSIMS STEP program which is a log interpolation program. The three wells that line 571 cross were used and a basic model was defined using the horizons from the seismic. The program then interpolated between the logs using parameters we input. The resulting model demonstrated the characteristics expected for a pinching out sand body as those found in the middle fan facies. Further refinement would enhance the results we had.

The second pass at modelling utilized Landmark's UNISEIS raytrace modelling system. Two models were generated from horizon and fault interpretation on seismic lines 1339 and 571. Depth conversion was achieved by using an power function fitted to the same set of time vs. depth data provided by the Interpretation Center as was used to depth convert maps. The data was plotted linearly and as a In/In plot. The In/In plot showed 3 distinct linear segments. Upon further investigation, the breaks in slope were extraordinarily good fits, with statistical correlation coefficients better than 0.999. This is consistent with prevailing mathematical models dealing with basin fill velocities.

Severe distortions to the model geometry occurred when attempting to use these three functions to convert to depth. The extreme magnitude of block faulting brought out the need for either a much more detailed set of velocity control or to fall back on an approximate depth conversion using a single power function fitted over all the time/depth points. This latter function yielded a respectfully good fit, with a correlation coefficient of 0.998. The depth converted model produced was considered more than adequate for the first pass.

Normal Incidence runs were made on each model. This mode emulates the stacked, unmigrated seismic section. Ray traces of individual layers within each model were also run to aid in interpreting the events on the time series traces. It can be seen from the models that the volcanics are not clearly distinguished from conglomerate beds in conventionally acquired and processed data. Also, conglomerate pinch outs are subtle, but apparent in modeled traces. Whether they are equally visible in real data is dependent on quality of the data and the migrations.

PROSPECTS

Due to the proprietary nature of the prospects, we did not bring back to the United States any specific locations, nor do I plan to discuss them here. Rather a generalized approach on what to do with all the 165+ maps on the workstation in order to find oil would seem appropriate. My interpretation is limited to a very localized area and some of these thoughts might change if the larger picture were brought into focus.

The isochrons seem to me to be the place to start looking. I would start with the envelope around the middle fan and then do detail mapping on the horizons of interest within. The individual horizons will have a shape characteristic to their deposition and the present day structure will be crucial. I would also flatten at the base of the fan to see which way any oil would have migrated. We only did three fans, and there is a lot of potential to the North and South along the fault scarp. The fastest and safest bet seems to stay above the T-5-2 to avoid the volcanics. Then carry the interpretation down to the deeper conglomerates, which will probably have a more massive appearance than the shallower ones which had a larger area to deposit in. Once the deeper horizons have been mapped, and probable volcanics sorted out, a detailed analysis using offset studies could be of great assistance.

Before drilling recommendations were made, the porosity maps and thickness maps on the computer should be overlayed on the prospect maps to check out known geology and verify porosity. By combining each of these items, and additional 5-8 wells will probably become available on short term notice along with the 5-7 locations discussed jointly in China.

LOOKING FORWARD AND BACK

There are several things that seem important looking back, the stratigraphy should play a greater role in deciding the structural fabric of the basins. The relationship of the geology to the mega units of the seismic should make carrying around the horizons easier. Then a much more detailed approach to the velocities would solve many of the problems we had. Using a single velocity in such a complex structure and stratigraphy to me is obviously dangerous. In the longer term, the lines need to be processed with wavelet processing to get them all on the same wavelet. There were too many lines that just didn't tie that should have. I am highly suspicious of large phase differences between several of the lines that could be corrected with wavelet processing.

I mentioned early on that one of the tools I felt would be a key in differentiating volcanics and conglomerates would be a shear wave study. Especially after seeing the amplitude studies done on the offset traces, I think the shear wave approach would delineate a lot of things not yet seen. Even longer offsets to allow converted wave studies might help.

SUMMARY

The Ling Guo basin is a rift basin filled with Oligocene conglomerates coming from the nearby paleozoics which also form

the half-graben Buried Hills that have provided much of the oil production from the Eastern China Platform. These conglomerates formed a series of fan-deltas, and submarine fans in the lake that shored on the rifted fault scarp. The facies can be broken down into three major facies that can be linked to the subsurface control, seismic data, present day surface deposits, and similar analogs in other parts of the world. Basic stratal interpretation techniques can help to differentiate these zones and help distinguish the conglomerates from local intrusive volcanics. Additional offset amplitude studies provided interesting data to be used in further analysis.

There were comments about finishing the project being made from the first week I was there, and I see this as a project that will never be finished. But I feel we attained our major goals, at least those that were physically realizable with the resolution of the data. There were many explorationists who now can use the workstation to accomplish their goals, if they are willing to trust themselves and sit down and try. The Training will be an ongoing thing. The technology transfer and search for oil will hopefully be a continued joint effort for many years. And the interpretation will continue on as long as someone has hope for one more well.

The project brought many new ideas out that had not been used before, both by the Chinese and Landmark. We have shown that the workstation can be used effectively if one is willing to sit down and use it. Several techniques have been shown to use the workstation effectively for structure and stratigraphic interpretation. Both the Chinese and Landmark have much to gain in continuing a joint transfer of expertise, ideas and the ever changing Technology.

ACKNOWLEDGMENTS

A project like this is never done alone, but there is always a large number of people who worked very hard to make it a success. As is normally the case, I will not be able to recognize most of these people but I must make special notice of several who did so much.

My special thanks go to the Chinese people who worked so hard for so many very late nights, and then turned around a were gracious hosts for my four months in China. Mr. Yuan was always there with a challenging thought, Madam Zhong fought the structure so diligently till we felt good about it, and my good friend Mr. Fang, who kept us honest and happy. The interpreters, who are Madam Li and Mr. Chen and the young aspiring geologists, geophysicists, and programmers, Mr. Shi, Mr. Wang, Mr. Chen, Miss Lee, and Mr. Wu, who put up with my odd humor and still worked till the wee hours of so many mornings. Madam Jhao and Madam Wang supported us from the Interpretation Center with tapes, synthetics, paper sections, very good interpretations and many smiles. I was told that there were 5 very highly respected geophysicists in the Bureau and we had the privilege of working with the top three.

From Landmark's side the same problem exists but I must mention several names. Dr. Brad Macurda, from the Energists, helped the project start off by setting a stratigraphic mood and helping get the basic framework going. The leadership team that committed the resources to make this project happen included Mr. Gene Ennis, Mr. Ken Strode, and Mr. Richard Todd. Mr. Chuck Edwards provided support and insight throughout the project. Mr. Roice Nelson added his management capabilities to his magic touch on the computer (and many hours) to bring it all together. And last but not least, my wife and family, who put up without me for the time I was gone.

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Outline-Joint Interpretation Project Presentation - 07 July 1987

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      - f. Fault Maps
    - ii. Isochron and Residual Maps
      - a. [T-5]-[T-2]
      - b. [T-5-2]-[T-2]
      - c. [T-G-1]-[T-2]
      - d. [T-5-2]-[T-5]
      - e. [T-G-1]-[T-5-2]
      - f. [T-G-1]-[T-5]
    - iii. Velocity and Depth Maps
    - iii. Conglomerate Maps
    - iv. Volcanic Maps
    - v. Thickness Maps
    - vi. Amplitude Maps
  - F. Prospects
  - G. Models
    - i. Step
    - ii. Geosim
    - iii. AGS
  - H. Amplitude with Offset Study
  - I. Wavelet Processing
  - J. Drilling Recommendations

III. Plans
  - A. Interpretation Project
  - B. Landmark Plans

Joint Interpretation Project Landmark Presentation - 07 July 1987

We are pleased to present this report on our joint interpretation project in the Lang Gu Basin. Because of the limited time available for presentation, we wrote our presentation out and will have it read only in Chinese. However most of the interpretation team is here to answer questions. Participants in our interpretation team come from Zhi Da University, the Bureau of Geophysical Prospecting, the Ren Qiu Oil Field and Landmark Graphics Corporation. You all know the Chinese corporations. However, you might-not know Landmark and so we will start by briefly introducing the company.

Landmark is a prototype of the new type of products company that will become one of the major big businesses of the future. Many of you remember or have heard about when GSI formed Texas Instruments (TI) as a new type of products company, specifically to build electronic equipment to support seismic exploration. Of course, you know what a major international company TI has become. Similarily the next major business development is just beginning now. These companies are building interactive scientific and business workstations to improve the productivity and quality of results for a variety of business processes.

Landmark is the only successful company like this in the Geophysical marketplace. Landmark is the leader in building microprocessor based workstations optimized with turn-key software solutions to aid oil and gas exploration. Landmark has sold more interactive seismic interpretation workstations than all of our competitors combined. In fact, eight days ago, Landmark signed a single contract, with one of the five largest international oil companies, for 20 workstations. THIS ONE ORDER is for more seismic interpretation workstations than the total number of presently supported workstations delivered to oil companies by any of the other companies participating in this interpretation system evaluation evaluation. First slide please.

S1L A Joint Interpretation Project in the Lang Gu Basin

Participation in this interpretation project has been a good learning experience for both Landmark and our Chinese partners. Our use of Landmark products for what they were designed to do has helped us learn more about our strengths and to recognize some weaknesses. We have already made major efforts to correct obvious weaknesses. For instance, two days ago we first demonstrated ~~a~~ new ~~set~~ 2D interpretation menus, displayed with Chinese characters in order to help remove the language barrier from efficient use of our products in China, as shown on the slide on the right.

S1R Picture of Chinese Character Menus on Screen

As we present the results of this joint interpretation work, you will see the major strengths of our interpretation system. We hope this joint project has provided a precident for future joint development between Landmark and the Ministry of Petroleum Industry, the Bureau of Geophysical Prospecting, and various Chinese oil fields.

S2L The Interpretation Team

Before talking about the project we would like to briefly introduce all of the members of the Landmark interpretation team.

Zhi Da University
- Madam Zhong, interpretation team leader
- Miss. Li, secretary
- Mr. Wang, programmer
- Mr. Chen, young geophysicist
- Mr. Li, translator

Bureau of Geophysical Prospecting
- Madam Wang, processing and aided interpretation
- Madam Jhao, paper section interpretion

Ren Qui Oil Field
- Mr. Fang, senior geologist
- Mr. Shi, geophysicists and interpreter
- Mr. Wu, programmer
- Mr. Xu, young geophysicist

Landmark Graphics Corporation
- Mr. Chuck Edwards, recently retired corporate geophysicist Cheveron Oil, now on Landmark's Board of Directors, and has been consulting on the project plans since the beginning.
- Mr. Gary Jones, seismic stratigrapher, Landmark's key technical support for this project.
- Mr. Roice Nelson, geophysical support.
- Mr. Geoff Morris, geophysical support, AGS modeling and Dynamic Graphics mapping expert.
- Mr. Mel Carter, formally a Vice-President of Energy Analyists and recently joining Landmark when our companies merged. His speciality is velocities and he reviewed the well and seismic velocities to guide proper depth conversion of the maps.
- Mr. Bruce Day, customer support engineer.
- Dr. Brad Macurda, a world class seismic stratigrapher that teaches to most of the major oil companies worldwide through his company The Energists and through Geoquest International. He is doing several projects with Landmark because our workstation is the best and most widely available.
- Mr. Noel Duncan, customer support engineer.
- Mr. Charlie Win, programmer, responsible for creating Chinese menus.
- Mr. Don Vossler, programmer, developed code to provide large scale seismic hardcopy.
- Mr. Richard Todd, formally manager of computer systems for Texaco New Orleans, and is now Landmark's manager customer support. He coordinated the people and Singapore equipment logistics.
- Mr. James Moore, hardware maintenance engineer.

S2R The slide on the right shows our senior seismic interpreter, Madam Zhong, working at the workstation. Like many senior interpreters, she did find it useful to work with the paper sections in conjunction with working on the workstation.

S3L Mr. Fang, our geologic conscience, made sure that the interpretation made geologic sense. He not only worked with traditional geologic data displays, but he became very good at doing interactive 2D interpretation.

S3R The slide on the right shows Mr. Fang and Madam Zhong hard at work on the interpretation of the fans.

S4L and S4R The left slide shows Mr. Shi getting the results ready for this presentation. The right slide shows Mr. Jones working with Mr. Wu, Mr. Fang, Mr. Shi and Madam Zhong.

S5L We would like to start out the Landmark presentation by reviewing the goals that were presented to us in March when the interpretation project first started. These goals are listed on the slide on the left. We will just read them now to introduce everyone to the interpretation objectives. You will notice that it is not feasible to accomplish some of the objectives with the low frequency data available for the interpretation. At the end of this presentation we will review the objectives again specifying studies and results related to each objective.

1. Determine paleogeography of Oligocene
2. Study conglomerates within Oligocene
3. Map thickness and changes in conglomerates
4. Study changes in porosity of conglomerates
5. Identify source and extent of volcanics
6. Find high porosity zones in igneous rocks
7. Look for top and bottom metamorphism associated with volcanics
8. Determine the time of the igneous intrusions
9. Study faults in conglomerates and volcanics
10. Identify potential hydrocarbon traps

S5R The slide on the right shows the project location in the Lang Gu Depression. Our area of study is outlined in red in the northwest corner. The study area is called JIJI.

S6L We used as many types of data as possible to help us do the best possible interpretation. Gravity and magnetic maps provided a nice regional picture of the depression. The slide on the left shows the control points that were entered and a triangulated contouring of the map. The two white marks in the center of the yellow map show the location of a major gravity high.

S6R This gravity high is highlighted with the color map used for displaying the gridded and smoothed gravity map. The red-blue boundary marks the boundary of the major basin controling Da Xing fault and the buried hills to the right. This gravity high was key to interpreting the key structural elements in the Jiji area.

S7L and S7R These two slides are similar dislays of the magnetic map. The magnetic map delineates the buried hill, as colored red on the smoothed and gridded map. It also shows well the deepest portion of the basin, as highlighted in dark blue and purple on this map. The slide on the left also includes two different perspective displays of this map. Flexible displays and different methods of looking at data values is one of the major advantages of interactive interpretation.

S8L There is a major unconformity at the Base Neogene which averages about 600 meters depth across the area. All of the prospects are buried beneath this detrital material. Since the Jiji area is buried, there was no surface geologic information available. However, there has been a lot of exploration work in this area. This is shown by the geological cross-section on the left slide showing the Lang Gu oil and gas traps.

S8R Even though there was not surface geological information, there was a lot of subsurface geological information available. The slide on the right shows an example of available well information. This geological cross-section runs east-west across the area of interest along seismic line LF78-571. Well data was available from wells 36, 34, 38 and 16. This cross-section was made to highlight the key seismic horizons that were interpreted, including T-5, T-5-2, and T-G-1. One of the most exciting exploration data sources to Mr. Jones was the detailed cores available on all wells. Mr. Jones visited the Hua Bei Oil Field and evaluated several cores to help him better understand the conglomerate objectives. High quality core samples were taken through-out the drilling, including samples from all of the different types of lithology. This quality of information is not normally available in the United States, since the normal procedure is to only core the sands..

S9L Three of the logs shown in the previous paper log display are shown here as displayed on the interactive system. These composite log displays consist of up to 5 synthetic traces, an SP log, a lithology log, the resitivity log, a sonic log, and a gamma ray log. The colors on the lithologic log are orange for conglomerates, yellow for sands, blue-green for shales, and purple for volcanics. There is also a darker blue color set up for limestones, but it is not used on these three logs. The display on the left has been interactively labeled with information about porosity, production, and well name.

S9R The display on the right is of the same three logs, but the logs are displayed separated by the seismic control. The seismic control also has the key horizons posted. The top horizon is the T-2, which is the Base Neogene and is colored yellow in this display. This horizon's color is actually red, but the active horizon, or the one being edited, is always displayed in the annotation color. The blue horizon is T-5, or the Top Sha-3. The orange horizon is the TC04, or the Top of Conglomerate 4. The green horizon is T-5-2, or the Middle Sha-3 horizon. TV01, TV02 and TV03 are volcanics and are colored violet, blue and purple. At the bottom of the right two panels is a green horizon, T-G-1 or the Top Ordovician. Faults are also posted, and the yellow fault in the right panel is the Da Xing fault that controls the half graben basin we are working in.

S10L This project was largely based on the seismic interpretation. The slide on the left is a zoomed map of the area. The location of line 571, which was shown with the well displays in the last slide and is repeated on the right hand side, is highlighted in green. The three horizontal lines at the top of the map are where the well log information is stored, which allows it to be projected onto any appropriate seismic section.

S10R The seismic section on the right is typical of the quality of data used for the interpretation. Available seismic data consisted of 52 recently reprocessed and migrated 2D sections. These data were provided in a SEG-Y format at 1600 bpi. Because of reprocessing, some of the lines used were not available on tape until a couple of weeks ago, or three months into the interpretation project. This made it important to be able to pick on paper sections and/or digitize those picks into the interactive system. This capability also made the transition easier for some of the older interpreters that are used to working with paper sections.

S11L** and S11R A majority of the interpretation time has been spent developing a structural picture of the basin. The left slides shows Line 571 with the interpretation of the objectives we will be working towards, ~~have been looking at. The left shows the data~~ and the right slide highlights the interpretation picks. The horizons that were picked, going from top to bottom, are: the red horizon, T-2, Base Neogene; the blue horizon, T-5, Top Sha-3; the orange horizon (colored yellow because it is the active horizon), TC04, Top Conglomerate 4; the green horizon, T-5-2, Middle Sha-3; the violet, blue and purple horizons, TV01, TV02, and TV03, the volcanics; and the dark green horizon, T-G-1, the top Ordovician.

S12L and 12R These slides show the location and migrated section of north-south line 546. The yellow vertical lines are well position and Resistivity or SP logs. Notice the low frequency of the data, and the strong migration effects. The effects of the major Da Xing fault that defines the north and western edge of the basin is seen at the left edge of the section.

S13L and 13R The horizons are reasonably obvious once the structural relationships have been worked out. One of the most important and critical parts of the interpretation was building a reasonable fault pattern that fits seisimc and geologic control. The fault picks that are on these sections have been assigned to specific fault plnaes. Tools to interprete these fault planes was one of the big advantages of the interactive system. The fault interpretation package allows the interpreter to draw faults anyplace they are recognized. These "unassigned" fault picks are then correlated into fault planes using a variety of graphics tools including map windows, cross-section windows, perspective displays and dynamic color control. When an "unassigned" fault segment is assigned to a fault plane it is given a user defined color as shown on this seismic section. Another capability is the ability to draw a polygonal window on the screen and drag the window to correlate horizons and seismic across faults. A small yellow drag window was drawn on this section to illustrate the process.

*However, like many interactive procedures this is hard to demonstrate this process using slides. It should be pointed out that many of the slides taken off of the screen do not have the same quality that is seen by looking at the screen.

S14L and S14R These slides show the results of the fault correlation process. The same windows are in each section. The faults on line 571 are shown in the cross-section window just above the map view. The long line above this is a south-west to north-east line 520. The other five cross-sections are perpendicular to 520, starting at the north of the survey and continuing to the south. Each of these lines are about 5 km from it's neighbor. This set of lines will be used to describe the results of the interpretation project. The differences between the ~~two cross-sections~~ displays are found in the map views. The left slide only highlights faults cuts that are between 300 and 500 ms. There is only one major fault this shallow that cuts the Base Neogene, and this is shown as a yellow triangle in the north-west corner of the map. The slide on the right shows fault cuts that are between 1.0 and 1.5 seconds. It is obvious that at this time we are cutting many of the faults. For these displays the faults are colored according to their individually assigned colors.

S15L The camera was zoomed in on the 1.0-1.5 second window on the fault plane map in the slide on the left to show the complexity of the structural interpretation.

S15R One of the many advantages of interactive interpretation is the flexibility of viewing the data offered the interpreter. The right hand slide is the same map, but the contours are colored as a function of time instead of fault color. In addition, the system allowed the interpreter to make an instant pixel replecation zoom of the window.

S16L and S16R Perpspective views are very useful in relating different faults. These slides show the same 1.0 to 1.5 second window of the fault planes, but in a perspective display. The left window is colored according to fault colors and the right window according to travel time. The yellow fault in the back is the Da Xing fault.

S17L and S17R At deeper times we note that the Da Xing fault has the same shape as was noted on the regional gravity and magnetic maps earlier. The left slide is a window from 2.0 to 2.5 seconds, and the right slide is a window from 3.0 to 3.5 seconds. Notice how much the Da Xing fault moves spatially at depth.

S18L and S18R The curved shape of the Da Xing fault is highlighted in these perspective displays. Note that the time colored fault-plane-windows show the attitude or dip of the fault plane, while the fault colored fault-plane-windows allow the interpreter to rapidly identify which fault is which.

**S19L The fault pattern was partially unraveled as horizons were picked. The table on the left hand slide shows different geologic layers for the area and their relationship to the seismic horizons. In order to further describe the basin structural setting, we will review the four key structural maps generated during this interpretation project for the seismic horizons T-2, T-5, T-5-2, and T-G-1. We will also review the associated paleogeographic or isochrons maps associated with these regional horizons.

S19R The slide on the right is a perspective view of the top seismic horizon named T-2. Notice that the T-2 is relatively flat. This horizon is at the Base Neogene. The map was calculated using the Dynamic Graphics mapping package on Landmark's new RT product in the Singapore office. The paper maps were plotted using the pen plotter at the Zhi Da University. The Dynamic Graphics mapping package will not run at the Zhuoxian system site until that system is upgraded to Unix. However, with that upgrade that system will be able to run any mapping system of choice. Landmark users tend to like different mapping packages depending on the part of the world they live in. For example, several customers in England use Zycour, in continental Europe they use Sattlegger, in the states Radian, and each major oil company has their own mapping package.

S20L and S20R These two slides show T-2 as calculated on the workstation. There is a quick mapping package avaiable called HMAP that triangulates surfaces across control points. The slide on the left shows the result of this process. This package also allows cross-sections and perspective views to be made of any map, any portion of a map or combinations of maps. HMAP assumes flat triangle sheets between control, and there are often edge effects because of this. By reading these surfaces into a grid, and smoothing the grid with the 3D interpretation software's horizon computations a good quality map can be quickly generated. Edge effects seem to be the only major problem with this process. The straight blue line at the south-east corner of these maps is an example of how the process straight-line interpolates between control. The white lines on the right slide represent the seismic line locations, and the black crosses show well locations.

**S21L and S21R Edge effects and fault polygons can be eliminated by drawing polygons around areas of no control. These maps of T-2, the Top Sha-3, show a large blank area in the north-east corner of the area. This is the location of a buried hill, and the T-2 is eroded here. One paticularly useful interactive tools was to calculate the intersection between the fault planes and the horizon, and then use this as line as a guide to drawing the fault polygon. As you remember from the gravity and magnetic maps there is a deep depression in the south part of the area. At the T-2 level there is an unusual high ~~at the T-2 layer~~ that the interpretation team named the pagoda. This local high is marked with the cursor on both the HMAP and smoothed-gridded map. The effect of the fault polygons is highlighted by the sinusoidal data gap on the west side of the map. This is Fault 2, the blue fault in the fault displays we looked at earlier.

S22L and S22R It is a simple process to subtract the shallower T-2 from the deeper T-5 to create an isochron map. This map shows the paleogeomorphology of the T-5, or top of the Sha-3. The left slide shows a Dynamic Graphics display of the isochron. The thicks were colored orange. The smoothed gridded map on the right shows the same information, but the colors are reversed. The darker colors show the channels and the yellows show the thins. The colors can be dynamically changed on the screen to emphasize areas of interest, which needless to say is not possible using colored pencils.

S23L The Middle Sha-3, T-5-2 horizon, was the most structurally complex horizon interpreted. The left slide shows an HMAP representation of this surface. The colors selected are a little bright and do not emphasize all of the fault polygons. The data cutout on the east is from the buried hill.

S23R Of course, the smoothed-gridded map shows the same structure. This seismic horizon drops off from 700 ms against the buried hill in the north to 2200 ms beneath the Pagoda and to almost 3200 ms in the south-east portion of the study area.

S24L These slides show the smoothed-gridded isochrons from the T-5-2 to the T-2 and to the T-5. There is a lot of similarity between these maps. The left hand slide, the [T-5-2]-[T-2] isochron, has the cursor on the Pagoda. This shows the high has moved about 10 km to the south-south-west when compared with the T-5 horizon.

S24R The right hand slide is the [T-5-2]-[T-5] isochron. There is a channel of sediments between the Pagoda and the Burried Hill that is highlighted by the blue contours and the cursor.

S25L and S25R The T-G-1, the Top Ordovician, is a lower limit on the potential conglomerates for the area of study. These maps show a complicated structural picture. There are a dozen major faults at this level that are associated with ~~continued with~~ continued subsidence through the Oligocene. The high is colored yellow on both the HMAP and the smoothed-gridded maps and is associated with the buried hill. The deeper portion of the basin to the south shows no effect of the pagoda.

S26L and S26R These slides show the [T-G-1] to [T-2] isochron or the full Oligocene. The thin associated with the buried hill is again colored yellow and red. The deepest portion of the basin is best highlighted with the smoothed-gridded map on the right. The cursor was placed on a thin or a paleo-high north-west of the buried hill. Note, the color map that has been shaded in steps to highlight the illusion of thickness in the purples.

*S27L The [T-G-1] to [T-5] isochron is similar to the previous map. There is a paleo-high that is marked with the cursor in the south-west quadrant on the HMAP display on the left. The T-G-1 picks on the buried hill have large gaps associated with the basement faulting. This separation was highlighted by placing a black marker in the time window where there was no control. The fault gaps were not drawn in as heave lines on the isochrons, since there is still thickness from the fault plane to the next higher horizon.

S27R The slide on the right is another example of a Dynamic Graphics map. This map was generated for the same [T-G-1] to [T-5] interval as is shown on the left.

S28L These slides show the isochron of the Lower Oligocene or the bottom half of the Sha-3. This map shows the top of the Paleozoics. The high on the east side in the center-south portion of the Jiji area was picked on line 535. When the map was first displayed there was concern that it was wrong, until the seismic data was checked.

S28R When this smoothed gridded map is overlaid on the [T-G-1] to [T-2] isochron it shows that the T-5-2 was not picked across the buried hill. In reviewing the seismic it was discovered that the reason is that T-G-1 was not picked on the downthrown side of the Tomba Fault or F-1. It is possible that the alternating lows and highs against the buried hills are related to ancient fans off of the buried hills. This is probably to deep to be presently economic.

*S29L and S29R These slides summarize the major structural points of the Jiji prospect area. The T-G-1 horizon is plotted in the background. Both maps have the Gravity map overlaid. The effect of the buried hills is obvious on the gravity high. The relation of the drop off of the high and the basin controlling Da Xing fault were discussed earlier. The right hand slide has the location of the 9 seismic lines selected from the 48 lines interpreted overlaid on the maps. NP

S30L The slide on the left is a map of existing production in the Lang Gu Basin. The Jiji area is outlined in red at the north-west corner of the basin. This map is shown here to show how the fault and structural interpretation presented to this point is related to the exisiting understanding of the basin. We would like to spend most of the rest of our presentation discussing the detailed interpretation of the conglomerates and volcanics, and this prospect map acts as a good introduction. NP

S30R The slide on the right shows a geologic analog to the Jiji project. It consists of submarine fan deposits in Greenland as mapped by Finn Surlyk (from The Sedimentology of Gravels and Conglomerates, CSPG, 1981, p.359). This is a close analog because there is a large fault scarp like the Da Xing fault. There are also massive conglomerates being deposited on the downthrown side. The formations have been mapped on the surface in Greenland and match many of the facies characteristics from the well cores from the Jiji area.

S31L The slide on the left shows northwest-to-southeast trending Line 1339 with the well data from wells 36 and 101 inserted. The regional horizons that we have been reviewing are posted to show the intervals of interest. This line and line 571, which was shown earlier, have the characteristics expected for massive fan deposits. The proximal fan has a mounded or humocky appearance to the data. Often this is with medium to high amplitude reflectors over a short distance. The middle portion of the fan becomes more concordant with higher amplitude continous reflectors. These reflectors are interterpreted as being related to channeling, subaqueous bars and massive gravity slump deposits. The distal portion of the fan is low amplitude mudstone and sand stringers. These often give long, continuous, low amplitude reflectors.

S31R The slide on the right shows a depositional model for generalized facies relationships and inferred depositional environments (after Wescott and Ethridge, 1983). The area we are interested in for our interpretation project goes from the slope to the proximal submarine fan to the distal submarine fan environments. In the slope environment the deposits are massive conglomerate detrital deposits, or base of slope breccia. The proximal submarine fan is associated with braided fan channels which interfinger with the shales. This forms the middle fan channel deposits, with minor sorting, lower clay content and increased permeability and porosity. In the distal submarine fan environment there is more fingering of thin sand stringers and mudstones. This depositional model is for the lower Eocene Wagwater and Richmond Formations, Wagwater Trough, eastern Jamica.

S32L and S32R These slides show a depositional model of conglomerate fans in both cross-section and map view (after Surlyk, 1981). These examples are based on fans in Wollaston Forland, Greenland that date to the Early Cretaceous time. The facies as described by Surlyk is a very close fit to the facies analysis as done interactively on the Jiji seismic data. In both areas the conglomerates show an overall lack of grading and an absence of sedimentary structures. Both areas are clast supported with a mudstone matrix. The clasts vary from pebble to boulders in size, and are poorly sorted. The combination of the type of mudstone and the massive deposits of conglomerates indicate submarine fan type deposits. In Greenland. the facies change from a base of slope brecia to a braided fan channel to outer fan mudstones and thin sands. Both the seismic and the cores indicate the same environment exists in the Jiji area. The braided fan channel facies is the best facies for development of porosity and entrapment of hydrocarbons as they are fingering in and out of organic rich shales. The production from well 34 appears to be from this type of fan channel.

S33L and S33R Inorder to review the conglomerate fan interpretation in detail, we will step-through the seismic and associated interpretation on eight critical sections. The northwest-to-southeast sections that cut the Da Xing fault in the dip direction are 1357, 1351, 539, 1339, and 535. The dip-direction sections are separated by approximately 5 km. Line 1357 is at the north of the survey, is highlighted with a green color on the location map, and has the curser pointing to it. The key perpendicular tie line is 520, which runs through where the cursor is. The slide on the right is the raw seismic data.

S33AL and S33AR The process used to interpret the fans has been catagorized as a stratal interpretation by Peter Vail. These slides illustrate the concept. Each valid reflector is picked as a vector list (unassigned fault segment). The stratigraphic character of the reflections are maintained, i.e. hummochy, concordant, parallel, etc. Packets of associated reflectors are assigned to the same file (called a fault plane, because we used the fault interpretation package to do this work). The pixel zoomed section on the right shows the three depositional environments we just discussed. The proximal fan is marked with orange picks, the middle fan environment with yellow and the distal fan with blue picks. Notice the chaotic nature to the orange picks, that can be associated with base of slope breccia deposits and reworked fan channels. The parallel strong reflectors in the middle fan zone are marked with yellow colors and finger into the more distal environment to the southeast. A point that will be confusing is that the intersections between different lines were marked with vertical yellow lines for the perspective displays of the stratal interpretation. These vertical lines can be confused with well locations because they were both given the same color in this set of slides.

~~**reviewed to here~~

S34L The slide on the left shows the stratal interpretation in a little more detail. The seismic data was colored gray using the color marker option, and then the image was pixel zoomed. The different fan characteristics are obvious on the section. Three separate fans were picked using the stratal interpretation technique. They are refered to as the Upper, Middle and Lower fans. This will be particularly important later when we look at thickness maps of these depositional packages.

S34R The right hand slide is included to allow easy correlation with the structural interpretation of this same section. The fans lie in the geologic window between the T-5 (blue) and the T-5-2 (colored yellow because it was selected as the active horizon). Note the relationship to the Da Xing fault (yellow) to the northwest (left).

S35L and S35R These are the last two sections on line 1357. Here the Middle Sha-3, T-S-2, was flattened to show the paleostructure. The shape of the fan is even more pronounced with these displays.

S36L and S36R These two slides show the interpreted structural environment for line 1351. Notice the termination of the Upper Sha-3 between the blue (T-5) and yellow (T5-2) horizons against the Base Neogene (T-2). This occurs in the distal subaqueous fan environment. Once an interpreter is looking for this type of information is is relatively easy to recognize.

S37L and S37R These slides show the stratal interpretation for line 1351. The middle fan was the only fan picked on this line. Notice on the right-hand slide all of the dashed lines. Since the stratal pattern is being picked using the interpretation tools developed for fault interpretation, it was interesting that when the stratal picks were made on the sections on either side of line 1351, that the upper and lower fans are projected onto this line.

S38L and S38R The next section to the southwest is line 539. These two slides show the interpreted structural environment for line 539. The yellow horizon above T-5-2 is TC04 or the Top of Conglomerate 4. Notice the shape created between this horizon and T-5-2. The thinning sequence to the east has the appearance of fan fingers.

S39L and S39R The stratal interpretation on this section closely resembles the geologic analogs presented earlier. The left vertical line shows the location of the intersection with line 520. However the two vertical yellow lines close together and to the right side of the section are logs from a significant discovery. Well 34 had multiple pay zones. There is 63.5 Tn/D of oil and 3532 M**3/D of gas between 1506 meters and 1535 meters. In addition, there is 174 Tn/D of oil and 6863 M**3/D of gas between 1542 and 1549 meters depth. The conglomerate is high, but trapping is controlled by updip pinchout. Porosity is fracture controlled.

S40L and S40R The paleo sections for line 539 flattened on the T-5-2 are an excellent example of the development of the conglomerate fans.

S41L and S41R The next two lines to the south were displayed simultaneously. The order from north to south goes line 539, line 1339 and the line 535. The location of these two lines is shown on the left and the structural interpretation is shown on the right.

S42L and S42R These two slides highlight the stratal interpretation on line 1339. There are two wells on this line. Well 36 is on the west and Well 201 is on the east or right. The vertical yellow line between the wells is a line tie with line 520 for the perspective displays. Both wells are downdip from well 34 and produced water. The character of each of the three fans interpreted using this technique (upper, middle and lower) is easily recognized with the stratal interpretation. There was great detail done in interpretating the hummochy characteristics of the lower fan.

S43L and S43R These two slides show the paleoreconstruction of the three fans by flattening on the T-5-2.

S44L and S44R These two slides show a pixel zoom of the stratal interpretation on line 535. Note that the bottom fan was not picked on 535, but the fault interpretation software projected it reasonably well onto the section. This projection process is by interpolation, and requires assigned stratal picks be on the sections on either side.

S45L and S45R **Line 520 runs along basically strike of the Da Xing Fault. This is shown on the structural interpretation. The Da Xing fault is the deepest pick, that looks almost like a horizon. Notice the conglomerate buildup above the T-5-2 where well 37 is drilled. This well has minor oil production. It is a good conglomerate, but is not as porous as updip wells like well 34.

S46L and S46R The location map on the left slide shows the portion of line 520 that is displayed. The displayed portion of the section is about 17 km. Notice that line 520 ties all of the other lines we are displaying to review the results of our interpretation. The well that was pointed out on the previous slides is on the stratal interpretation slide to the right. It is the only yellow line that gets up into the mute. The other vertical yellow lines highlight the location the ties to the dip sections.

S47L and S47R These two slides show an expanded view of the left or southwest end of line 520. Notice that we are at the distal portion of the conglomerate fan. The lower and middle fans each die out in this vacinity. Again remember that the two vertical yellow lines are line tie locations and not well locations.

S48L and S48R The northwest end of line 520 shows ~~the~~ that the lower fan has a thicker section of conglomerates. As you come up in the section, the overall fan movement is towards the Da Xing fault. In the bottom fan massive conglomerates are picked, while in the upper fans no proximal massive conglomerates are present. These are replaced by the distal fans and shales. This implies that the lower fan is farther out in the basin than the upper fans. These fans have large areal distributions. The portion of the line being displayed is about 12 km long and the fans have not started thinning out yet. This section also shows the undulating nature of the front of the fan. The fan axis is longer in the strike direction than the dip direction, which is expected because of the massive nature of the dump. Many of the sediments were probably worked up and down the strike of the fan.

S49L and S49R These sections are paleoreconstructions of line 520, again made by flattening on the T-5-2, Middle Sha-3 horizon.

S50L The next sequence of slides show how the tools available on a properly designed interactive system were used to do a detailed stratigraphic interpretation. The slide on the left shows a display of all eight sections of interest and their relative map position. Line 520, the diagonal strike line is drawn at the top. East-west line 571 is just above the map. The dip lines start with 1357 at the top, then 1351, 539, 1339, 535, and 533 at the bottom. The cross section windows on this slide show the stratal interpretation on all three fans. The color bar was used to highlight the differnt colors on the cross-section displays. The three large bars represent the three major environments: orange for proximal massive conglomerate dumps; yellow for middle sandstone and shale lobes; and blue-gray for distal shales and thin sand stringers. There are also six small bands of color that represent stratal picks that mark the upper and lower boundary of each fan. The upper fan has pink boundaries, the middle fan lime and the lower fan violet boundaries.

*S50R The way colors were assigned to the picks represting individual facies within each fan is shown on the data and "fault" color table. The words stratal picks should be used to replace fault picks, because we are using the fault interpretation tools to do a stratal interpretation. Three environments were picked for each fan before the stratal picks were assigned to an environment. This allowed the different fans to be individually evaluated three-dimensionally.

S51L and S51R These two slides show the upper and lower fan in cross- section and perspective views. The perspective displays are particularly useful in that they allow all of the data to be viewed simultaneously. For example, this view shows the spatial relationship of the massive conglomerates on three lines and both fans. The window on the left screen shows the subset of the picks that were displayed in perspective window.

S52L and S52R These two slides show the lower fan extent in map, cross-section and perspective view.

S53L and S53R A window was selected to cut down on the extent of the data displayed in the perspective view. The perspective view is looking at the massive conglomerates.

S54L The interactive workstation allows these perspective displays to be rotated dynamically. The slide on the left is a different view of the same subset of the lower fan in the same displays.

S54R The isochron maps of the three fans are shown on the right slide. Notice the shape. These maps were made by calculating an isochron along the 2D control, gridding the isochron in HMAP, writing the triangulated surface into a grid, smoothing the surface, and plotting each isochron as an individual 3D horizon map. Picture files were taken of each map and the pictures composited to show the relative extent of each fan.

S55L and S55R These slides show the spatial extent, cross-sections and perspective views of the middle fan. Notice that the shales and sand stringers seem to be quite far extended towards the southeast in the perspective display.

S56L and S56R These slides show the spatial extent, cross-sections and perspective views of the upper fan. Notice that the massive conglomerates are thick and form a vertical line paralleling the Da Xing fault.

S57L The left slide is a composite display of the lower fan, colored in shades of brown. Contours of the middle fan are overlaid. This map nicely shows how the deeper earlier fan controlled the location of the later middle fan.

S57R The right slide shows a composite display of the same lower fan, but this time it is overlaid with contours from the upper fan. Notice that the upper fan has approximately the same spatial position as the middle fan relative to the deeper fan. As the fans built up at the base of the Da Xing fault they migrated towards the northwest or updip the large controlling fault.

S58L The left slide shows a composite display of the middle and upper fan. This time the middle fan is displayed in color and the upper fan is overlaid as contours. Notice that the fans almost overlay each other, but deposition moved slightly parallel to the major fault and away from the middle fans.

S58R The right slide shows the stratal interpretation for the three fans along east-west line 571. The west end of the line is closest to the Da Xing fault. The hummochy character of the massive conglomerates is obvious in all three fans. The continuous reflectors in the middle environment are broken up by volcanics in the lower fan. The "V" on the volcanic picks was put there to identify the stratal pick as a volcanic when it was originally made. The top fan shows that the distal environment has moved to the west, which is both towards the Da Xing fault and south along the coast. This fits with the interpretation of the overlaid fan thickness maps, like the middle and upper composite fan mode on the left slide.

S59L and S59R These two slides show the stratal interpretation overlaid on two scales of 571 seismic sections. The volcanics stand out on these sections.

S60L The left slide shows the structural interpretation along line 571. Note the conglomerate, which is the yellow or active horizon on this section, and the three volcanic horizons beneath the T-5-2 horizon. The remainder of this presentation will cover some detailed interpretation done relative to these events.

S60R The right slide is the same section 571, but it was plotted on a color versetec in Landmark's Houston office. Notice that the horizons are posted on the hardcopy interpretation.

S61L and S61R Some of the detailed studies of the hydrocarbon targets were based on seismic attribute studies. These slides show small windows of interest over line 571 with several attributes. The left slide has two windows, one showing normal seismic amplitudes and the other a wiggle variable area display of the same set of data. The right hand slide has three windows with the standard Hilbert transform attributes of reflection strength, instantaneous phase and instantaneous frequency. One of the suprises was the way the frequency could be colored to highlight the some of the targets. Notice that this type of display allows the interpreter to visually compare different attributes of the same data immedeately.

S62L and S62R The next step was to tie these areas of interest down with the well control. These two slides show reflection strength on the left and instantaneous phase on the right with the data from wells 36, 34 and 38 plotted in splits in the seismic section at the appropriate traces.

S63L The left slide shows the instantaneous frequency section for east-west line 571 with the well information inserted at the appropriate place. Notice how the shale or distal portions of the fans can be recognized by the light brown or low frequency areas. This is especially true above TCO4, the Top of Conglomerate 4.

S63R The right slide shows the results of an amplitude study that was done on the producing conglomerate horizon of line 571. The first step of the study was to acurately pick the key reflectors. We picked the peak that is associated with the producing conglomerate shown on the well log. We then extracted seismic amplitudes, scaled the amplitudes so they would cross the horizon at the well log and then smoothed the scaled extracted amplitude. The resulting curve shows the extent of the amplitudes that are at least as strong as the amplitude at the well. This is a little to the left of trace 8000. We also extracted amplitudes from the strong trough that followed the conglomerate reflector, calculated a composite amplitude, and normalized this composite amplitude to use it as a scaling factor to correct the isocron between the two reflectors to reflect "net gas sand thickness." This test was over such a limited area and small number of lines that we could not confirm the value of the study. There was one oter factor that was interesting about this section and it was relative to the volcanics. We believe that the way the volcanics cut the horizons at the bottom of this section is related to this being close to the source of the volcanics.

S64L and S64R Another test we ran was to create a model across the section based on the sonic and density logs from the three control wells available for this section. This was done using the STEP program. This program will extrapolate well logs based on the interpreters guidance to create the type of model shown on the right hand screen. The menus are similiar to the menu shown on the left screen.

S65L and S65R These slides show the menu used to calculate and display the model as well as the results on the screen. The STEP package interpolates and extrapolates well logs and then calculates synthethics. These synthetic sections can then be directly compared with the seismic sections. We have a color versetec paper section and an Epson line printer generated synthetic section calculated for line 571 available for review by any of you that are interested.

S66L Amplitude with offset studies were undertaken to see if we could identify the differences between the conglomerates and volcanics. There were problems with the data that was available, but the results we obtained show promise. The left slide shows one of the problems we encountered. This slide is a near-trace gather of line 571, the same line we have been evaluating. Notice that there are a large number of traces missing, and furthere that these fall right where the key conglomerates and volcanics are located. Because the data in this gap is not available yet we went to a different line for our evaluation.

S66R The near trace gather for line 546 is shown on the right hand screen. Again blocks of CDP gathers were missing, but the traces over the key conglomerate and volcanic reflectors were there. A 3D project was created and the CDP gathers for line 546 were loaded as a 3D seismic survey. The three dimensions of the survey are trace along the line, seismic travel time, and offset. Loading the seismic this way allows the interpreter to display CDP gathers from any trace, or to display constant offset gathers at any available offset. Line 546 is 12-fold, so the 3D grid was 1000 traces/offset x 4.0 seconds x 12 traces offset/CDP gather.

S67L and S67R First we will review the stacked data. The left slide shows the entire line stacked. On the right slide the interpreted horizons are overlaid.

S68L and S68R These slides are a display of reflection strength for line 546. The horizons are again overlaid on the right hand slide.

S69L The left slide is a black and white display of instantaneous phase with the horizons for line 546 posted.

S69R The right slide is a color display of instantaneous frequency displayed in color. Notice the washed out areas above the T-5-2. These are the shale environments in the distal fan environments. Also notice how in the vacinity of the conglomerates and the volcanics the display is enhanced by the darker colors representing higher frequencies.

S70L and S70R Having reviewed the entire line we will now review a software zoomed window of data around the targets. These slides show the stacked data displayed black and white from traces 579 to 857 and from time 1290 ms to about 2200 ms.

S71L Although our interpretation team preferred to work with black and white seismic displays, color is always available to enhance the display. The stacked section on the left is shown to show the additional apparent frequency shown by displaying the peaks and troughs in different colors.

S71R The right hand slide is an instantaneous frequency display of the same data window, although the camera was a little closer to the screen when the picture was taken.

S72L and S72R These slides show the reflection strength section over the window of interest. Notice how stong the amplitudes are on the target conglomerate and volcanic horizons. The only difference between the displays is the color map that was used for the display. The left screen is graded from red to white, and the right screen has a color spectrum.

S73L and S73R These slides show instantaneous phase over the same data window of line 546. Notice the continuinty of the reflectors. The color map used on the right consists of thin colors at 5 key phase angles. Notice how continuous the events are across the section. This type of display is very useful for studing subtle faults, or correlating an event across faults.

S74L and S74R Having reviewed the data in some detail we will now review the results of the amplitude with offset study. These sections show the near trace gathers over the same window we have been looking at the stacked and attribute data over. The slide on the left is graded black to white and the right slide has been colored to emphasize certian amplitudes. Notice how poor the quality of the data is. This quality varied even more when the gathers were first loaded. There was considerable variation in trace amplitudes not only along the line but also in the offset direction. Therefore, in order to normalize the amplitudes trace-to-trace in both the trace and offset axes, an AGC with a 3.6 second window was applied to all of the traces. These displays are of data that has had the AGC applied.

S75L and S75R These slides show the data in both the trace and offset direction. The only difference between the two slides is that the left one is graded black to white and the right one is colored. Starting at the left of the screen we are at the near offset on trace 750. This first panel goes from near to far offset, just a 12 fold CDP gather. The second panel is a constant far-offset display from trace 750 to trace 700. The third panel goes, left-to-right, from far offset to near offset at trace 700. The fourth panel is constant near-trace offset from trace 700 to trace 650. And the last panel on the right is a near-to-far-offset CDP gather for trace 650. The horizons that were picked across this 3D survey are overlaid. The green is the T-5-2 horizon, which you remember we used to flatten displays on earlier. The orange horizon is TC04, top conglomerate 4. The three other horizons are volcanics, going from top to bottom TV01, TV02, and TV03. In the offset direction these amplitudes are the required NMO correction. Notice the amplitudes.

S76L Once horizons had been picked for each of the target reflectors at each offset there were some horizon computations and horizon displays made. The slide on the left shows a map of amplitudes extracted along the TCO4 picks. This is not a seismic section. It is a map, where the vertical axis is trace number and the horizontal axis is offset. The blacks represent strong amplitudes, and the overlaying contours are the times picked for the TCO4 horizon in trace-offset space. The contours in effect show how the velocity to correct for NMO varies along the line. These contours were displayed only to confirm there are smooth changes in the times representing required NMO correction. The important point about this display is that the amplitudes vary greatly in the offset axis. There is not a consistant amplitude at all offsets on any trace in the survey. This can be a result of many factors, but the leading hypothesis now is that it is a result of lithology.

S76R The right hand slide shows the same type of display for amplitude vs offset for the top volcanic, TVO1. Notice how consistant the amplitudes are at all offsets where there was a strong amplitude at the near offset. This appears characteristic of the volcanics. The traces that did not have strong amplitudes at the near trace do also not have strong amplitudes at the far offsets. This implies that whe the volcanics were picked they were laterally extended along the line farther than appropiate.

S77L and S77R These two slides confirm the results obtained and presented with the previous displays. The left slide is of the second volcanic, TVO2, and the right slide is of the bottom volcanic TVO3. The fact that where the amplitudes are strong on the near trace they are also strong on the far traces stands out in these displays.

S78L and S78R These are the final slides on line 546. The left slide shows a variable density display at the top and a wiggle variable area display at the bottom. The strong reflection amplitudes stand out on these displays. The right hand slide shows windows over the area of interest all along the line showing each of the different Hilbert Transform attributes: reflection strength at the top, phase in the middle and frequency on the bottom.

S79L and S79R The last slides of results from this joint interpretation project are related to the creation of depth maps. Landmark realized the importance of velocity to this study and so we did several studies. To briefly digress, about two months ago Landmark finalized the merger of a company in Dallas, Texas into our company. This company is Energy Analysts and one of their specialities is velocity analysis. A principal of Energy Analysts, and of course now a Landmark employee is Mr. Mel Carter. He is a world class expert in velocity analysis. The methods they have been using continuously for the last ten years are currently being programmed on the Landmark system. As a point of interest, the seismic velocity database technique was used by Occidental Petroleum in all seven areas of the initial offshore China study. Although the calibration step was ommitted du to the lack of well control, there were only five wells for over 100,000 km of seismic data, the accuracy of the velocity effort is indicated by the fact that the only component of the initial study still in use by Occidental is the seismic velocity database. Back to the report. Mr. Mel Carter took data from 12 wells and six key horizons and examined the time-depth conversion problem using both well depth data and seismic times. It turned out that a simple time-depth function is suffecient for converting time to depth. The maximum error from projecting the linear time-lines into the wells off of the seismic lines was just over 14 ms. Mr. Carter will be presenting a paper on the use of normalized velocities in the depth conversion process in a talk at the August CPS/SEG meeting in August of this year.

These two slides show the velocity curves used to do map depth conversion with. The time-depth velocity conversion curve was read into the workstation and written into a seismic-type file for every 10th trace of every line. Amplitude extraction was used to get the velocity to specific horizons on each of these traces. These velocities were gridded, and then used to convert the seismic time maps to depth.

S80L The left slide is the extrapolated velocity map for the T-2 horizon.
S80R The right slide is the resulting depth map for the T-2 horizon.

S81L The left slide is a seismic time map for the T-5 horizon.
S81R The right slide is a depth map for the T-5 horizon.

S82L and S82R The left slide is the depth map that had been made for the T-5 horizon before we started this project. The right slide is the depth map generated on the Landmark system on the same horizon. The important thing about interactive systems is that once a map is built it is very easy to go in and do detailed analysis of portions of the map, to update existing maps, to overlay different maps, to mix maps and to generate new maps. This morning Mr. Morris of Landmark counted the number of maps on the system in the Jiji project. There are 165 maps, showing everything from porosity, to well derived thicknesses, to many of the displays you have seen in this presentation.

Interpretation Project Plans

As described in this report the goals of the joint interpretation project have been met. The Chinese members of our interpretation team will be finalizing their report. Landmark's support of this interpretation project has far exceeded the economic and time requirements of our contractual agreement. Therefore, until we have business commitments from the Ministry of Petroleum Industry future support of this interpretation project will probably be limited to normal customer support visits. The exceptions to this will be the post-stack processing of some data to demonstrate some unrecognized wavelet substitution and filtering capabilities of the Landmark system. It is also possible that we will do some AGS modeling of a couple of key profiles in order to demonstrate our 3D, ray-trace modeling capabilities.

Landmark Plans for Business in China

About a year ago Roice Nelson was optimistically discussing opening an Landmark office in China. An equally optimistic officer of the Bureau of Geophysical Prospecting suggested that the office should be in Zhuoxian, largly because a new freeway would be built between Zhouxian and Beijing within a year and Zhuoxian would then only be an hour away from the airport. New developments only come through optimists, but perhaps now is the time for a little realism. Unfortunately Landmark has not had enough business in China to justify opening an office. The freeway is not close to completion, and even when it is completed it will take longer than an hour to reach the airport.

This meeting is an important juncture in the Ministry of Petroleum Industry's road to modernizing seismic interpretation procedures. It is Landmark's understanding that there has already been a decision by the Bureau of Geophysical Prospecting to build an interactive interpretation system. If this is true, it seems that there are three basic choices that the ministry can make to modernize seismic interpretation procedures: (1) attempt to completely develop required interactive interpretation systems internally; (2) buy some of all the available interpretation systems, and try to copy appropriate functionality into the internally developed system; or (3) to enter into a mutually beneficial joint development with the leader in interactive interpretation systems. Let's review each of these options individually.

The decision can be made to do all of the development of Chinese seismic interpretation systems within the Bureau of Geophysical Prospecting. Like the optimistic time-frame and traffic-flow for the freeway to Zhuoxian, this choice will not be able to effectively compete economically or in performance with developments like those presented in this report. Remember, Landmark has 115 of the best trained experts in the world as employees, and these profesionals are dedicated to making sure our interactive interpretation products are the best in the world. In addition, with an average of 4 users per system, Landmark has about 500 end users from the largest, the smallest, and most aggressive oil companies in the world. These explorationists daily use Landmark products and making suggestions about how the products can be improved to better help them solve their interpretaion problems. Unless Landmark makes a major mistake, no group will be able to compete with this type of development momentum, especially a group that is somewhat isolated from the latest in hardware and software developments. For example, Mr. Nelson has a picture of a new screen that is a meter square, has 4000 pixels in each axis, and is being provided to Landmark for free testing of viability for use within our industry, with the understanding that if the tests are successful Landmark will have an exclusive distrubution of this product in the oil industry worldwide.

The second catagory suggested above was for the Ministry of Petroleum Industry to buy some of all available interpretation systems, and try to copy appropriate functionality into the internally developed system. If there is no concern about performance, response time, and the resulting amount a system is ultimately used this might be considered a viable option. It is a well accepted fact by the developers of interactive scientific workstations, in many different specialities, that it is not yet possible to build a truely interactive system that is hardware independent. This means that software can not be taken from one system and implemented on another system without rewriting it by optimizing data I/O, graphics I/O, building an effective user interface, etc. This creates a problem because of the rapid hardware developments.

Landmark is committed to isolating end users from all of these changes. We call this antiobsolescence. Antiobsolescence mean that forward planning is made in selecting hardware platfoms, so that when new changes occur they can be easliy implemented on the system. The first Landmark system was delivered with an Intel 8086 microprocessor. This was upgraded to an 80286 in the field. In a couple of months this system will be upgraded to an 80386 with the Unix operating system. This is significant. Landmark is the first company in the world to have Unix running on a microprocessor. In addition, there has only been one company in the world, before Landmark, to upgrade an operating system in the field. This was when Cray Research upgraded their systems to Unix. A leading software developer in England, Dr. Les Hatton, a founder of Merlin Geophysical and the leader in development of their SKS seismic processing system, has just formed a new company to develop system independent software. He catagorically states that software tools can be system independent only under a universal operating system like UNIX. He just as strongly states that an interactive applications must be closely tied to hardware that has been optimized for the applications, or they will be too slow to be called interactive.

To test interactivity, go into any major oil company that has a hardware independent software package (like 3D ray-trace modeling) and find out what the response time is under normal working conditions, the impact on throughput of the processing that the computer was originally purchased for, how much the user interface changes from machine to machine, and how many people regularly use the software. It is not possible to jury-rig an interactive system. By definition, an interactive system must be internally efficient and tied together so that it provides the user with response time appropriate to the task. Otherwise the system is not interactive.

Landmark believes the only long term viable option for the Ministry of Petroleum Industry to modernize seismic interpretation procedures is to enter into a mutually beneficial joint development with the leader in interactive interpretation systems. This type of joint development agreement has several benefits. First, it would provide a means for oil fields to immediately obtain interactive systems for priority projects. Second, it would tie the Bureau of Geophysical Prospecting's development of an interactive interpretation system into the latest developments in software and hardware. These developments include UNIX, X-Windows, the Intel 80386, the IBM RT-PC and other significant advances that are not public yet. A third benefit is that an evaluation of the price-performance of Landmark products will prove to be, by far, the most economical solution to providing an appropriate number of interactive interpretation systems to Chinese oil fields. And fourth, the transfer of Landmark technology to the Ministry of Petroleum Industry would prove to be the quickest and least expensive means of developing the capabilities to build the Ministry's own interpretation systems.

In summary, Landmark has participated in this interpretation project beyond our original plans, as a statement of our interest in doing business with the Ministry of Petroleum Industry. Landmark personnel are available to visit any of your oil fields to discuss our technology. In addition arrangements have been made to provide demonstrations and a detailed disclosure of our technology to any of you that are interested the remainder of this week.