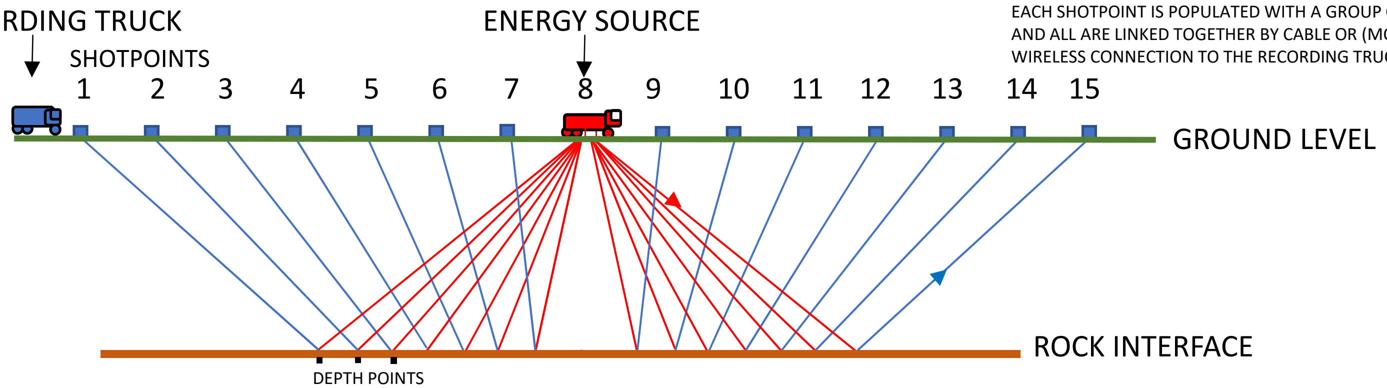
INTRODUCTION TO ONSHORE SEISMIC ACQUISITION AND PROCESSING

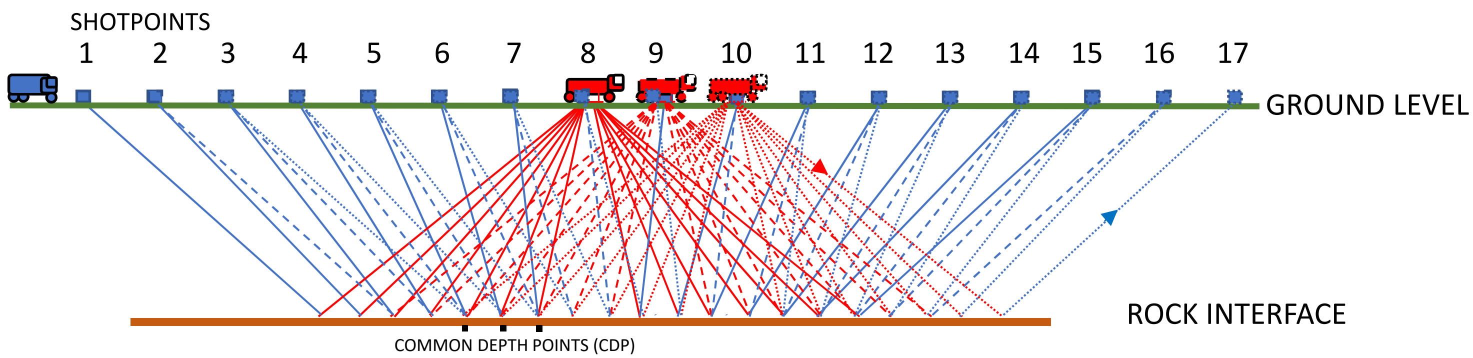
SEPTEMBER 2017

SIMPLIFIED DIAGRAM OF SPLIT-SPREAD REFLECTION SEISMIC DATA ACQUISITION



EACH SHOTPOINT IS POPULATED WITH A GROUP OF GEOPHONES AND ALL ARE LINKED TOGETHER BY CABLE OR (MORE RECENTLY) WIRELESS CONNECTION TO THE RECORDING TRUCK

ASSUMING THE ROCK INTERFACE IS HORIZONTAL, THEN PART OF THE INDUCED SEISMIC ENERGY WILL BE REFLECTED SYMMETRICALLY TO THE RECEIVERS AND A REDUCED LEVEL OF ENERGY WILL CONTINUE DOWNWARDS TO BE REFLECTED FROM DEEPER INTERFACES. THE AMOUNT WHICH IS REFLECTED DEPENDS ON THE LEVEL OF CONTRAST AT THE INTERFACE ("REFLECTION COEFFICIENT"). CLEARLY, THE SITUATION WILL BE MORE COMPLICATED FOR DIPPING BEDS, WHEN THE DEPTH POINT THAT GIVES RISE TO A REFLECTION WILL NOT BE IN THE SAME PLACE AS THE MID POINT BETWEEN SOURCE AND REFLECTOR. IN ADDITION, THE SOUND WAVES WILL BE REFRACTED AS THEY PASS THROUGH EACH INTERFACE.



THE FIRST DIAGRAM WILL GENERATE A SINGLE SHOT RECORD. SINCE ABOUT 1970, MULTIPLE FOLD SEISMIC DATA HAS BEEN RECORDED, SUCH THAT THE ENERGY SOURCE IS MOVED ALONG ONE OR TWO STATIONS ("SHOTPOINTS") AND THE RECEIVING SHOTPOINTS ARE ALSO ROLLED FORWARD IN THE SAME DIRECTION. IN THIS WAY, EACH REFLECTING POINT ALONG THE LINE IS SAMPLED MANY TIMES (DEPENDING ON THE NUMBER OF RECORDING STATIONS IN THE LINE). IN THE CASE OF THE LINE USED AS AN EXAMPLE BELOW (BP91-204 FROM SOUTH DORSET), THE MAXIMUM NUMBER OF TIMES EACH POINT IS SAMPLED IS 72 (OR "72-FOLD COVERAGE"). IN PROCESSING, THE REFLECTIONS BELONGING TO EACH INDIVIDUAL CDP ARE EXTRACTED FROM EACH OF THE SINGLE FOLD SHOTS AND ADDED TOGETHER ("STACKED") TO FORM A SINGLE RECORD. THIS PROCESS ACCENTUATES WEAK REFLECTORS AND AIDS IN REDUCING EXTRANEOUS NOISE.

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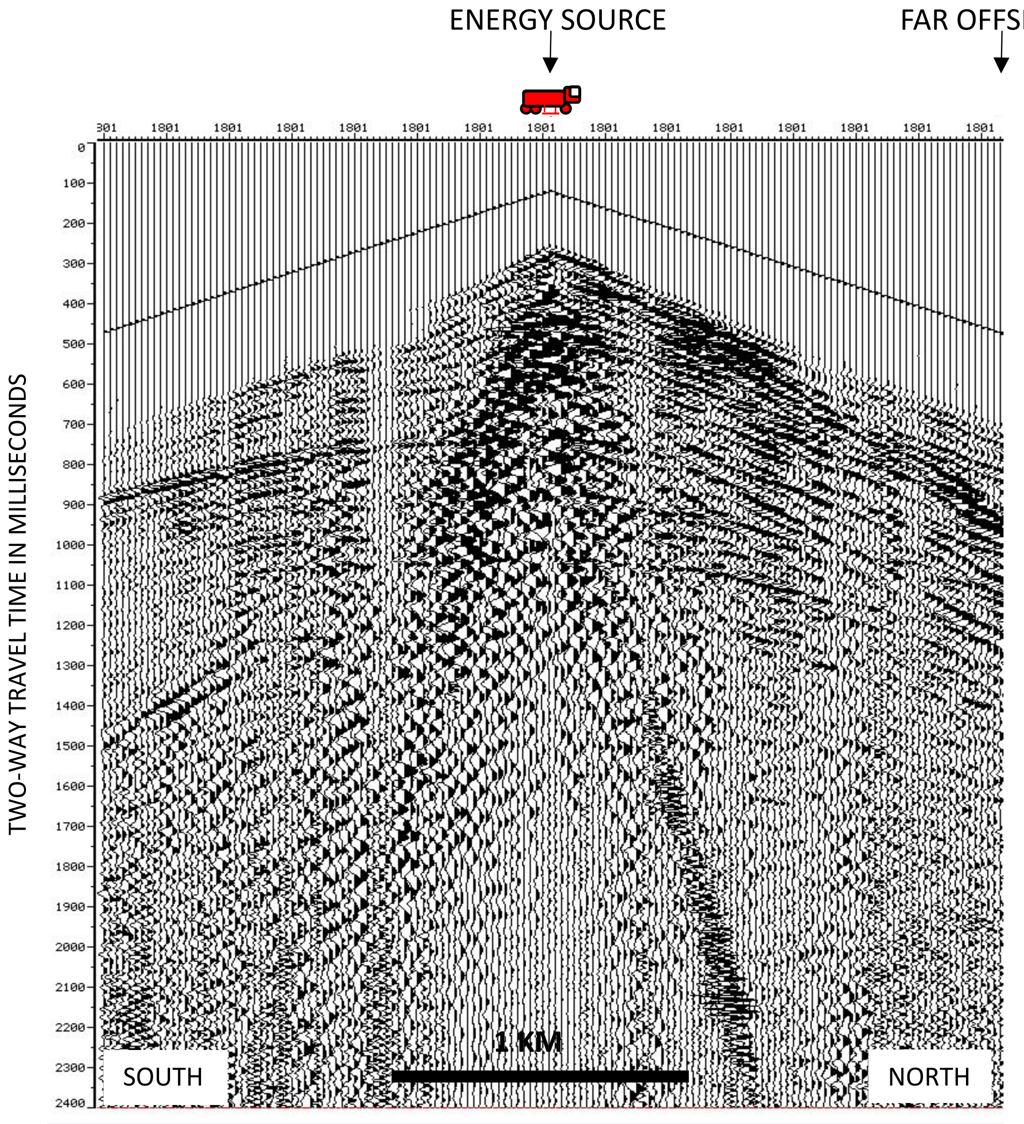
RAW SINGLE SHOT RECORD FROM EXAMPLE LINE BP91-204 (SOUTH DORSET)



IN THIS CASE, THE “SHOT” WAS GENERATED BY A VIBRATOR TRUCK WITH A SWEEP FROM 10 TO 80 Hz.

THE LOWER THE FREQUENCY, THE DEEPER THE PENETRATION, SO THE FREQUENCY CONTENT REDUCES DOWN THE SECTION. HIGHER FREQUENCY ENABLES THE DEFINITION OF THINNER BEDS, SO THE ABILITY OF THE SEISMIC DATA TO RESOLVE INDIVIDUAL BEDS REDUCES IN THE DEEPER SECTION.

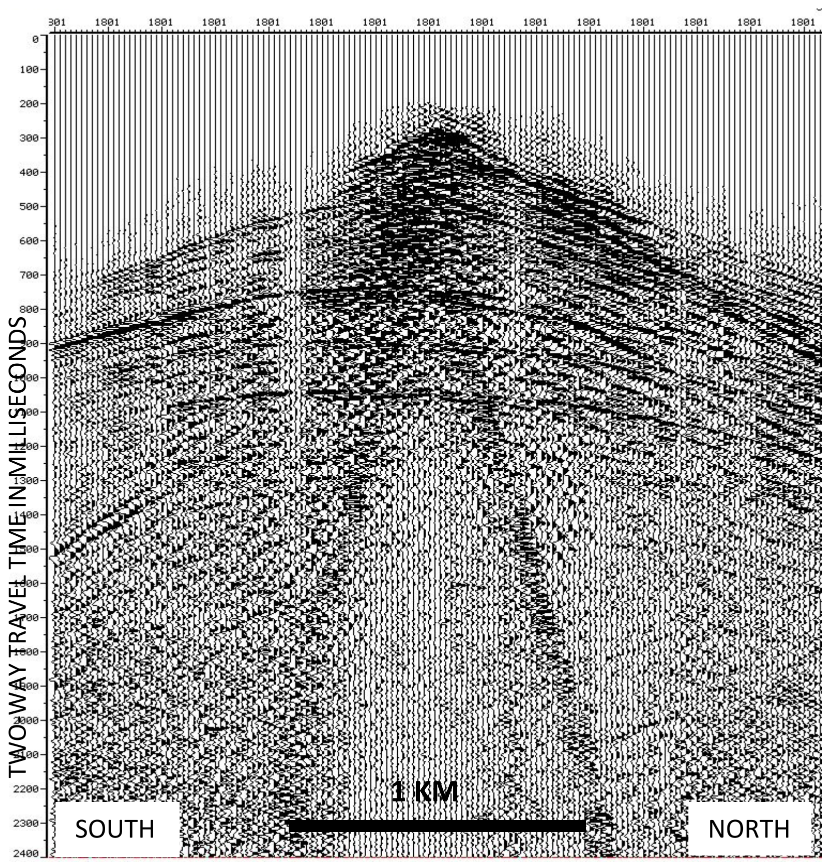
NOTE THAT THE FURTHER THE RECEIVER IS FROM THE SOURCE THE LONGER IS THE PATH TAKEN BY THE SOUND WAVE. HENCE THE RECORD HAS AN INVERTED “V” SHAPE. THIS IS TAKEN CARE OF LATER IN THE PROCESSING BY THE NORMAL MOVEOUT (NMO) CORRECTION.

THE LATE ARRIVING, HIGH AMPLITUDE EVENTS FORMING A TIGHT INVERTED “V” IN THE CENTRE OF THE RECORD ARE CAUSED BY SURFACE WAVES (“GROUND ROLL”)

NOTE THAT THE VERTICAL SCALE IS IN TWO-WAY TRAVEL TIME IN MILLISECONDS. THIS IS THE TIME TAKEN FOR A WAVE TO TRAVEL DOWN FROM THE SOURCE TO A REFLECTOR AND RETURN TO THE SURFACE AT A RECEIVER.

PROCESSING STEPS ON SINGLE SHOT RECORD FROM LINE BP91-204: PT 1

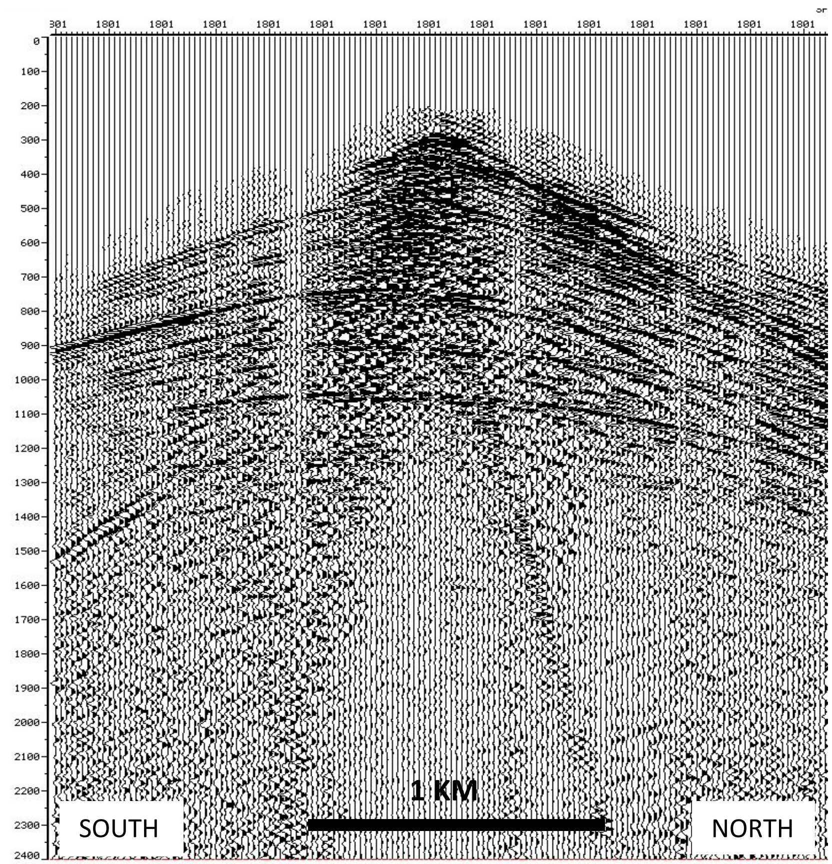
DECONVOLUTION AND FIELD STATICS



DECONVOLUTION IS A PROCESS THAT REMOVES REVERBERATIONS GENERATED BY STRONG REFLECTION COEFFICIENTS

FIELD STATICS ARE CORRECTIONS APPLIED TO INDIVIDUAL TRACES IN AN ATTEMPT TO NEUTRALISE THE EFFECTS OF CHANGES IN NEAR SURFACE VELOCITES CAUSED BY VARIATIONS IN THE THICKNESS OF THE WEATHERED LAYER AND TOPOGRAPHY.

DECON WITH FILTERING



FREQUENCY FILTERS ARE APPLIED TO REDUCE THE EFFECTS OF UNWANTED NOISE AND GROUND ROLL. IF IT WAS NOT ALREADY BUILT INTO THE RECORDING SYSTEM, THE FREQUENCY OF THE LOCAL POWER SUPPLY (50 Hz IN UK) IS ALSO FILTERED OUT

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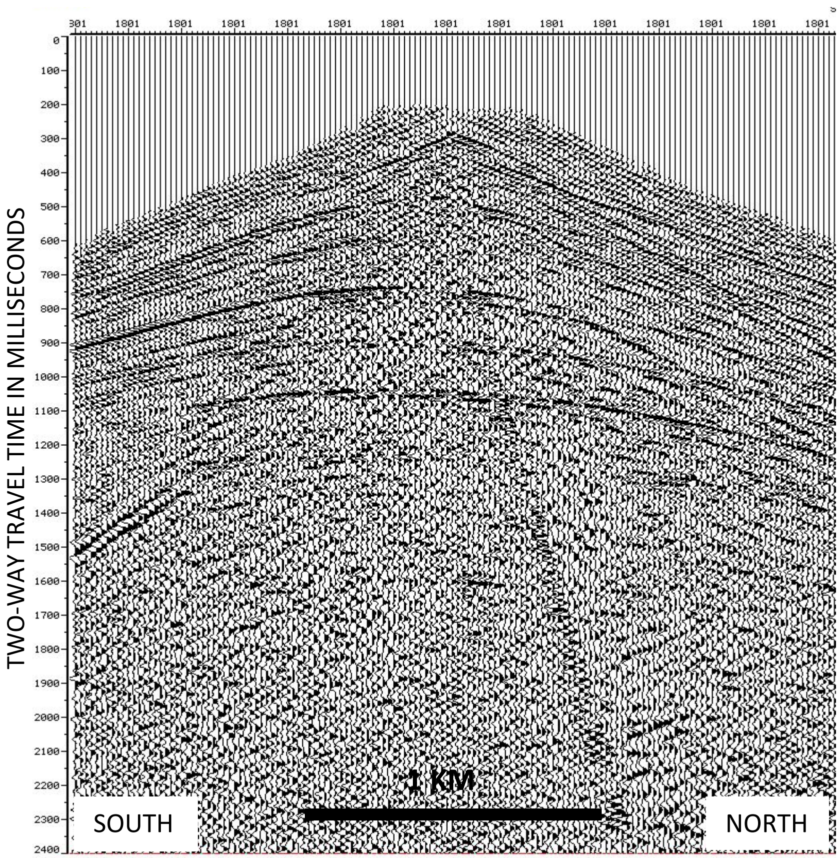
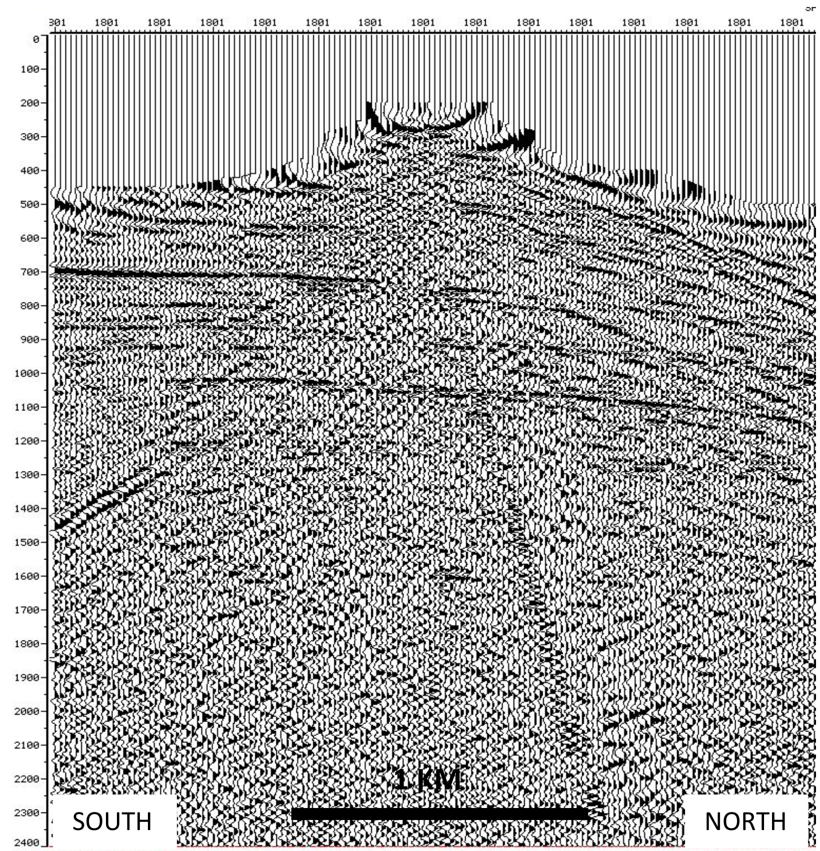
PROCESSING STEPS ON SINGLE SHOT RECORD FROM LINE BP91-204: PT 2

DECON WITH FILTERING AND AGC



AS NOTED EARLIER, THE POWER OF THE INDUCED SEISMIC WAVE IS REDUCED EACH TIME PART OF IT IS REFLECTED. AUTOMATIC GAIN CONTROL ("AGC") ATTEMPTS TO CORRECT FOR THIS BY BALANCING THE AMPLITUDE OF DEEPER AND SHALLOWER EVENTS

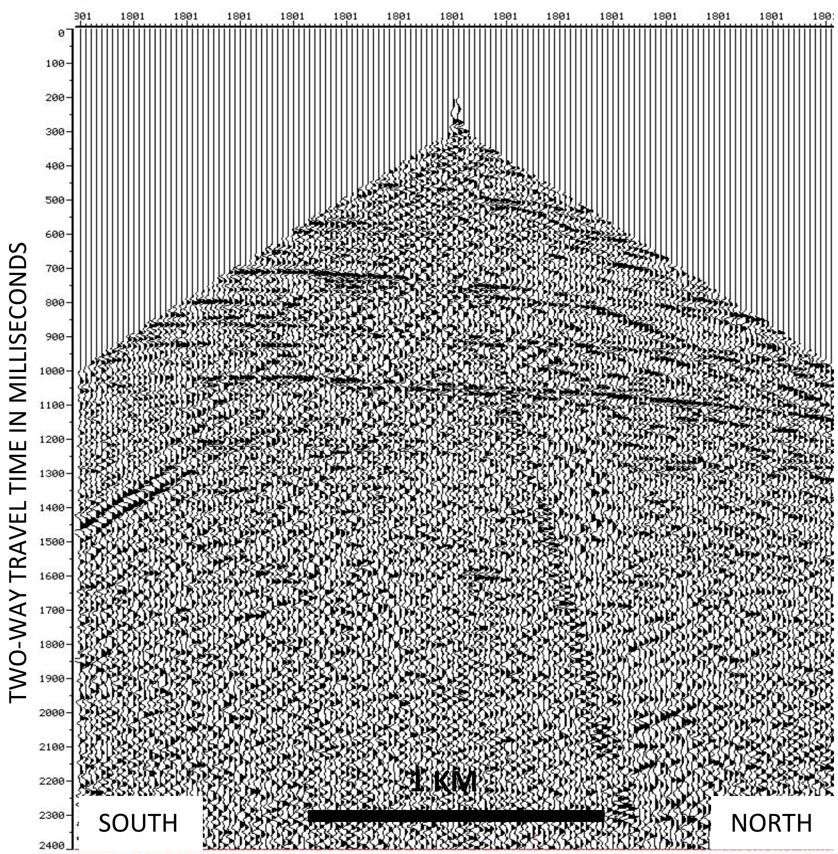
NMO CORRECTION APPLIED



AT THE END OF THE SHOT PROCESSING SEQUENCE, THE NMO CORRECTION IS APPLIED TO CANCEL OUT THE EFFECTS CREATED BY THE INCREASING LENGTHS OF RAY PATHS FROM SOURCE TO RECEIVER WITH INCREASING OFFSET DISTANCE. THIS CORRECTION REQUIRES AN ESTIMATE OF THE VELOCITIES OF THE ROCKS THROUGH WHICH THE RAYS HAVE PASSED – BUT THIS WILL BE REFINED IN THE STACKING PROCESS.

PROCESSING STEPS ON SINGLE SHOT RECORD FROM LINE BP91-204: PT 3

NMO CORRECTION WITH MUTE



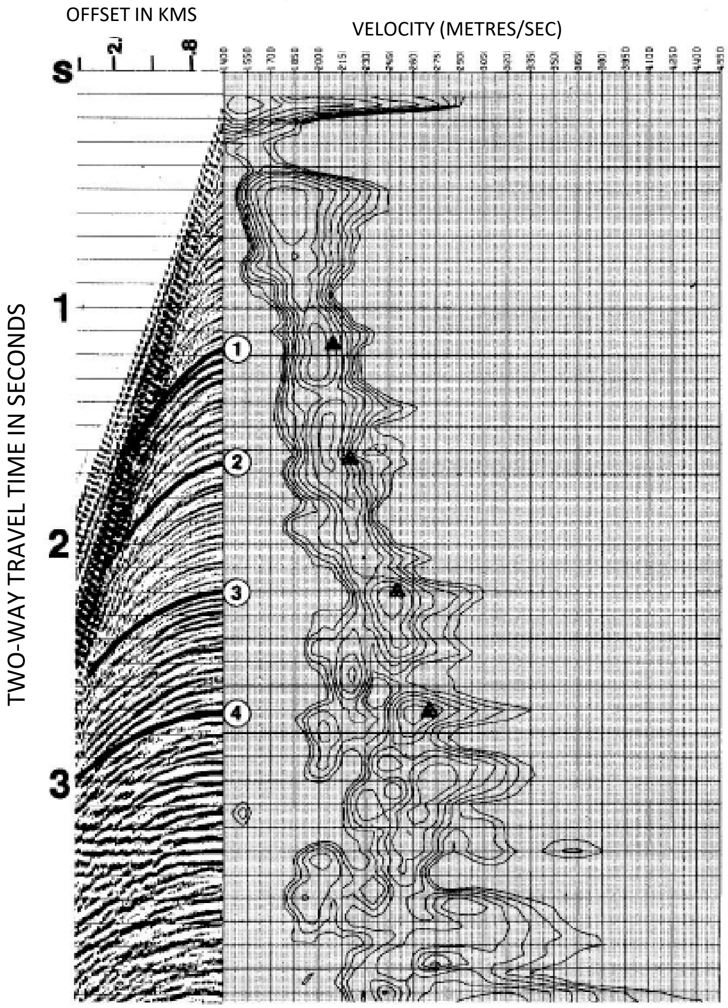
AS CAN BE SEEN ON THE PREVIOUS SLIDE, THE DISTORTION CREATED BY WAVES TRAVELLING CLOSE TO THE SURFACE IS MAGNIFIED WHEN THE NMO CORRECTION IS APPLIED. A MUTE IS THEREFORE APPLIED TO THE TRACES TO REMOVE THESE BEFORE STACKING THE SHOTS TOGETHER

MANY OF THE PROCESSES CARRIED OUT ON THE INDIVIDUAL SHOT RECORDS ARE REPEATED WHEN THE TRACES RELATING TO EACH CDP ARE STACKED TOGETHER

1 KM

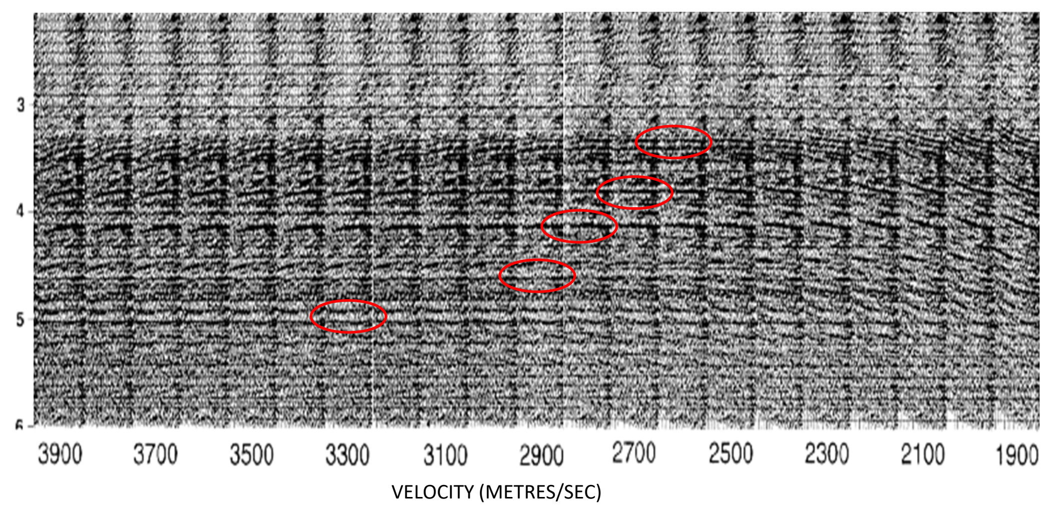
STACKING THE CDP RECORDS

THE INDIVIDUAL SHOT RECORDS CORRESPONDING TO A SINGLE CDP ARE COMPILED INTO A CDP GATHER. AS FOR THE SINGLE SHOT RECORD, AN NMO CORRECTION WILL BE NECESSARY BEFORE STACKING THE RECORDS INTO A SINGLE TRACE. SINCE ALL THE RECORDS IN THEORY CORRESPOND TO A SINGLE LOCATION, WHATEVER THE DIP OF THE BEDS IN THE SUBSURFACE THE EFFECT OF THE NMO CORRECTION MUST BE TO FLATTEN EACH OF THE HORIZONS ON THE GATHER



THIS NMO FLATTENING REQUIRES EACH INDIVIDUAL HORIZON TO BE COMPENSATED BY THE ROOT MEAN SQUARED VELOCITY OF THE BEDS THROUGH WHICH THE SOUND WAVES HAVE PASSED ABOVE IT. THESE RMS VELOCITIES ARE CALCULATED MATHEMATICALLY BY APPLYING A WIDE RANGE OF VELOCITIES AND PICKING THAT WHICH CORRESPONDS TO THE HIGHEST AMPLITUDE (POWER) WHEN THE TRACES ARE COMBINED. THESE AMPLITUDES ARE CONTOURED ON A PLOT OF VELOCITY VS TWT, AS SHOWN IN THIS FIGURE AND POINTS ARE PICKED (BLACK TRIANGLES) TO DEFINE A VELOCITY TREND TO USE.

THESE PICKS CAN BE CHECKED BY PLOTTING OUT A STRIP OF CDP GATHERS CORRECTED AT ISOVELOCITIES, AS SHOWN BELOW FOR A DIFFERENT SEISMIC SECTION, AND PICKING THE BEST FLATTENING VELOCITY FOR EACH HORIZON. THESE ARE CIRCLED IN RED.



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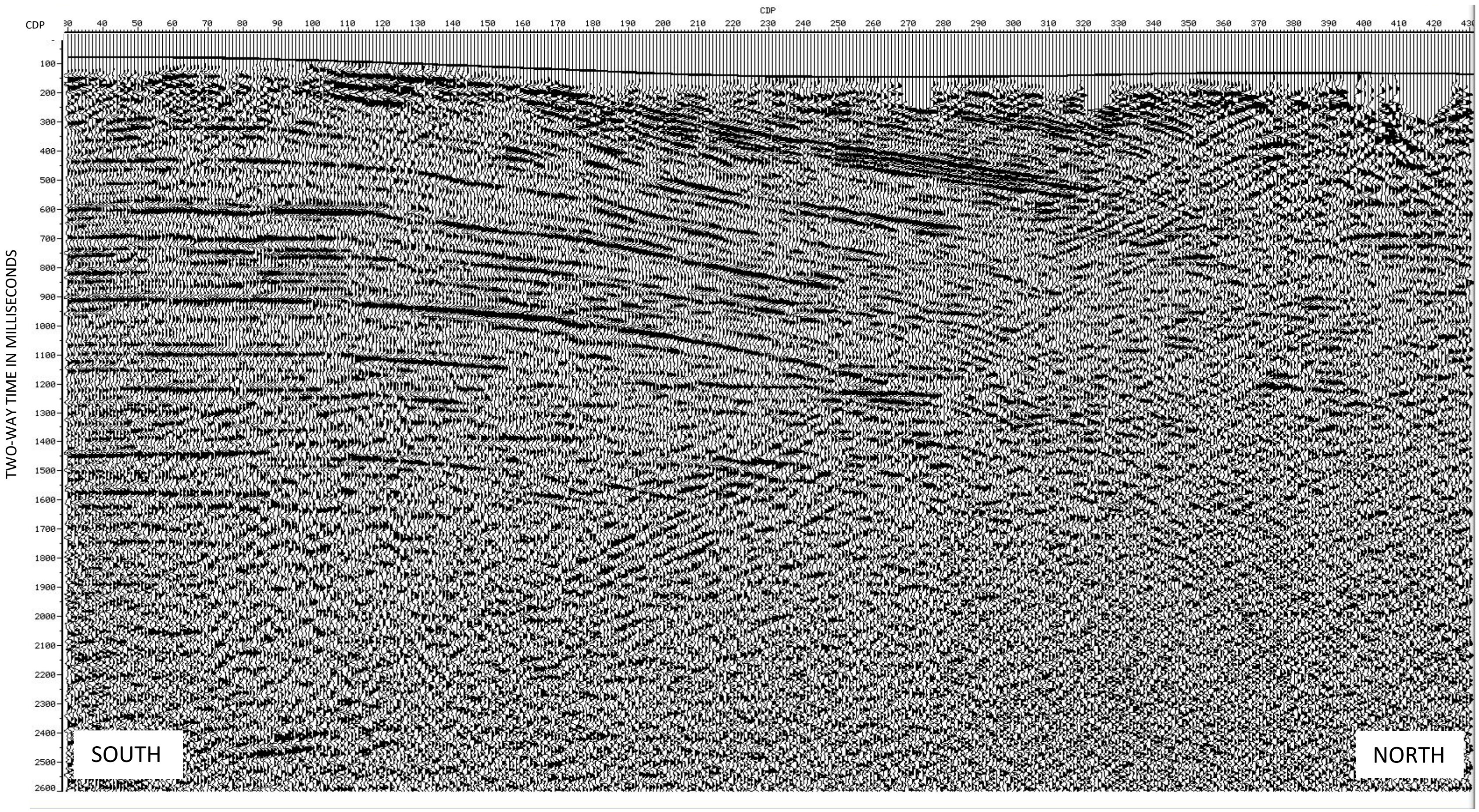
MAINLY CONTRIBUTED BY ÔZ YILMAZ

BP91-204:
RAW STACK WITH FIELD STATICS



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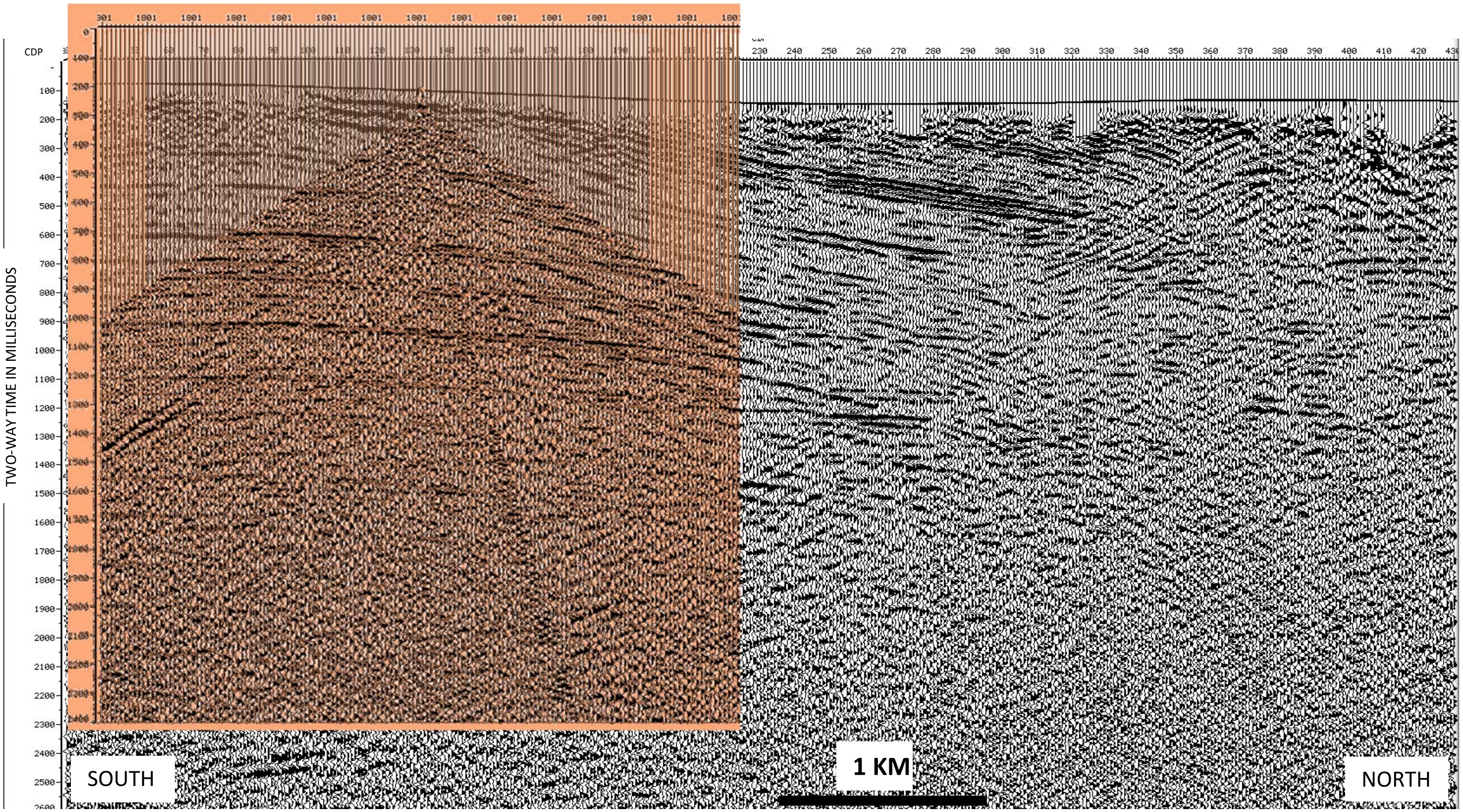
BP91-204:
RAW STACK WITH FIELD STATICS – WITH NMO-CORRECTED SINGLE SHOT RECORD SUPERIMPOSED



NOTE THAT THE NMO VELOCITIES HAVE BEEN REFINED IN THE STACK, SO THE DIPS INCREASE TO THE NORTH ON THE STACK WHEN COMPARED TO THE NMO-CORRECTED SINGLE SHOT RECORD

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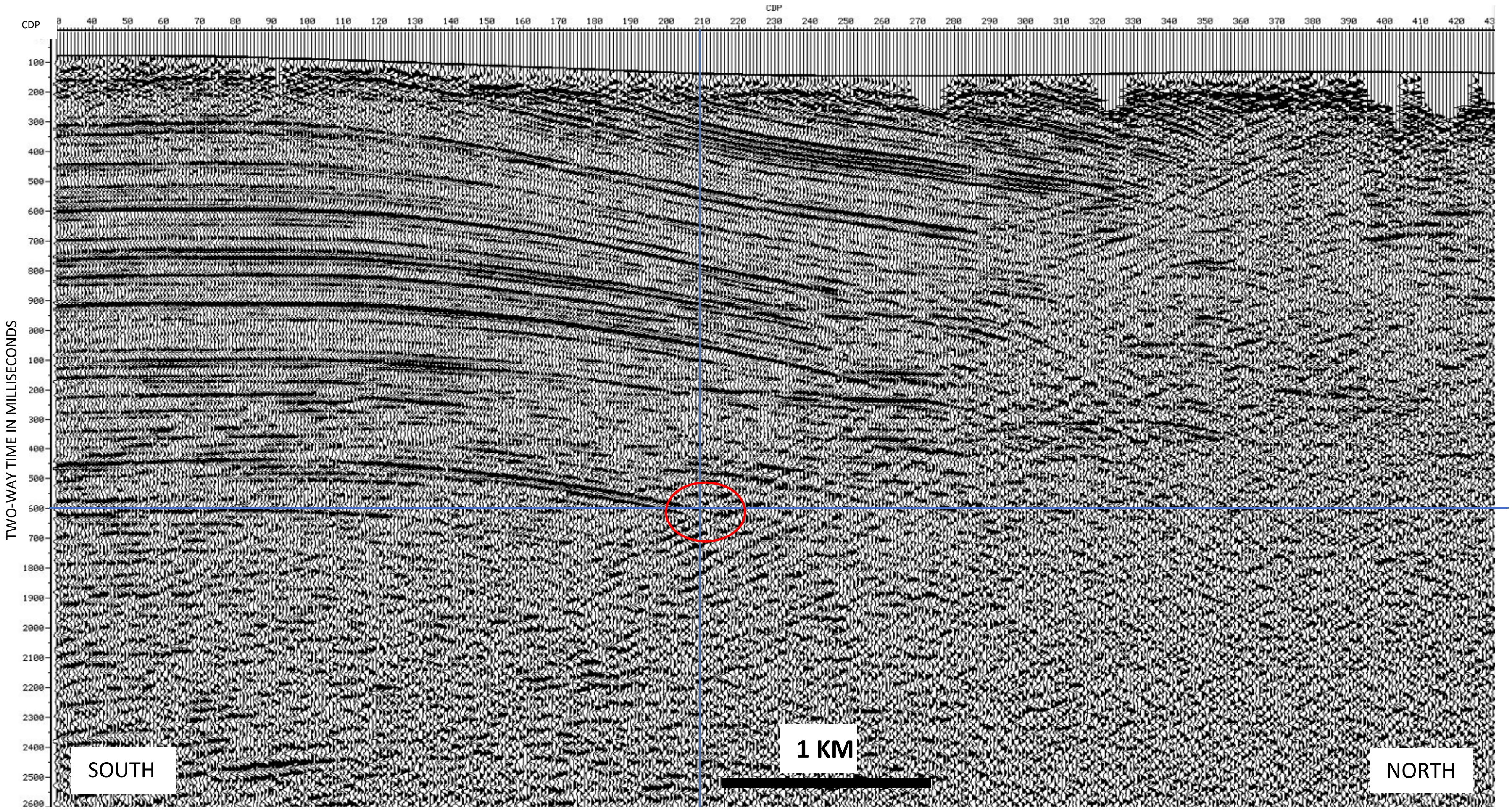
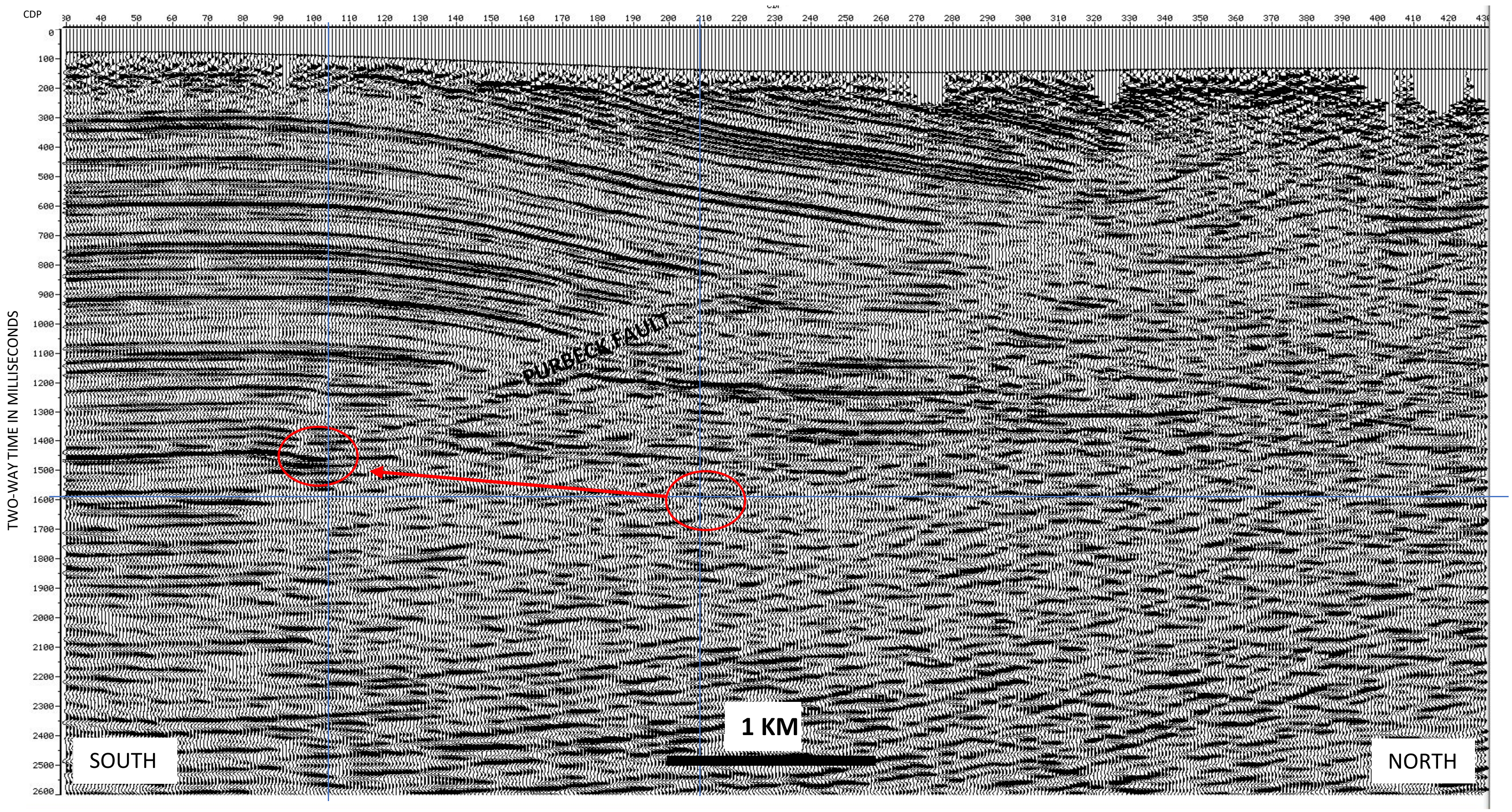
BP91-204:
DECON STACK WITH 3 ITERATIONS OF RESIDUAL STATICS



RESIDUAL STATICS ARE RUN IN AN ATTEMPT TO IDENTIFY AND CORRECT FOR SMALL OFFSETS OF INDIVIDUAL TRACES IN RELATION TO SURROUNDING TRACES THAT MIGHT BE CAUSED BY IMPERFECT FIELD STATIC CORRECTIONS. A COMPARISON WITH THE SHALLOW PART OF THE SECTION IN SLIDE 8 SHOWS THAT THE EFFECT IS TO SMOOTH HORIZONS AND IMPROVE CONTINUITY. EXCESSIVE RESIDUAL STATIC CORRECTIONS CAN MASK SMALL FAULTS. THE RED CIRCLE IS EXPLAINED IN THE NEXT SLIDE.

BP91-204:
POST-STACK MIGRATION



THE STACKING PROCESS ASSUMES THAT EACH CDP LIES DIRECTLY BELOW THE MID POINT BETWEEN SOURCE AND RECEIVER FOR EACH REFLECTED EVENT. IF THE BEDS ARE DIPPING, THIS WILL NOT BE THE CASE. MIGRATION ATTEMPTS TO CORRECT THIS BY USING WAVE THEORY AND REFINED VELOCITIES TO MOVE EACH CDP TO ITS CORRECT POSITION. COMPARISON WITH SLIDE 10 DEMONSTRATES THAT THE DIPPING EVENT AT ABOUT 1600 ms AT CDP 210 HAS COLLAPSED AND MOVED ABOUT 2 KMS TO A SHORT DIPPING SEGMENT AT ABOUT 1500ms AT CDP 105. SHALLOWER EVENTS, WITH LOWER VELOCITES, ARE MOVED SHORTER DISTANCES BY THE MIGRATION ALGORITHM BUT THE OVERALL EFFECT IS TO IMAGE TERMINATIONS OF THE DIPPING BEDS ALONG A STRAIGHT LINE THAT REPRESENTS A MAJOR FAULT (THE PURBECK FAULT). NOTE THAT THE FLAT-LYING BEDS DO NOT MOVE.

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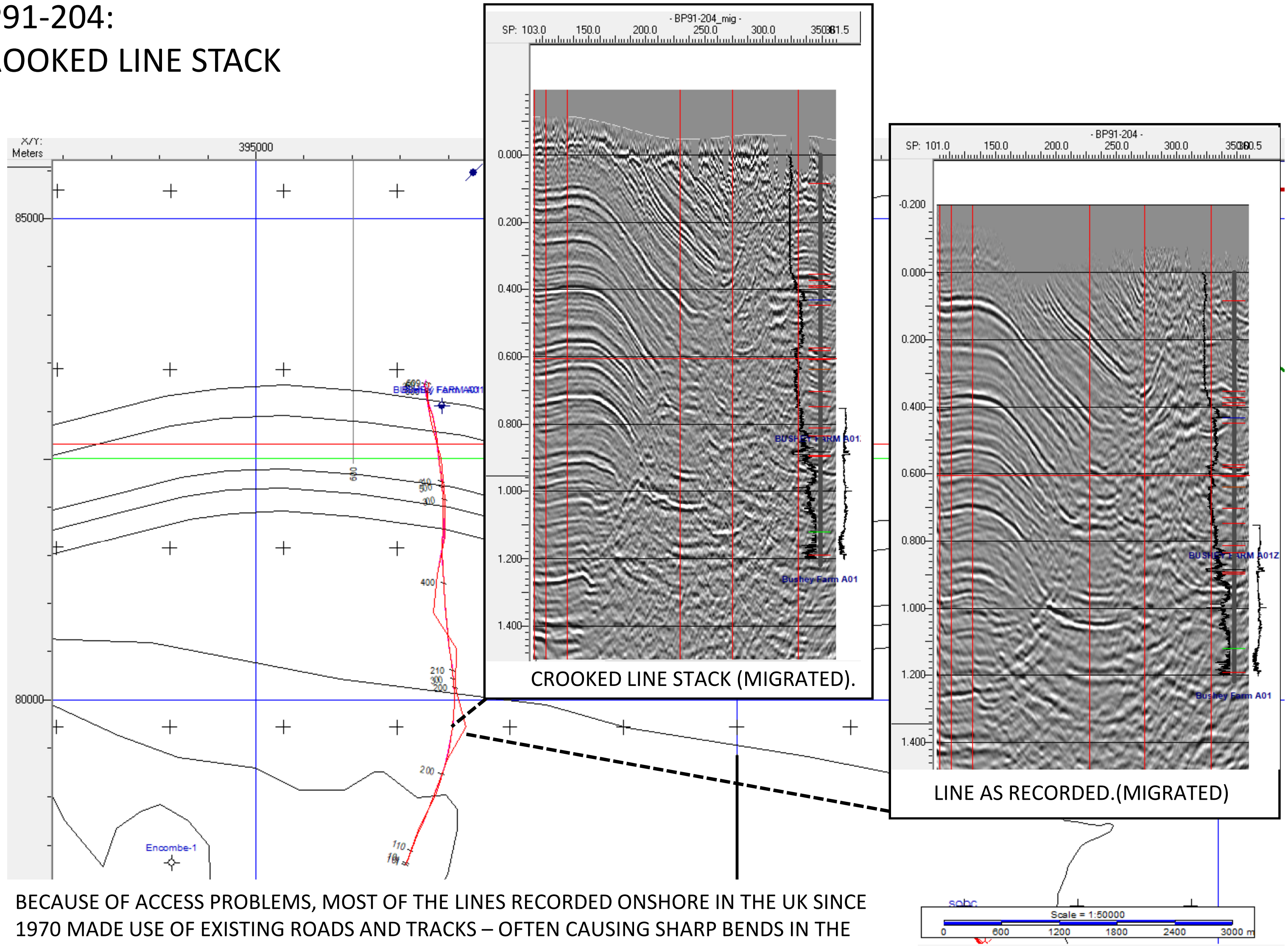
BP91-204:
CROOKED LINE STACK



CROOKED LINE STACK (MIGRATED).

LINE AS RECORDED.(MIGRATED)

BECAUSE OF ACCESS PROBLEMS, MOST OF THE LINES RECORDED ONSHORE IN THE UK SINCE 1970 MADE USE OF EXISTING ROADS AND TRACKS – OFTEN CAUSING SHARP BENDS IN THE LINE. TO AVOID DISTORTION CAUSED BY THESE SHARP CHANGES IN DIRECTION, THE CDPs ARE RESAMPLED AND PROJECTED ONTO A SMOOTHED LINE, WHICH SHORTENS THE LINE SLIGHTLY. NOTE THAT MANY LINES ON UKOGL BASE MAPS ARE CROOKED LINE STACKS, WHICH MAKES THEM LOOK AS IF THEY WERE RECORDED ACROSS COUNTRY (AND HOUSES), RATHER THAN NEARBY ROADS AND TRACKS..

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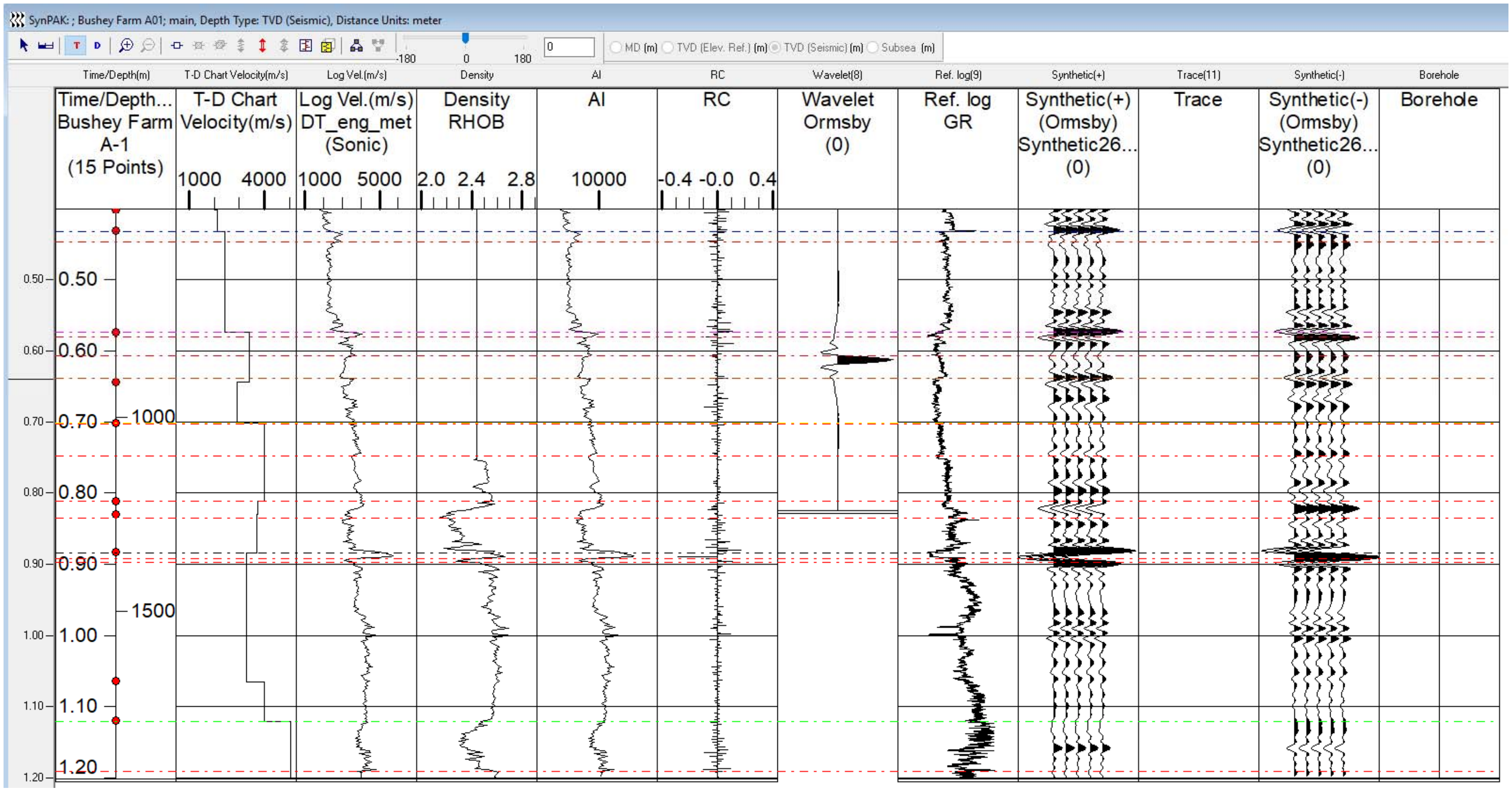
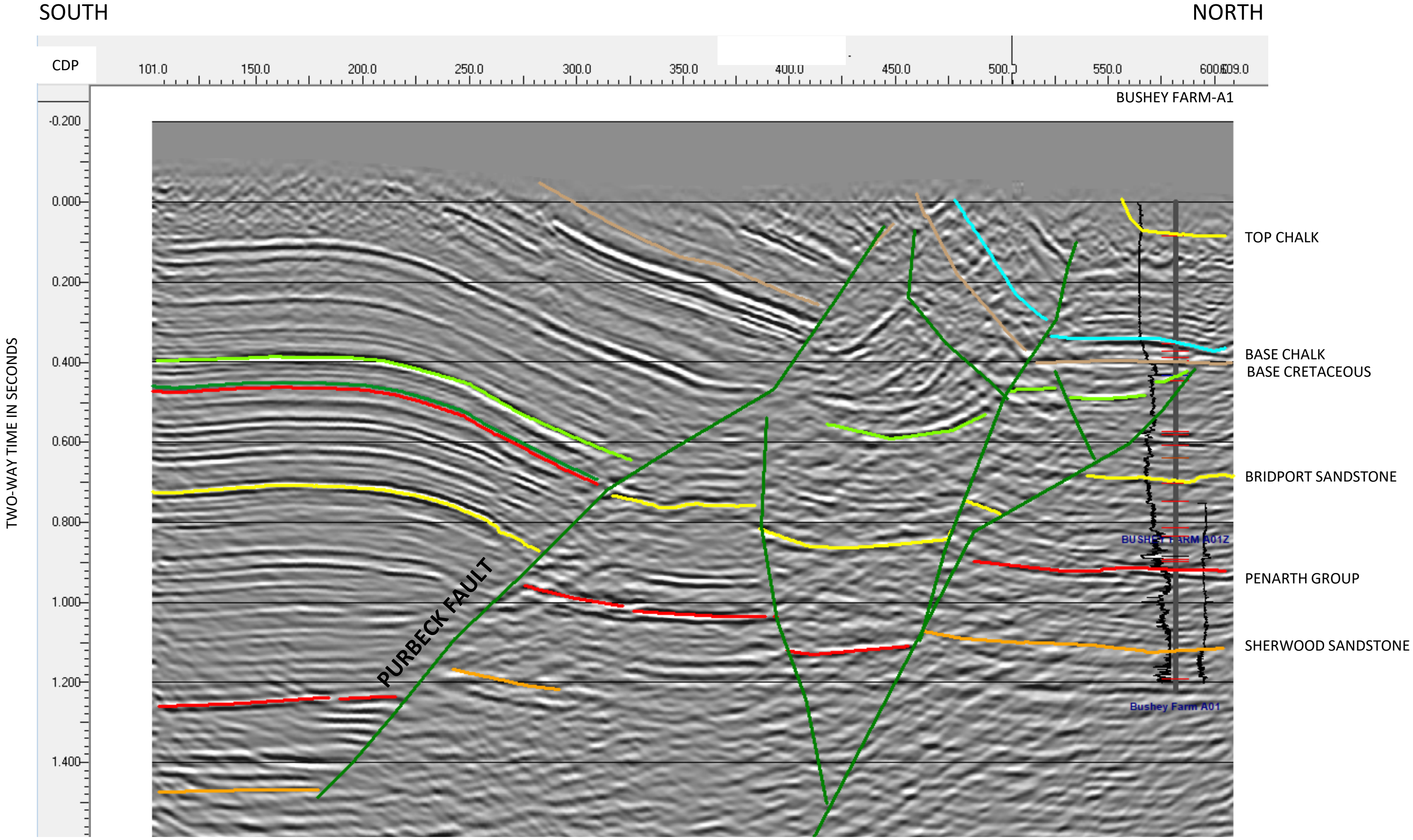
BUSHEY FARM-A1:
SYNTHETIC SEISMOGRAM GENERATED FROM DOWNHOLE ELECTRIC LOGS AND VELOCITY SURVEY



VELOCITY SURVEYS ARE CARRIED OUT BY LOWERING A GEOPHONE DOWN THE BOREHOLE, APPLYING A SOURCE AT THE SURFACE AND RECORDING THE TIME TAKEN TO SPECIFIC DEPTHS. THESE TIME/DEPTH PAIRS ARE THEN USED TO CALIBRATE THE DT (SONIC) LOG IN TIME. ACOUSTIC IMPEDENCE (AI) AND REFLECTION COEFFICIENT (RC) ARE COMPUTED USING THE DT AND DENSITY LOGS. AI AND RC ARE CONVOLVED WITH THE DESIRED WAVELET (NORMALLY COMPUTED FROM NEARBY SEISMIC LINES) TO PRODUCE THE SYNTHETIC SEISMIC TRACES. FORMATION TOPS IDENTIFIED IN THE WELL ARE SHOWN BY THE COLOURED HORIZONTAL LINES

BP91-204:
HORIZON INTERPRETATION



BY CORRELATING THE TWO-WAY TIMES RECORDED IN THE WELL AND SHIFTING THEM SLIGHTLY AS NECESSARY TO MATCH THE SYNTHETIC SEISMIC TRACE WITH THE ACTUAL SEISMIC DATA, INDIVIDUAL HORIZONS CAN BE TRACED ALONG THE SEISMIC LINE AND TRANSFERRED TO OTHER SEISMIC LINES AS THEY INTERSECT. IN THIS CASE, THE RATHER DIFFERENT HORIZONS TRACED ON THE SOUTH SIDE OF THE LINE HAVE BEEN DERIVED FROM WELL SOUTHARD QUARRY-1, LYING TO THE EAST OF THIS LINE, WHICH PENETRATED THE THICKER SECTION TO THE SOUTH OF THE PURBECK FAULT.

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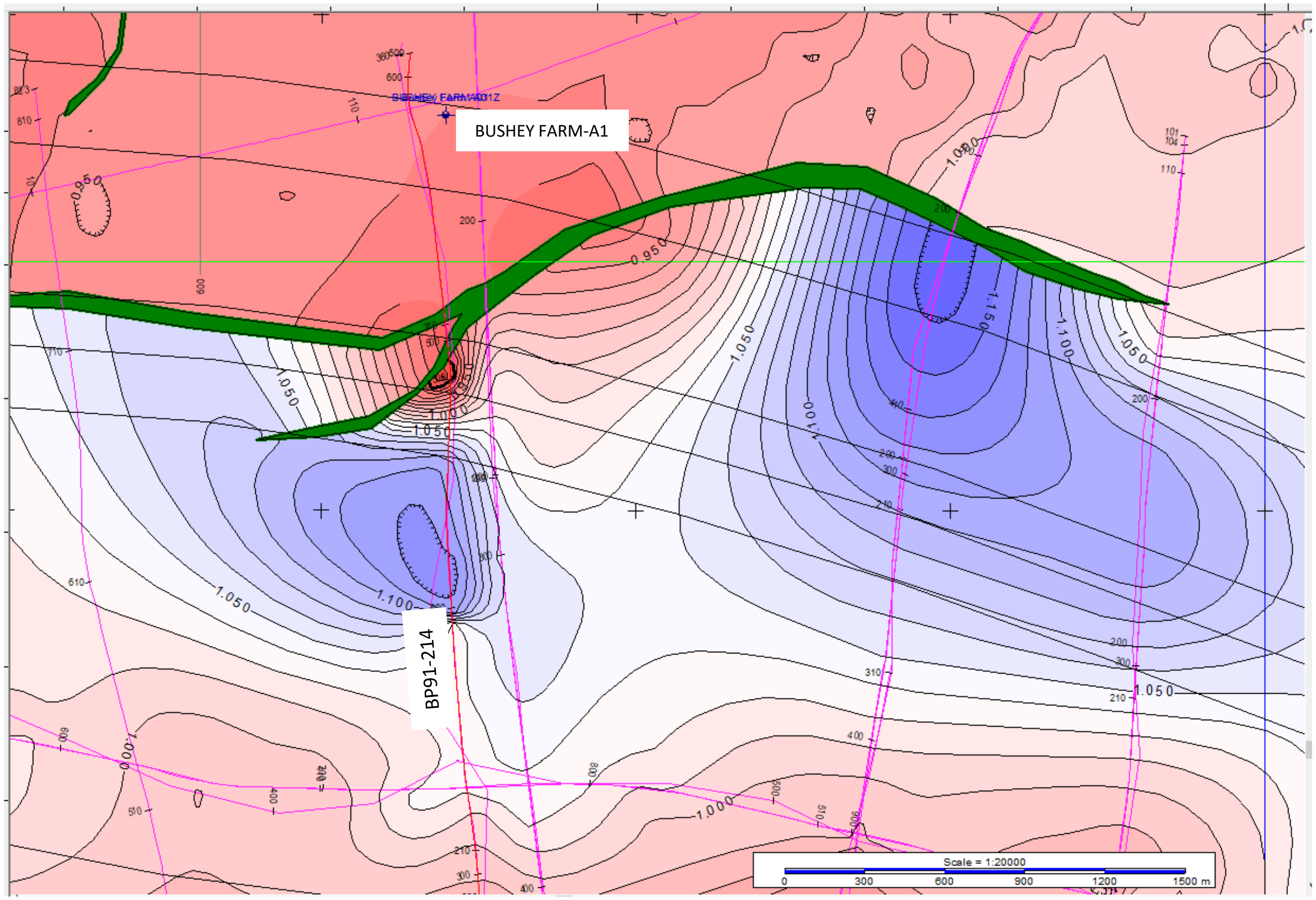
BP91-204 AREA:
HORIZON MAPPING



HAVING TRACED A HORIZON AROUND ON THE NEARBY SEISMIC LINES, THE VALUES CAN BE CONTOURED UP TO MAKE A MAP. THIS IS A SIMPLISTIC MAP ON THE PENARTH GROUP HORIZON AND IS SCALED IN TWO-WAY TIME FROM MEAN SEA LEVEL IN SECONDS. USING THE VELOCITIES FROM NEARBY WELLS, THE MAP CAN BE CONVERTED TO DEPTH.

3D SEISMIC SURVEYS:
BASIC PRINCIPLES

IN 2D SEISMIC ACQUISITION AND PROCESSING, WE MAKE THE ASSUMPTION THAT THE WAVE FRONT GENERATED BY THE SOURCE LIES IN A VERTICAL PLANE BENEATH THE ACQUISITION LINE. OF COURSE, THE SOURCE ACTUALLY GENERATES A SPHERICAL WAVE FRONT THAT PROPOGATES IN ALL DIRECTIONS FROM THE SHOTPOINT. IF THE BED INTERFACES BELOW THE LINE ARE HORIZONTAL OR ONLY DIP AT AN ANGLE PERPENDICULAR TO THE LINE THEN THE 2D MIGRATION WORKS. HOWEVER, IN REALITY THE GEOPHONES RECEIVE REFLECTED ENERGY FROM DIPPING BEDS OUTSIDE THE PLANE OF THE SEISMIC LINE. THESE REFLECTIONS ARE KNOWN AS “SIDESWIPE” AND CAN CAUSE SIGNIFICANT CONFUSION TO THE STRUCTURAL PICTURE ON A 2D LINE.

IN THE LATE 1970s, WITH INCREASES IN COMPUTER POWER, COMPANIES BEGAN TO RECORD DATA OFFSHORE BY STEAMING WITH AN AIRGUN SOURCE AT THE FRONT OF A LONG CABLE ARRAY POPULATED WITH GEOPHONES IN A SERIES OF CLOSELY-SPACED LINES (25 TO 50 METRES), SUCH THAT A GRID OF SOURCE:RECEIVER PAIRS COULD BE COMPILED. TRACES COULD THEN BE DERIVED FROM ANY POINT WITHIN THE GRID AND PROCESSING COULD SELECT THE POINTS THAT CORRECTLY IMAGED BED INTERFACES INTO CDP “BINS”. THIS WAS INITALLY A VERY SLOW AND EXPENSIVE PROCESS BUT BY THE MID-1980s ADVANCES IN COMPUTING AND NAVIGATION ALLOWED IT TO BECOME GENERALLY ACCEPTED AND IT IS NOW ALMOST A REQUIREMENT FOR ANY OFFSHORE DRILLING PROJECT.

ONSHORE ACQUISITION OF 3D SEISMIC DATA IS ACHIEVED BY LAYING OUT CLOSELY-SPACED LINES OF GEOPHONE STATIONS AND SOURCE LOCATIONS BUT IT IS NOT NECESSARY FOR THEM TO BE IN THE SAME DIRECTION. THE OFFSHORE GRID SYSTEM, WITH EVENLY SPACED SOURCE AND RECEIVER LINES, WORKS FINE IN UNPOPULATED AREAS BUT ONSHORE IN THE UK IT IS VERY DIFFICULT TO LAY OUT EVENLY SPACED LINES. THIS IS PARTICULARLY THE CASE FOR SOURCE LINES, BECAUSE OF HOUSING AND INFRASTRUCTURE RESTRICTIONS. PROCESSING STILL GENERATES REGULARLY SPACED CDP BINS IN BOTH “INLINE” AND “CROSSLINE”* DIRECTIONS BUT THERE MAY BE FEW NEAR TRACES IN THE BINS, BECAUSE OF GAPS IN THE ACQUISITION. THIS CAN LEAD TO POOR RESOLUTION OF SHALLOW BEDS, ALTHOUGH DEEPER RESOLUTION IS USUALLY GOOD.

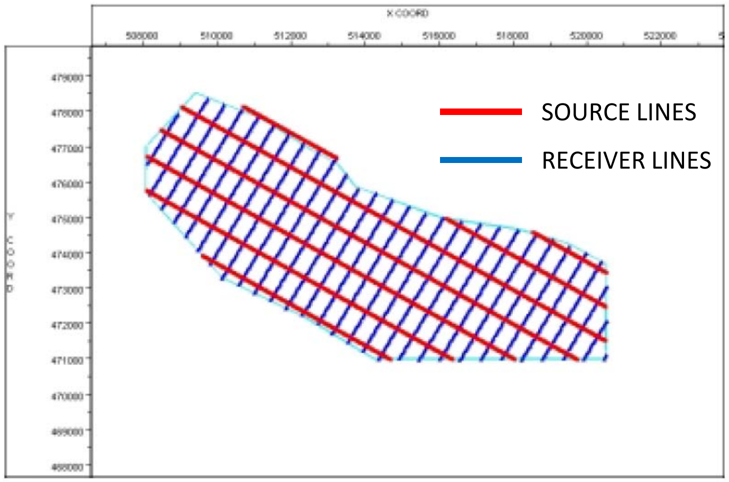
THE NEXT SLIDES SHOW A TYPICAL EXAMPLE OF AN ONSHORE 3D SURVEY IN A RELATIVELY POPULATED AREA OF COASTAL YORKSHIRE

*NOTE THAT THE PROCESSING ACTUALLY GENERATES A SERIES OF REGULARLY SPACED LINES (12.5 TO 25 METRES APART), WITH REGULARLY-SPACED CDPs (NOT NECESSARILY THE SAME SPACING AS THE LINES BUT NUMBERED SUCH THAT THEY ALIGN ACROSS THE SURVEY). THESE MAY BE INDEPENDENT OF THE ORIENTATIONS IN WHICH THE DATA WAS ACTUALLY ACQUIRED. BECAUSE THE DATA IS VIEWED DIGITALLY, LINES CAN BE PULLED UP ON THE SCREEN IN THE LINE ORIENTATION (“INLINES”) OR PERPENDICULAR TO THE LINE, ACROSS THE MATCHING CDP LOCATIONS (“CROSSLINES”). SOFTWARE ALSO ENABLES ARBITRARY LINES TO BE SELECTED ACROSS THE GRIDS, AS WELL AS “TIMESLICES” CREATED BY SELECTING THE SAME TWO-WAY TIME LEVEL ON ALL INLINES AND CROSSLINES AND DISPLAYING AS A MAP.

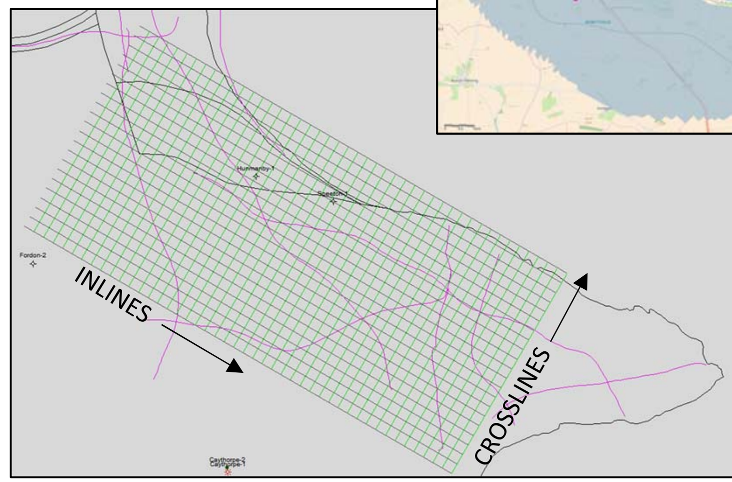
BEMPTON ONSHORE 3D SURVEY (YORKSHIRE): LOCATION ISSUES

LOCATION MAP FROM UKOGL WEBSITE

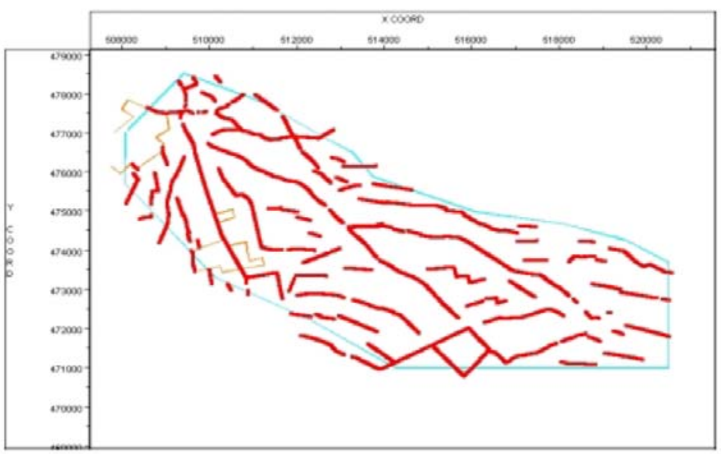
DESIGN OF THEORETICAL 3D ACQUISITION GRID



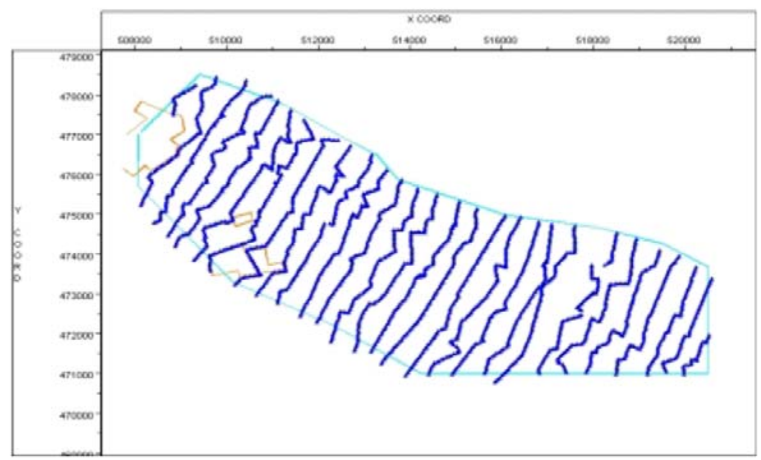
PROCESSED 3D GRID



ACTUAL SOURCE LOCATIONS



ACTUAL RECEIVER LOCATIONS

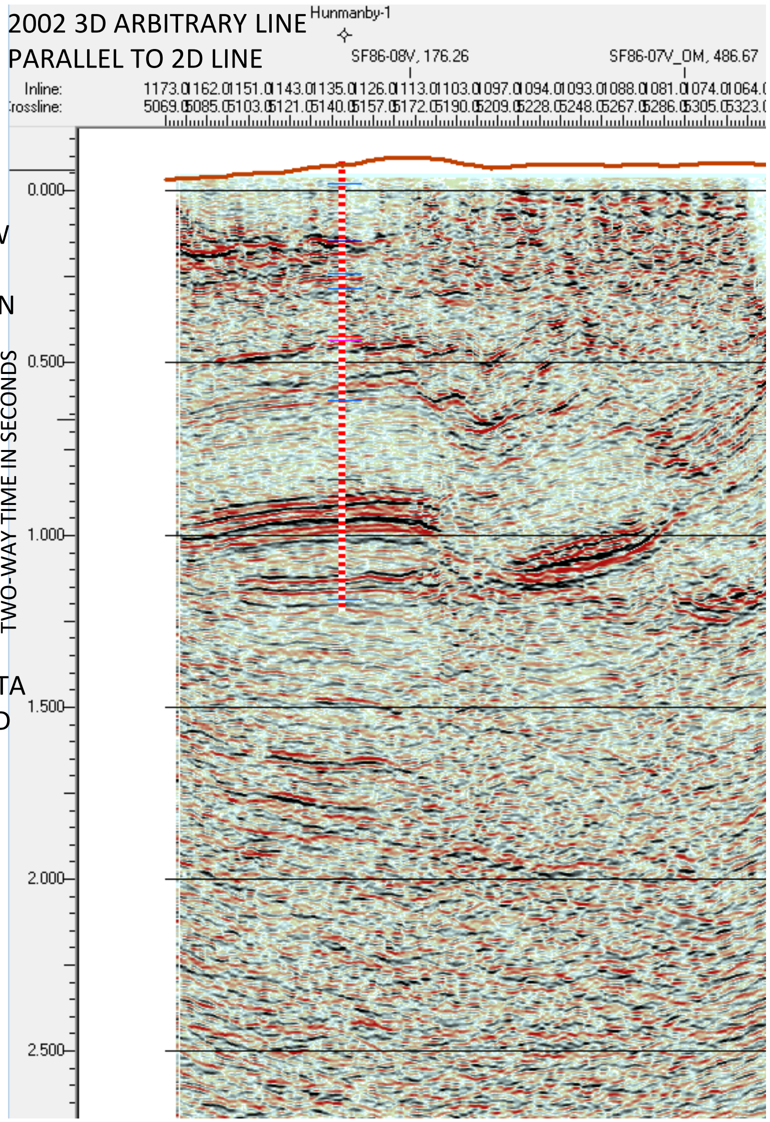


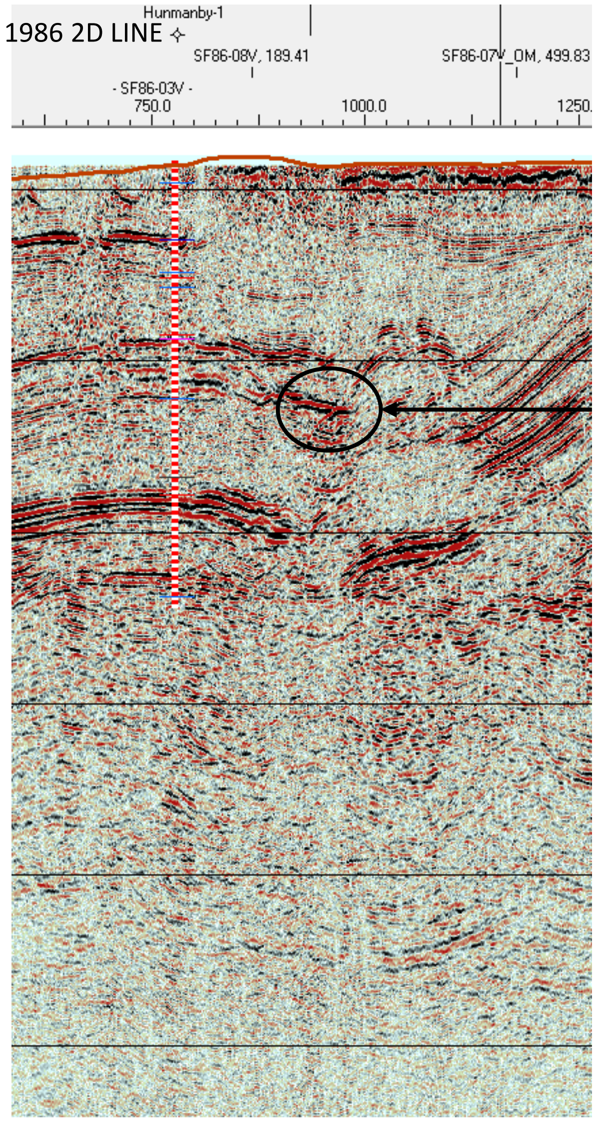
INFORMATION DERIVED FROM SURVEY REPORT IN UKOGL ARCHIVES

BEMPTON ONSHORE 3D SURVEY (YORKSHIRE):
DATA COMPARISON: 3D VS 2D

3D SHALLOW DATA MUCH WORSE THAN 2D LINE

3D DEEP DATA NOT IMAGED ON 2D LINE





POSSIBLE SIDESWIPE PROBLEM

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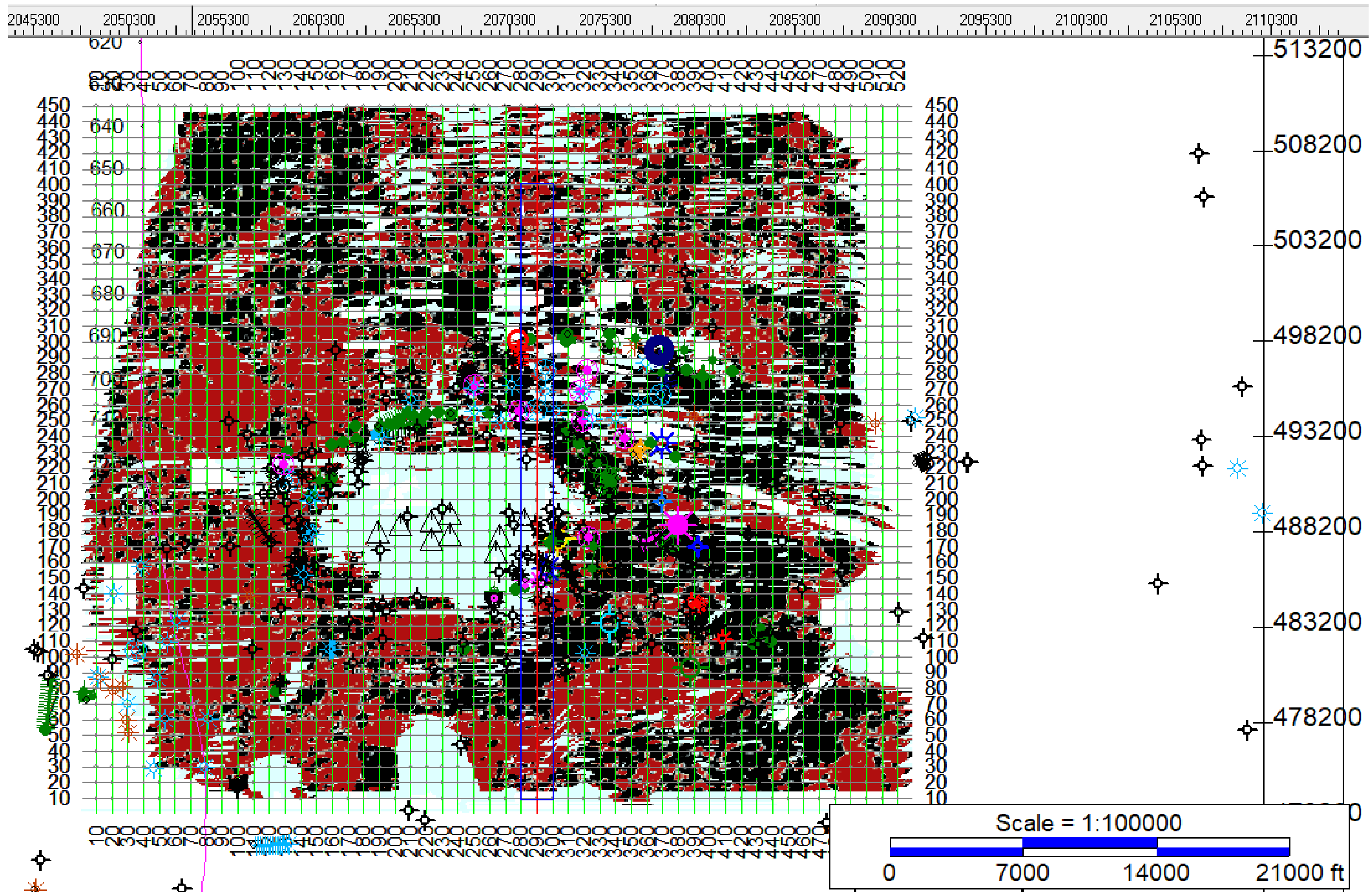
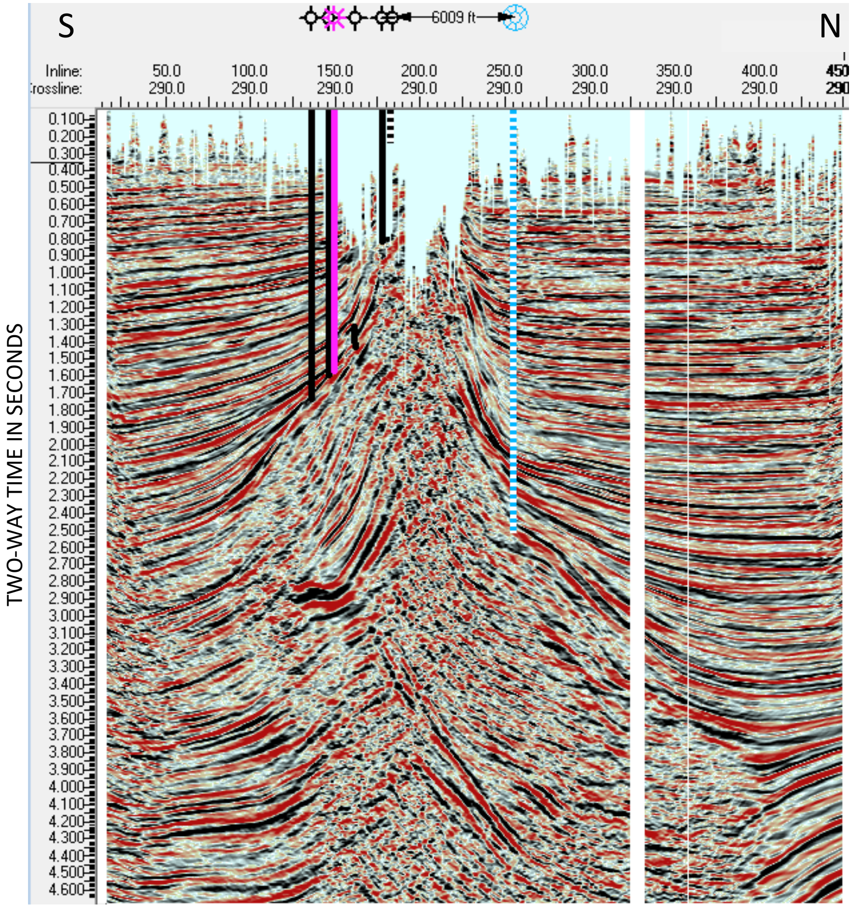
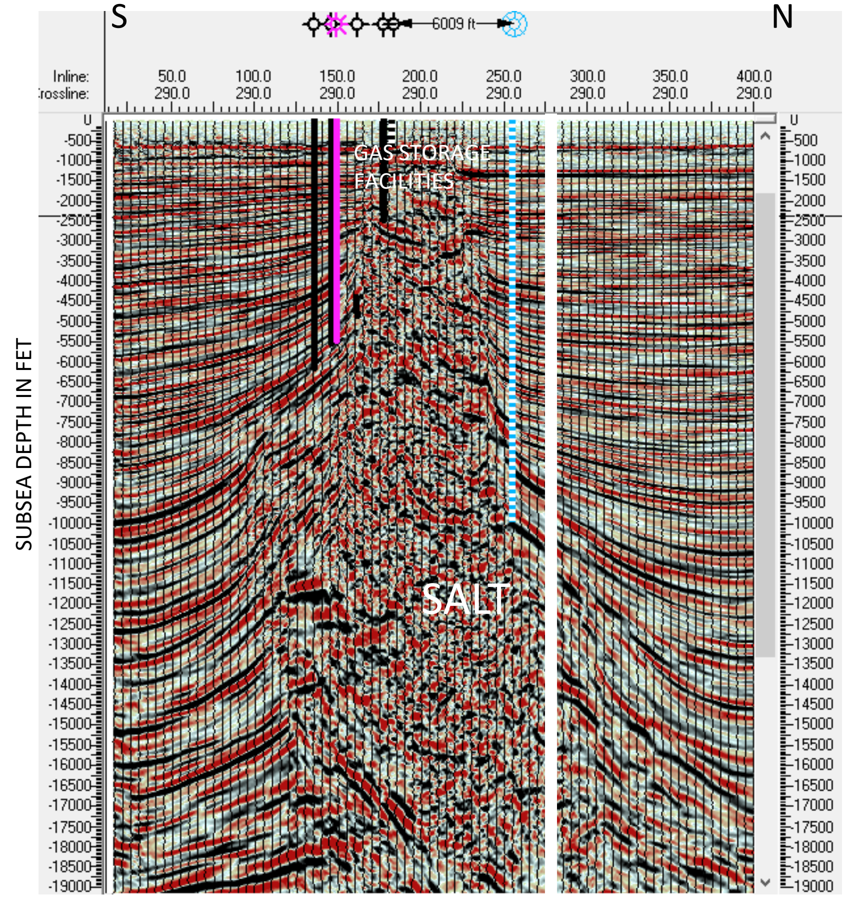
ONSHORE LOUISIANA: 3D TIMESLICE AT 0.500 SECS

NOTE AREAS WITH NO SHALLOW COVERAGE, DUE TO LACK OF ACCESS, AND PARTICULARLY THE LARGE AREA IN THE CENTRE WHERE A SALT DOME IS CLOSE TO THE SURFACE AND THERE ARE A NUMBER OF GAS STORAGE FACILITIES (THE SOURCE USED WAS DYNAMITE!)



ONSHORE LOUISIANA: PRE-STACK TIME AND DEPTH MIGRATIONS





NOTE THAT THE LARGE GAP IN SHALLOW COVERAGE HAS GOOD DATA AT DEPTH BECAUSE OF “UNDERSHOOTING”. NO SHOTS WERE ALLOWED IN THE CENTRAL AREA, ALTHOUGH IT WAS POSSIBLE TO LAY RECORDING GEOPHONES IN SOME LOCATIONS.

BOTH OF THESE MIGRATIONS WERE CARRIED OUT ON THE SEISMIC RECORD VOLUMES BEFORE STACKING. DEPTH MIGRATION IS THE MOST COMPLEX (AND EXPENSIVE) PROCESS, IN WHICH THE COMPUTED INTERVAL VELOCITIES ARE USED TO DEPTH CONVERT AND MIGRATE THE VOLUMES BEFORE THEY ARE STACKED. THIS GIVES THE MOST ACCURATE POSITIONING OF FAULTS AND DIPPING INTERFACES IN AREAS WHERE THERE ARE LARGE LATERAL VARIATIONS IN INTERVAL VELOCITY – BUT IT IS DIFFICULT TO ACHIEVE WITHOUT GOOD VELOCITY CONTROL FROM WELLS.

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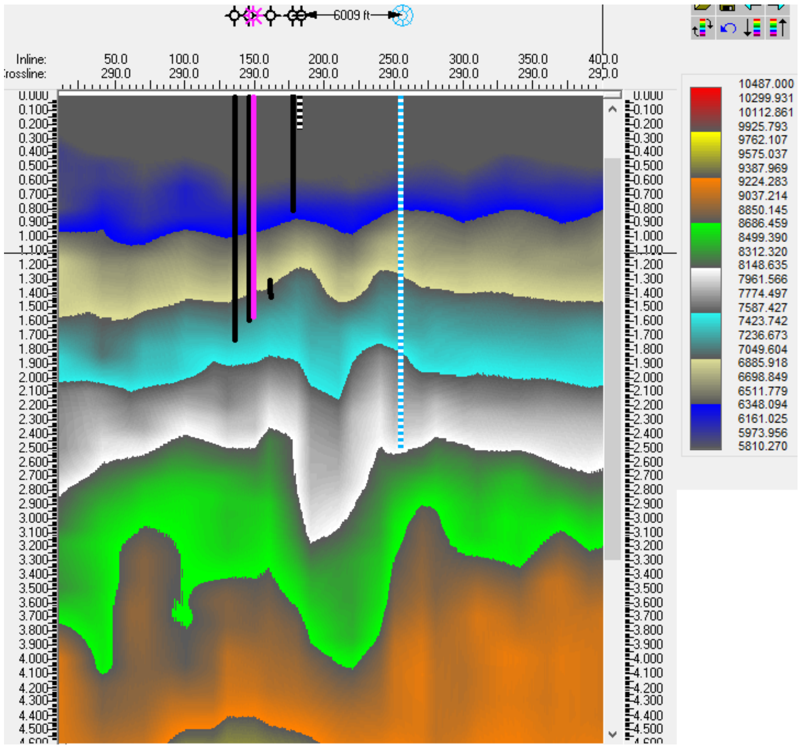
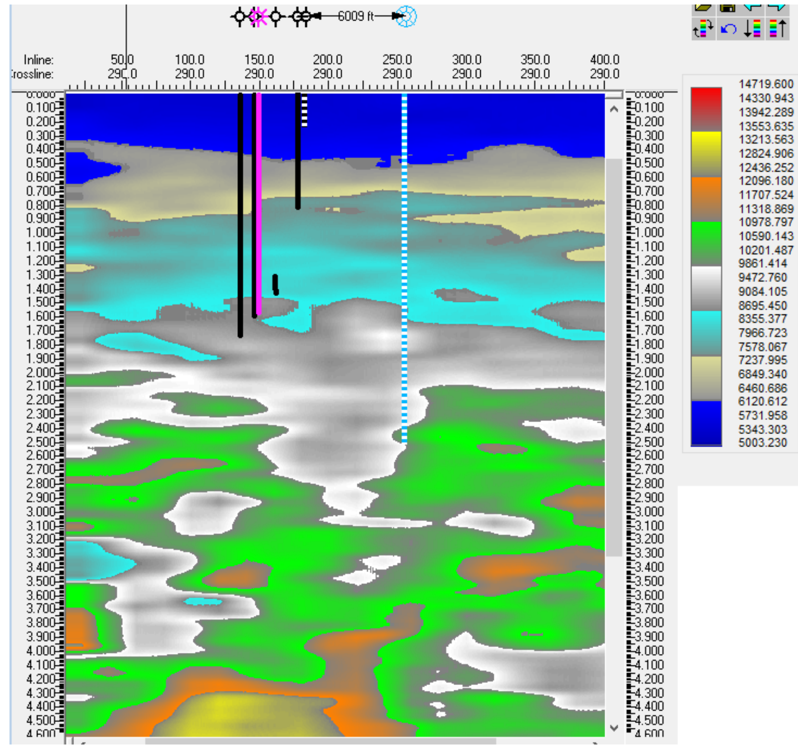
ONSHORE LOUISIANA: VELOCITIES DERIVED FROM 3D PROCESSING

RMS VELOCITIES



INTERVAL VELOCITIES – DERIVED FROM RMS



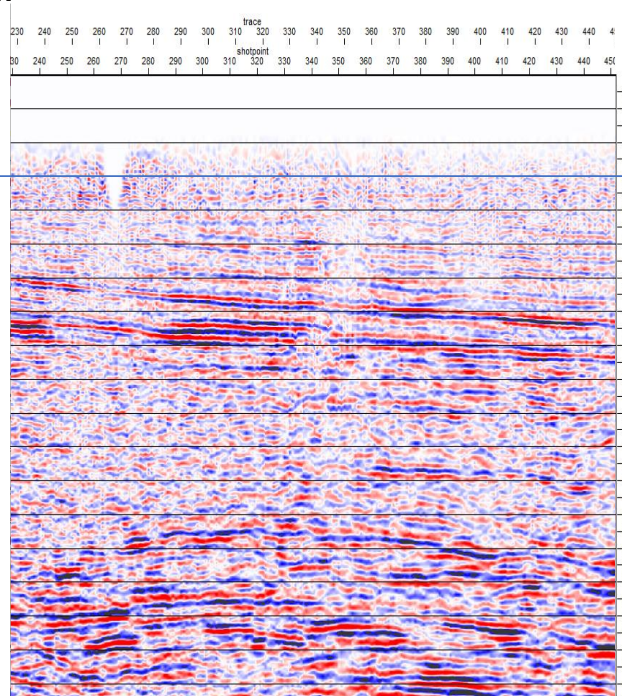
NOTE THAT THE RMS VELOCITIES SHOW A STEADY INCREASE WITH DEPTH, WHEREAS THE INTERVAL VELOCITIES COMPUTED FROM THE RMS SHOW MUCH MORE VARIABILITY. THE EFFECT OF THE SALT IS OBVIOUS ON BOTH FIGURES.

THESE VELOCITY TRENDS ARE TYPICAL OF THOSE IN THE GULF COAST AREA, WHERE SEDIMENTS ARE MAINLY DELTAIC AND MARINE SANDS AND SHALES. RMS VELOCITY INVERSIONS OCCUR IN OTHER AREAS (FOR EXAMPLE THE NORTH SEA), WHEN HARD LIMESTONES OVERLAY SOFT SHALES.

COMPARISON OF HIGH FREQUENCY SHALLOW TARGET DATA WITH BROAD FREQUENCY DEEP TARGET DATA

CLY-83-07

W **E**

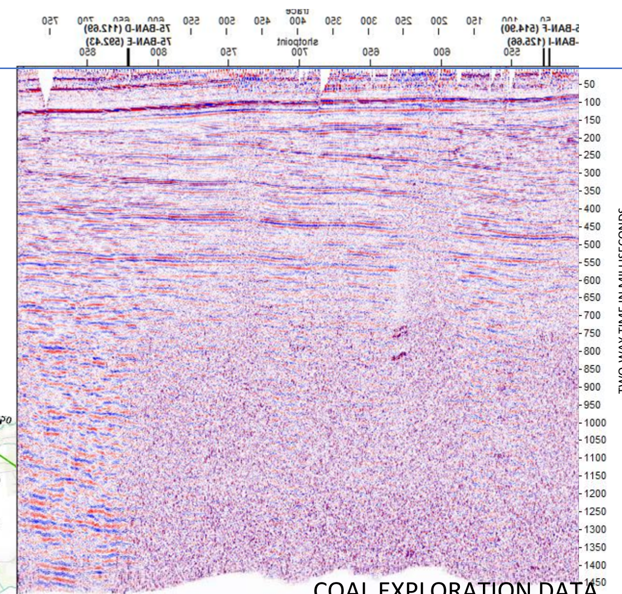


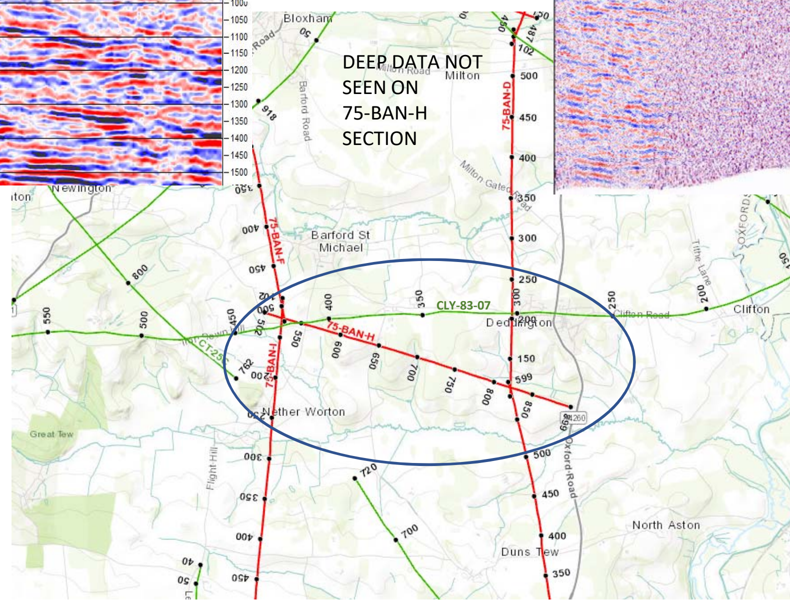
SHALLOW UNCONFORMITY NOT SEEN ON CLY-83-07 SECTION

75-BAN-H

W **E**

0ms





OIL EXPLORATION DATA
50M STATION INTERVAL
48-FOLD COVERAGE
2ms SAMPLING

GENERALLY SPEAKING, 2D IS BETTER THAN 3D FOR SHALLOW INVESTIGATION IN THE UK ONSHORE – AND COAL EXPLORATION DATA IS BEST.

COAL EXPLORATION DATA
10M STATION INTERVAL
12-FOLD COVERAGE
1ms SAMPLING

A HIGHER FREQUENCY SOURCE AND SHORT OFFSETS ENABLES THE RESOLUTION OF THIN BEDS IN THE SHALLOW SECTION – BUT PENETRATION IS LIMITED

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