PAPER Q

STP SOFTWARE UPDATE

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ABSTRACT

This purpose of this paper is to describe modifications and enhancements to the TIMS (Tomography Imaging and Modeling System) software since its first release last year, and describe other software available that is not part of TIMS, such as the reflection processing. In TIMS there are several new utility modules, and various enhancements have been made to the main programs to facilitate and improve processing of crosswell seismic data.

INTRODUCTION

The STP software currently includes both TIMS (Tomography Imaging and Modeling System) and reflection processing software. A full description of the first release of the TIMS software for processing crosswell data can be found in STP 3.1-P. The basic processing flow has not been changed, but the new software and updates provide more versatility and convenience with regard to picking, inversion, manipulating data and analyzing data.

STP SOFTWARE

The STP software currently consists of two parts: the TIMS package, and software that has been developed in the ProMAX development environment, such as the reflection processing. Both are discussed separately below. There is also a brief look at future development of these packages, plus what other code may be included later on.

TIMS Update

TIMS is a collection of software programs that provides end-to-end traveltime processing of crosswell seismic data. The programs include the ability to: read several

forms of SEGY data and convert to the TIMS seismic data storage format; pre-process traces; interactively pick the data; run inversion code. The software is designed to work in a heterogeneous distributed network of UNIX workstations. To review a typical processing flow:

1. Put data in TIMS SEGY format.
2. Convert to TIMS netCDF format for picking.
3. Trace pre-processing.
4. Pick the data using xpick.
5. Create geometry files prior to inversion.
6. Run the inversion.
7. Display tomogram.
8. Use output from inversion to iterate from step 4.

Changes to Xpick

xpick is an interactive pick program written, using the X window system, specifically for picking traveltimes from crosswell seismic data. The new version of the program contains more error-checking, more versatility and more functionality. The most significant changes are that: a 2D image of the picks can be displayed while picking; picking can be done by drawing a line and having the picks adjust to the nearest peak (maximum or minimum or first break); picks can be projected onto the next or previous gather by linear extrapolation (with moving to peak or first break); model picks from the inversion program can be imported and displayed; interactive model-based raytracing can be applied while picking; the data can be displayed in Common MidPoint Gathers (gathers of traces of which the average of the source and receiver depths are the same).

The pick image is useful to show where large jumps occur in the picking process. If the data are initially picked in common receiver gathers, the pick image will appear streaky in the common receiver direction, and the picks will look jittery in common source gathers. The pick image can help identify such areas of inconsistency in picking.

Being able to move picks to the nearest peak, and being able to project picks forward or backward speeds up the picking process enormously. With large datasets of 40,000 traces or more, this becomes increasingly important. The picks can be projected one gather at a time, or several. Unlike ProMAX 4.0, which paints your last picks on the next gather and allows you to snap to the nearest peak, xpick uses the picks on the current and previous gathers to extrapolate to the next gather. If a pick on a previous gather is missing,

correlation with an adjacent trace is used to estimate the new pick. The slope of the line used to calculate the extrapolated pick can be adjusted to accommodate the non-linear moveout.

The model-based raytracing feature allows you to import a slowness model, trace rays through the model, and display the resulting calculated traveltime on the current gather. The slowness image can be displayed, and the ray paths superimposed. Either an average well distance can be used for each gather, or the geometry files used in the inversion program can be read in if it is important to make allowance for any well deviation. Fig. 1 shows a screen dump of the xpick program displaying a slowness image (with rays), the pick image, and the traveltimes calculated from the slowness image (blue circles). The regular picks are shown as red crosses.

xpick reads and writes picks to netCDF files. To facilitate data exchange, two utility programs have been written to convert the netCDF pick data to and from ASCII format. These programs are pickread and pickstore.

Update on Inversion Routines

One variation of the string inversion routine included in this year's distribution is 'block'. block is a more traditional parameterization of the crosswell tomographic inversion where the slowness model is defined by discrete pixel-sized elements. This version calculates the traveltime of each ray by multiplying the slowness of each pixel traversed by the ray by the length of that ray in the pixel The back projection of traveltime residuals is consistent with this manner of calculating traveltimes. In contrast, the string inversion assumes a smoothly varying slowness function. The slowness function is represented by nodes and the slowness at any point is determined by the linear interpolation of the surrounding nodes.

A second difference in the two programs is in the definition of a back projection. The string algorithm defines a single back projection by the shooting of rays from sources to receivers or receivers to sources. Since neither string nor block attempt to link rays, one-sided shooting can leave holes in ray coverage. In an attempt to force the ray coverage to be more uniform, block defines a single back projection as shooting in both directions, sources to receivers and receivers to sources.

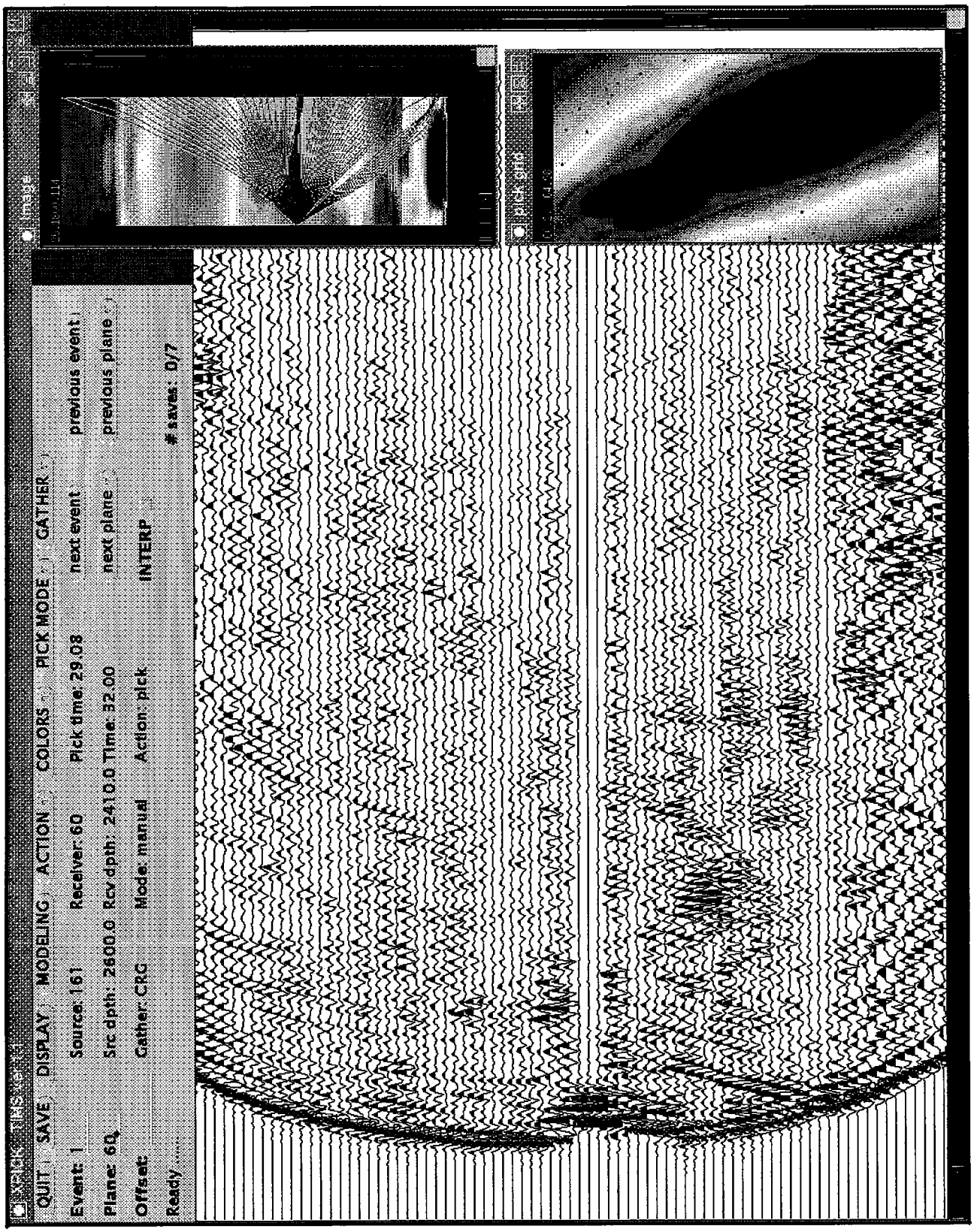

Figure 1. Screen dump of xpick showing slowness and pick images.

Other Modifications to TIMS

Most other modifications have been made to increase convenience and versatility, such as being able to read more SEGY formats and excluding zero values in grid arithmetic calculations. In particular the format of the binary grid files has been slightly modified to allow for an ASCII header before the binary part of the file. This allows the header part to be viewed directly with simple UNIX commands. A list of the programs included in the TIMS distribution is given in Appendix A. Programs that have been modified, or that are new, have been marked.

Reflection Processing

The reflection processing package provides all the programs necessary to create reflection images. This software has not been modified recently, and remains integrated with the ProMAX environment. A description of all the ProMAX modules written by STP personnel can be found in Appendix B.

Future

While continuing to improve the pick program and inversion techniques, in the short term we will also be working on including Reinaldo Michelena's anisotropy inversion code in the TIMS software package. Long term we are looking at parallelizing suitable code, such as the string program, to take advantage of distributed computing. We may also convert xpick and grdview to a different X toolkit (such as Xt) to maximize their portability. In addition, we are looking at some form of data compression for storage of our large datasets. Other students' code will be included as it matures, such as the crosswell migration code.

APPENDIX A - TIMS PROGRAMS

Program	Description	Author(s)
Data Formatting		
cdf2segy**	convert seismic data from netCDF format to SEGY format	CL
cdftoppm	convert grid in netCDF format to ppm format	CL
field2tims	convert seismic data from field format to SEGY format	WW/CL
grd2segy	convert grid to pseudo-SEGY format for ProMAX display	CL
grdtocdf	convert binary grid to grid in netCDF format	CL
grdtoppm	convert binary grid to ppm format	CL
ppmtogrd	convert from ppm format to binary grid	CL
segy2cdf**	convert SEGY data to TIMS netCDF format	MF/CL
segy2grd	convert pseudo-SEGY data from ProMAX to binary grid	CL
segydisk**	convert SEGY to SEGY; read SEGY from tape	MF/WW/CL
synpkcdf	convert ASCII picks to picks in netCDF format	CL
grdto1d*	extract a column from a grid file, output in ASCII	CL
mimtrans*	convert from SIERRA MIMIC format to binary grid	CL
Trace Processing		
agc1	perform AGC on seismic traces	GM
bpf1	bandpass filter	GM
fkf1	time domain filter	GM
fks1	2D spectral estimation	GM
hil1	Hilbert transform	GM
med1	minimum phase deconvolution	GM
Picking Tools		
xpick**	X window based interactive picker	CL
pickread*	read picks from netCDF, output in ASCII	CL
pickstore*	read picks in ASCII, output in netCDF	CL
Inversion Programs		
pikint	interpolate picks on a regular grid	JH
ipgen	create image plane geometry files	JH
string	string inversion	JH
block*	block inversion	MVS
Inversion Utilities		
convert	convert between ASCII and binary grid format	CL
deviation	add deviation information to data in netCDF format	JH/CL
devlog	convert log wireline depths to XYZ well coordinates	JH
invert	invert grids between slowness and velocity	JH
logtogrd**	create slowness grid from sonic log data	JH
modtogrd	create slowness model from velocity nodes	JH
pikreg	register gridded picks to wireline depths	CL
pikshift**	add a constant to interpolated picks	CL
smooth	smooth a binary grid	JH
ray*	raytracing program	JH

Program	Description	Author(s)
Display Tools		
coverage	display source-receiver map from data in netCDF format	CL
grdview**	display binary grids	CL
gridlog**	plot logs and grids together on the Versatec plotter	CL
segyplot**	plot SEGY data on the Versatec plotter	MF/CL
versagrid**	plot grids on the Versatec plotter	CL
versatrace**	plot data in netCDF format on the Versatec plotter	CL
Miscellaneous Utilities		
grdarith**	perform basic arithmetic operations on two grids	CL
grdmerge	merge grids into a single file	CL
ncCheck	check the data in netCDF format	CL
ncDump	dump a netCDF file	CL
segydump	dump the headers from SEGY data in netCDF format	CL
timesl	extract a time slice from SEGY data in netCDF format	CL
segyhdrs*	prints headers of SEGY file	CL
grdfft*	computes FFT of binary grid	CL
grdmask*	mask portion of grid beyond well boundary	CL
wellcoord*	print out well coordinates used in inversion	CL

Authors

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JH	Jerry Harris
GM	Gary Mavko
MVS	Mark Van Schaack
MF†	Mike Fitzpatrick
WW†	Winnie Wan

*new
**modified
†no longer at Stanford

APPENDIX B - REFLECTION PROCESSING MODULES

Program	Description	Author(s)
Crosswell Processing		
angtrans	angle transformation	SL
angtrans2	newer version of angle transformation	SL
cdpflat	flattening of horizons in CDP gathers	SL
dstatic	corrects for differences in reference depth between mapped gathers (data stored in CDP gathers)	SL
edstatic	corrects for differences in reference depth between mapped gathers	SL
fillgaps	fill in missing traces with zero traces	SL
invflat	inverse flattening (reference at receiver well)	SL
labelsuperg	enables picking in supergathers, labels stacked data as unstacked	SL
mhorflat	horizon flattening (reference at receiver well)	SL
mhorflat2	horizon flattening (reference at source well)	SL
rt1d	1D ray tracing	SL
stplmo	linear moveout	SL
transhor1	transposes horizons picked in constant-angle sections into horizons in CDP gathers	SL
transhor2	transposes horizons picked in CDP gathers into constant-angle section horizons	SL
transtable	transposes mutes picked in constant-angle sections to mutes in CDP gathers	SL
vspcdpdn	VSP-CDP mapping (downgoing)	SL
vspcdpup	VSP-CDP mapping (upgoing)	SL
wcommodn	well-corridor NMO (downgoing)	SL
Crosswell Miscellaneous		
angweight	angle-dependent amplitude weighting	SL
bpicktable	copies picks into a parameter table	SL
combhor	combines different horizon files into one	SL
copymute	copies mutes defined for a reference CDP location to all CDP locations	SL
dvweight	depth-variable angle-dependent amplitude weighting	SL
horint	horizon interpolation	SL
invspcdpdn	inverse VSP-CDP mapping (downgoing)	SL
invspcdpup	inverse VSP-CDP mapping (upgoing)	SL
splithor	splits horizon file into different files	SL
transpick	transforms picks to comply with a particular forward-inverse mapping combination	SL
transpose	transposes a data file	SL
velancordn	corridor velocity analysis (downgoing)	SL
velancorup	corridor velocity analysis (upgoing)	SL
velopick	automated velocity picks	SL
timsfldin	STP SEGY field data input module	CL
thdrin	trace header input	CL
hdrsmth	trace header smoothing	CL

Authors

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REFERENCES

Lambert, C., and Harris, J.,1992, TIMS Software: STP-**3**, v.1, Paper P.