DATA PREPARATION UNIT

for Seismic Tomography System XTomo-LM 3

Version 3.0.2

User Guide

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Data Preparation Unit
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What's New in Version 3?

The purpose of Data Preparation Unit (DPU) is extracting information from field data for input into seismic tomography system XTomo-LM®. Version 3 of XTomo-LM (two releases have been published since November 2013) radically differs from the previous versions due to new data store architecture and many important innovations. Version 3 was fully adapted to the latest Windows versions. DPU 3.0.1 represents the result of similar modernization of DPU 2.

Keeping the base product functionality, DPU 3 provides the following two features:

1) general simplification of the user interface and focusing on the main function of serving as the input block of XTomo-LM;
2) dramatic growth of productivity at the expense of concurrent and parallel computations wherever it is possible.

For example, creation of a new project includes now building of line geometry for 2.5D profiling and is performed "by a single click". The user interface of picking arrival times is simplified and made more convenient. More options of graphic and text export are available. DPU can export data of 3D observations to 3D tomography system Firstomo®.

DPU 3 can run on a computer with DPU 2 installed. Though projects of versions 2 and 3 are incompatible by data, it is possible to import arrival maps picked in DPU 2 to a DPU 3 project.

Introduction

1 Product Overview

Purpose of DPU – Transformation of coordinates – Picking arrival times – Kinds of observations – Introducing static corrections – DPU projects – Software. Documentation

Purpose of DPU

XTomo-LM input data consist of seismic wave arrival times for a set of source-receiver couples, each device being described by its ID and position. These data are packed into an ASCII file of the SRT format. The details can be found in XTomo-LM documentation (XTomo-LM 3.x is always meant). Extracting this information from large volumes of field data and making up an SRT file is a self-contained problem which can hardly be solved without appropriate software. DPU is just that kind of software. It can be applied to any data represented by common source point seismograms, each one in a separate SEG-Y/PC file, and, possibly, additional ASCII files with positional data. DPU requires that these files follow the "shots–stations–relations" model. Thus, positional data are either contained in seismogram trace headers or in three ASCII files. Details are given in the chapter Input Data.

When seismic stations are used as receiver devices, such as ocean bottom station, seismic traces are, naturally, gathered in common receiver point seismograms. DPU can be applied straight to this case as well: an OBS can be regarded as a source and an airgun shotpoint as a receiver. This is permissible because XTomo-LM is focused on *kinematic* interpretation only. Moreover, even in study of converted waves changing for *inverted* observation system is acceptable due to the new DPU feature of optional interchanging sources and receivers at the stage of creating of SRT file.

The observed data transformation from "CSP seismograms + positional data" into SRT file suggests getting solution to the following problems:

1. Import of field data and creating Geometry Database.
2. Transformation of coordinates.
3. Picking wave arrival times.
4. Creating target data (export).

Transformation of Coordinates

SRT file contains coordinates of sources and receivers in 2D coordinate system (X', Y') used in XTomo-LM. X' axis is directed along the seismic line, while Z' axis – vertically upward. Meanwhile, data delivered by a field crew are described in a coordinate system of its own choice, usually, UTM. In DPU it is supposed that positional data are presented in a local 3D coordinate system (X, Y, Z) with Z axis directed vertically upward. Thus, DPU must perform the transformation

(1) $(x, y, z) \rightarrow (x', z')$.

Depending on conditions of observations, source and receiver positions may, more or less significantly, diverge from the planned seismic line. Therefore, posing the problem in the form (1) may prove irrelevant. The approach used in DPU is based on pessimistic assumptions about the conditions of observations. DPU builds the observation system on a seismic line defined by source positions, which is as kinematically close to the experimental as possible. In particular, it keeps receiver offsets intact which is crucially important for arrival times interpretation. The details are given in the chapter Line Geometry.

Picking arrival times

Declining the exact implementation of phase correlation procedures, which are too sensitive to seismic record quality, DPU uses interactive approach, in which the user double-clicks a couple of signal phases on the record between which arrival times can be predicted and refined by simple and fast algorithms. The clicked phases are called checkpoints. Record quality influences only a necessary number of checkpoints for picking a phase lineup. A picked lineup represents a segment of a wave TX-curve (*tx-segment* or, simply, *segment*). The user can pick first and later arrivals of different seismic waves. A segment may contain one point as well. The result of picking from a seismogram is a set of tx-segments structured by waves. It is stored in a local database called *arrival map*.

Picking first arrivals is a comparatively easy task, but when layered model underlies data interpretation, picking goes in step with wave identification. This is not an unambiguous problem. Often, decision making requires studying and comparing maps picked from different seismograms as well as kinematic modeling. DPU delivers both services. It allows exploring *line arrival map* and plotting XTomo-LM forward problem solution over the seismogram image together with picked arrival map. DPU draws segments on the seismogram image so that each wave is painted with its own drawing attributes. DPU uses the same wave classification and encoding system as XTomo-LM. Details can be found in section Waves.

Kinds of Observations

Earlier in this section we implicitly assumed that input data were acquired during 2D seismic profiling. Two terms are used for such observations. We use the term *2.5D profiling* for the case when input data are described in 3D coordinate system (X, Y, Z). If they are described in 2D coordinate system (X, Z) or (Y, Z), the term *2D profiling* is used. The need to distinguish the cases comes from the technical problem of coordinate transformation discussed above.

However, input data can be acquired in other 2D surveys, such as borehole measurements or cross-borehole exploration. The name of *Other 2D observations* is used for them. Finally, data of 3D observations with any geometry can be input in DPU if only they are represented as a set of CSP seismograms. Results of picking first arrivals from these seismograms are exported to 3D seismic tomography system Firstomo as ASCII files of #DT type.

Introducing Static Corrections

The important application of seismic tomography in CMP technology is getting velocity distribution in near-surface layer and introducing statics corrections to compensate for referencing CMP data to new datum – a horizontal line. Both DPU and XTomo-LM are enabled to solve the problem as explained in section Geometry Database.

DPU Projects

A *DPU project* is a framework for processing the data acquired in a certain field experiment. At creation time, the following project properties are fixed: a kind of observations, a source of positional data, seismogram location, folder for export files and others. All intermediate data, such as geometry database, seismogram arrival maps, line arrival map, are stored in the *project folder* bearing the name of the project. Additionally, DPU uses three folders common for a set of projects: the working folder is a container of project folders; the export folder is a container for project import-export folders; the archive folders contains compressed files, each one storing all data of a project.

Software. Documentation

The head DPU program is Project Manager (DPM). It is launched when the user double-clicks the DPU icon on the desktop. DPM maintains the list of projects in the current working folder, manages projects' data and controls data processing. Processing operations are carried out by *executing modules*. When the user issues a command for a service or substantial operation, DPM launches the relevant module in accord with predefined processing workflow.

The users of version 2 are strongly recommended to look through the documentation to get acquainted with numerous innovations which, otherwise, my stay unused or misunderstood. Two manuals in PDF and CHM formats can be accessed through the Windows Start menu. DPU is provided with context help system , whose help topics are called by help buttons, help menu commands or by striking F1 key. If a window has a status bar at its bottom, it displays hints for any menu command in the window's menus and menus of invoked dialogs.

2 Line Geometry

The problem

In this section it is explained in detail how DPU transforms field device positions (X,Y,Z) into positions (X',Y') of two-dimensional XTomo-LM observation system. As mentioned in product overview, actual source and receiver positions do not belong to the planned seismic line – a straight line – and can deviate from it significantly due to unexpected obstacles, such as ice conditions in northern seas or natural obstructions in hard-to-reach areas. Summing up the practice of XTomo-LM application, DPU is designed in the way to embrace most pessimistic scenario for conditions of observations and uses the following problem statement.

Problem Definition

Let *d(A,B)* denotes euclidean distance between points *A* and *B* on (X, Y) plane. Let ***S*** be a set of actual shotpoints; ***R*** – a set of actual receiver positions; $\boldsymbol{R}_S$ be a set of receivers responsive to a source at point *S*. All points are defined in (x,y, z) coordinates.

The *line observation system* is defined by a straight line ***L***, a set of shotpoints ***S'*** and a set of receiver points ***R'*** satisfying the following requirements:

1) standard deviation of shotpoints $S \in \boldsymbol{S}$ from ***L*** is minimal among all possible positions of line ***L***;
2) ***S'*** consists of orthogonal projections of shotpoints $S \in \boldsymbol{S}$ onto ***L***;
3) for each shotpoint $S' \in \boldsymbol{S'}$, the set of receiver points $\boldsymbol{R}_{S'}$ consists of quasi-projections of receiver points $R \in \boldsymbol{R}_S$ onto ***L***; *a quasi-projection of a receiver point R* is defined by the conditions: $R' \in \boldsymbol{L}$; *d(S', R') = d(S, R); (S'R', SR) >= 0*;
4) z-coordinate of *S'* is equal to z-coordinate of *S*; the same is true for *R' and R*.

Comment

It follows from the least-squares method, that condition 1) defines the unique line ***L***. Condition 3) means that quasi-projection *R'* is the end of the line segment *S'R'* of length *d(S, R);* from the two feasible positions of *R'* we choose the one making the angle between vectors *SR* and *S'R'* acute. In other words, *R'* lies on the same side of *S'* as *R* of *S*.

Receiver quasi-projection depends on a source for which it is responsive. Fig. 1 shows that receiver R_1 has different quasi-projections R'_{11} and R'_{12} with respect to sources S_1 and S_2. The greater deviation of sources from the line, the greater divergence of receiver quasi-projections. Thus, the line observation system is essentially more complex than the initial: each source can have its own receiver set.

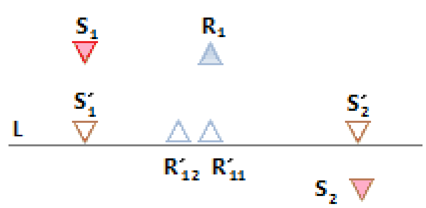


Fig. 1. Quasi-projections of receiver point R_1 with respect to shotpoints S_1 and S_2.

To justify this complicated construction, we have to answer the two questions: (1) what is the leading motive for it? and (2) what is the result if initial shot and receiver points belong to a straight line. The answer to (2) is obvious: the resulting observation system coincides with the initial. Imagine that the initial observation system is being changing so that its devices are approaching a line ***K***. Then ***L*** is tending to take position of ***K***, while the cluster of quasi-projections of each receiver *R* is gathering up into point *R*. As for the motive, it is simple: we want to build a line observation system in the way to keep intact receiver offsets, which enable us to reasonably define wave traveltime for each (*S', R'*) couple as *T(S', R') = T(S, R).*

Line coordinates

For a point $P' \in$ ***L***, which is a shot or receiver point, its line coordinates (x_L, z_L) are defined as follows:

$$x_L = d(O_L, P'), \quad z_L = z,$$

where O_L is a fixed point on ***L***, selected as the origin. DPU chooses the origin programmatically. That is not essential because the user can later shift the origin at his or her discretion.

Line stations. Space Resolution. Receivers' ID.

Of course, we cannot associate receiver quasi-projections with *seismic stations*, because they can be arbitrary close to each other, and this does not make physical sense. The more so that XTomo-LM works with ray approximation in which objects as close as two wavelengths and less cannot be discerned. To build a set of line seismic stations, DPU requests the user to define line spatial resolution D_X. It is similar to physical x-resolution in XTomo-LM (see section "Spatial Resolution" in XTomo-LM documentation).

DPU makes use of D_X in the following way: it sorts out all receiver quasi-projections by their line coordinate X_L and "glues together" those which differ from each other by less than D_X. The remaining quasi-projections form the set of *line stations*. The stations are numbered. *Each line receiver R' gets its ID and line coordinates from the nearest station*. Each seismogram trace is associated with a receiver and, hence, with the receiver quasi-projection onto the line and, hence, with its ID and line coordinates. So does each arrival picked from this trace. Now the line observation system (or line geometry) is built.

Of course, some receiver quasi-projections have same IDs and line coordinates, but those are quasi-projections generated by different sources. Receiver quasi-projections relating to the same source are, normally, well resolved — or resolution D_X is ill-defined being too large.

3 Waves

The below text is copied from the XTomo-LM documentation with minor changes.

Interpretation Models

It is assumed in XTomo-LM that kinematic interpretation can be based on two media models. The first is the gradient velocity model. It is used, for example, in seismology, where the classic first arrival tomography first appeared. First arrival is an event on seismic record: the first sharp break of seismic energy on a trace. The set of first arrivals is regarded as a set of arrivals of a wave propagating in a media with gradient velocity. The goal of first arrivals tomography is determination of velocity section.

The second model is the layered model, using recording of reflected and refracted waves, generated by seismic boundaries. Layered model study includes mapping seismic horizons and determination of velocity in layers. In the latter problem the tomography approach again can be applied, with using arrivals of different waves. Thus, both models complement each other in interpretation problems. The above considerations motivate XTomo-LM classification of waves.

Wave Types

The following kinds of waves are used:

- diving or transient wave;
- reflection;
- head wave;
- first wave.

An observed event on seismic record is supposed to fall into one of these categories. Diving (transient) wave is formed due to continuous refraction. *Head wave* is a wave propagating along an interface of small curvature dividing layers with velocity limit values V_1 (from above) and V_2 (from below) with $V_1 < V_2$. The implied physical model is a waveguide: a wave propagates within a thin layer under the interface generating upward rays attaining the surface. In the documentation and user interface the term "head wave" is used rather than "refraction" to avoid ambiguity.

First wave is placed in the same list, despite its formal definition, because its arrivals are interpreted as those of continuously refracted wave. If refraction(s) and/or head wave(s) are identified in the same study, first wave can include arrivals of different waves. For example, head waves from different horizons successively come out in first arrivals at large offsets; thus first wave may consists of diving wave and head wave arrivals. When data are being prepared for input into XTomo-LM, some arrivals can be used more than once, say, as part of first wave and as arrivals of head wave. At processing time, they may be used for different purposes, say, to determine velocity section (as first arrivals) and to build a refractor (as head wave arrivals).

Converted waves are allowed to come into play in modeling projects. The fact of conversion of a refraction or reflection on a seismic boundary H is treated as changing velocity of propagation from $V(x,z)$ to $C_H \cdot V(x, z)$, where V is defined by the model, C_H is *conversion coefficient (CC)*, depending only on a horizon H.

Numeric codes

A wave is identified with its numeric code or ID in the following way:

ID = 0 for diving or transient or first wave;
ID = <Horizon ID><Wave type> for reflection or head wave.

Horizon ID is an integer number in the range 1 to 99, for example, the ordinal number in the model. Wave type is encoded with one- or three-digit number:

0 – monotype reflection;
1, 100 – 199 – converted reflection;
2 – monotype head wave;
3, 300 – 399 – converted head wave.

To compare with version 2 two code ranges for converted waves are added. Here are examples of wave codes:

(1) 0, 10, 1101, 3302, 102.

They encode, respectively, diving wave, reflection from horizon 1, converted reflection from horizon 1, head converted wave from horizon 3, head wave from horizon 10. Encoding is far from being lucid, but the need for backward compatibility prevails. In the user interface, wave ID is displayed with hyphen between horizon ID and wave type:

(2) 0, 1-0, 1-101, 3-302, 10-2.

Internally, wave ID are stored as 4- or 5-digit numbers:

(3) 0, 1000, 1101, 3302, 10200.

In SRT files one can use representations (1) or (3).

Temporary waves codes

Wave identification is a difficult task in the sense that it cannot be carried out at one go. Often, one has to pick arrivals from several or all seismograms and only then one is enabled to make the final decision. Before export, one can use all available wave codes at one's own discretion under the only restriction that they be used in the same manner for each seismogram. After the final decision is made, codes in all maps can be replaced in the way to fit in the XTomo-LM classification.

Input Data

1 Overview

DPU Input data include seismic records gathered in CSP seismograms and, optionally, ASCII files with positional information. Each seismogram is stored in a separate SEG-Y file. Using the SEG-Y Standard is commented on in detail in section Seismograms. Positional data either are extracted from trace headers or supplied in ASCII files which describe observation geometry following the "Shots-Stations-Relation" model or in *SSR files*, for short. They are considered in section SSR Files. Correspondence between SSR files and seismograms are established by FID value, which is written both in each trace header and in Shot file. It happens sometimes that no identifying information is stored in seismograms. In such cases one can use the *modified SSR format* or, shortly, *SSR(m) files.*

In the SEG-Y Standard, value of a coordinate is defined by an integer and a *scaling factor*. DPU requires that scaling factors be the same for all traces of all seismograms and that SSR files use the same way of coordinate representation. At that, common scaling coefficients – there are two of them: one for X and Y, the other for Z – are not extracted from input data, but are defined by the user as a property of a project to create. Thus, values of coordinates in SSR and SSR(m) file must be integers.

2 Seismograms

The term *SEG-Y/PC* is used for the seismic file format that satisfies all requirements of SEG-Y Standard but one: order of bytes in a word encoding a number. The Standard requires that the first byte of the word represent the most significant bits of a number (big-endian representation). Meanwhile, the x86/Widows platform is based on the opposite byte ordering. Therefore, a SEG-Y file cannot be read by software for this platform without preprocessing. To conduct this preprocessing in real time would slow down the work. It is better to convert a SEG-Y file to SEG-Y/PC.

Because interpretation of the SEG-Y Standard varies, the exact way DPU does it follows now. It is convenient to use the notion of *information word* for meaningful portion of SEG-Y header. Information words may be of 2, 4, or byte length and are numbered starting from 1. In Appendix, one can find SEG-Y header layouts in which the words used by DPU are highlighted. DPU interpretation of the Standard and restrictions are summarized in the below statements.

1. The following signal sample formats are permitted: 2-byte integer (I2); 4-byte integer (I4);

4-byte floating-point (R4).

2. R4 sample must satisfy the IEEE 754 Standard. At that, file header word 10 encoding the sample format must have value 5; however, the value 1, once used for IBM mainframe format, is also permitted.
3. All trace in a seismogram must have the same number of samples.
4. At file opening time, the following file header words are interpreted: 6, 8, 10, 28–30. When reading file, DPU interprets the following words of trace headers: 2, 39, 40. If positional data are extracted from trace headers, then, additionally, the words listed in table 1 are interpreted. Source z-coordinate is defined as difference of values of words 14 and 15.
5. Textual file header is interpreted as ASCII text.

Table 1. Trace header words with positional data

Description	Word	Bytes
Field source number	3	9 - 12
Source X-coordinate	22	73 - 76
Source Y-coordinate	23	77 - 80
Day surface Z-coordinate at shotpoint	14	45 - 48
Source depth below surface	15	49 - 52
Receiver X-coordinate	24	81 - 84
Receiver Y-coordinate	25	85 - 88
Receiver Z-coordinate	13	41 - 44

If positional data are stored in SSR files, only word 3 is interpreted. If positional data are stored in SSR(m) files, none of these words is interpreted. Below is the list of SEG-Y file open errors. Error messages may refer to error codes in the list.

Table 2. Typical open/read errors for SEG-Y files.

Код	Описание
1	No file is found with given path or access rights are not sufficient.
2	Windows cannot determine file size.
3	Memory allocation error for file buffer.
4,5	Unidentified open error.

6	File is too small to be a SEG-Y file.
7	Disc read error.
9	Too large number of traces. Possibly wrong file format.
12	Illegal value of file header information word.
13	Cannot interpret an information word of file header.
14	File of Revision 1 with variable length of additional textual blocks.
15	Trace header error: sample interval or number of samples in trace differ from the respective value in file header.

3 SSR Files

The "Shots-Stations-Relation" model is used in standard seismic systems for processing CMP data. In CMP technology XTomo-LM is mostly used for studying near-surface layer and introducing static corrections in data (the details are here). Because this application is very important, the SSR model is used in DPU for representing observation geometry. It requires three ASCII files. File "Stations" contains the list of positions of all devices. In CMP technology they form a regular net on a seismic line or set of lines. File "Shots" contains the list of shotpoints with source FIDs, coordinates and references to the station list. File "Relation" establishes correspondence between seismogram traces and stations. DPU requires that files have the following names:

p_shot.txt, p_station.txt, p_relation.txt,

where prefix ***p*** is an arbitrary string without spaces, underscores and characters forbidden in file names. Each file contains a table whose cells are integers. The first file line contains column names and is not interpreted.

Example of file "Shots":

```
  #         X          Y       Z
  1   39910941   54334931    235
  2   39911200   54326938    196
  3   39911450   54318950    168
  4   39911700   54310962    151
  5   39911959   54302969    142
  6   39912209   54294969    141
  7   39912469   54286981    144
and so on.
```

Station numbers (#) follow without breaks; the first station number is not necessary 1. Coordinate triples must be unique. Table columns are not necessarily aligned. Spaces, commas or tabulation characters may separate number in a line. The last sentence pertains to all files.

Example of file "Shots":

Shot #	FID	Stn_#	X	Y	Z
1	216	134	39773900	53286100	379
2	217	136	39778469	53270750	381
3	218	138	39783041	53255400	383
4	219	140	39787609	53240050	374
5	220	142	39792181	53224700	368
6	221	144	39796750	53209350	296
7	222	146	39801319	53194000	355
8	223	148	39805891	53178650	302

and so on.

Here # is source ordinal number in the file; FID is source field ID; Stn_# is number of a station at which a source is located. The FID value must be written in word 3 of seismogram trace headers.

Example of file "Relation":

Shot_#	Trc1	Stn1	Trc2	Stn2
1	1	108	23	130
	24	138	47	161
2	1	110	23	132
	24	140	47	163
3	1	112	23	134
	24	142	47	165
4	1	114	23	136
	24	144	47	167
5	1	116	23	138
	24	146	47	169
6	1	118	23	140
	24	148	47	171
7	1	120	23	142
	24	150	47	173

and so on.

This file defines relation between trace numbers and station numbers, thereby connecting a trace to a receiver. The table consists of blocks. Each block matches a source whose number (Shot_#) stands at the first position of the first block line. First positions of other block lines are empty. Shot_# is source ordinal number in file "Shots". Each block line maps interval of trace numbers [Trc1, Trc2] onto interval of station numbers [Stn1, Stn2]. Minimal number of intervals depends on seismic design. In the example, each block consists of two lines, because shot response is not registered near the shotpoint. In block 1, the shotpoint coincides with station 134 (see example of file "Shots"). The response from shot 1 is registered by receivers at stations with numbers < 131 and > 137. That makes us to break trace numbers into two intervals [1, 23] and [24, 47] and map them onto intervals of station numbers [108, 130] and [138, 161] respectively. If observation system is not regular, a block may contain many lines; it is possible, though hardly probable, that a number of lines in a block is equal to a number of traces in a seismogram.

Файлы SSR(m)

The format is used for the case when seismograms do not contain FID in trace headers. The case occurs in geological engineering surveys with non-standard measurement systems. The format differs from SSR in two points:

1. File "Station" contains only receiver stations.
2. File "Shots" contains additional column with seismogram file names.

Example of file "Shots" of the SSR(m) format:

```
Shot_#        FID   Stn_#        X      Y        Z      Seismogram
    1        1380       0  1379814     30     -110      z1380.sgy
    2        1510       0  1510259     24      -69      z1510.sgy
    3        1610       0  1610276     35      -50      z1610.sgy
    4        1680       0  1680188     -1      -19      z1680.sgy
and so on.
```

References to stations are zeros due to condition 1. File names do not contain path. Path to seismogram location is a project property.

DPU Framework

1 Content of Processing

Problems to Solve

In product overview the following problems for DPU to solve are stated:

1. Import of the field data and creating Geometry Database.
2. Transformation of coordinates.
3. Picking wave arrival times.
4. Creating target data (export).

Elaboration

Problem 2. In case of 2.5D profiling, DPU builds line geometry. In case of 2D profiling line geometry is built formally too. For other observation kinds, initial positional data are stored. Irrespective of observation kind, data are reduced to the same format and are stored in *Geometry Database* (GDB). The database includes the files of local database management system and flat binaries of RLN type. An RLN file contains a slice of information pertaining to a seismogram in order to speed up export operations. In the user interface, RLN files are referred to in error messages, and this is the reason they are mentioned here.

Thus, problem 2 is the problem of building GDB which, together with data import, are stages of creation of a DPU project. Once a project is successfully created, module Geometry Database Viewer displays its entire contents for the user to explore.

Problem 3 in case of first arrival tomography is solved by module Arrival Times Picker which allows picking arrivals from a seismogram and creating an arrival map. But if study of layered model is under way, problem 3 turns into wave field analysis (see product overview) and requires involvement of additional tools down to modeling. To embrace all variants, we call the problem "Creating, editing and exploring arrival maps".

Problem 4 is a final DPU task. There are three points of exporting kinematic data. After picking arrival maps is finished, module Arrival Map Exporter can export an arbitrary sample of arrival maps to XTomo-LM or Firstomo. Export to XTomo-LM is allowed also from line arrival map which can be built and studied in cases of 2D and 2.5D profiling. Export of geometry data is responsibility of Geometry Database Viewer.

Workflow

Summarizing the previous notes, we can present the content of processing as the following operation list:

1. Creating a DPU project (and Geometry Database).
   - viewing and exploring Geometry Database;
   - shifting the origin of line coordinate system.
2. Creating, editing and exploring arrival maps.
   – picking phase lineups from seismograms and creating seismogram arrival maps;
   – importing arrival maps from another DPU 3 or DPU 2 project;
   – exporting line geometry to XTomo-LM with the aim of creating a modeling project;
   – creating arrival map from XTomo-LM solution of forward problem;
   – creating and exploring of line arrival map.
3. Exporting arrival maps.
   – exporting a subset of seismogram arrival maps to XTomo-LM or Firstomo;
   – exporting (a part of) line arrival map to XTomo-LM.

Processing stages form DPU workflow: 1 → 2 → 3. Operation of each stage are options which the user selects. Import of arrival maps suggests that different projects are based on the same set of seismogram. When exporting, DPU chooses the target file as SRT (XTomo-LM) or #DT (Firstomo) depending on dimension of data. The list does not show service operations, such as creation/ selection of common folders or manipulations with projects.

2 DPU Project Manager

Main window

The head DPU program, DPU Project Manager (DPM), is launched when the user double-clicks the DPU 3 icon on the Windows desktop or selects the Start menu command. DPM main window is shown on fig. 1.

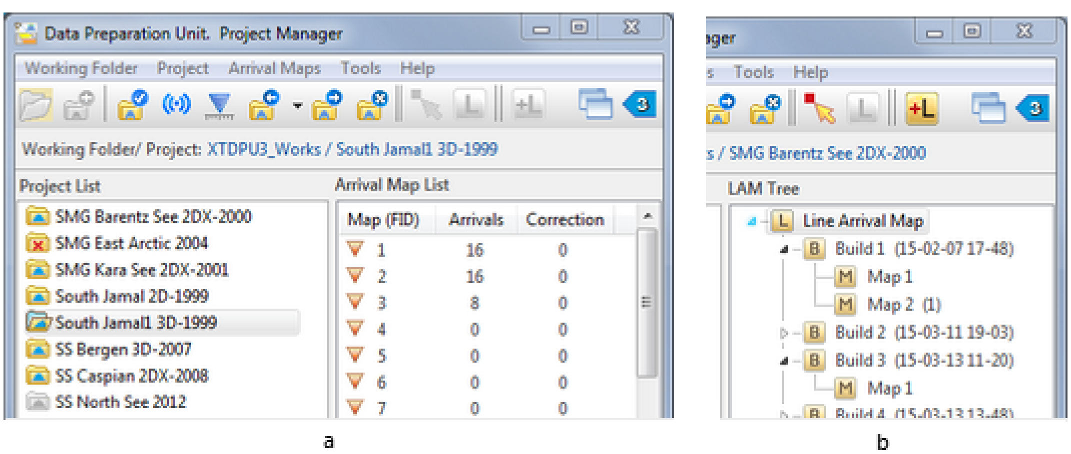


Fig. 1. Project Manager main window. a – in normal mode; b – in LAM mode.

The left panel contains the list of projects in the current working folder. The right panel displays the data of currently opened project: arrival map list in normal mode (fig. 1a) or LAM tree in LAM mode (fig .1b). LAM is a shortcut for Line Arrival Map. The mode becomes accessible after creating the first LAM build (details can be found in section Line Arrival Map). Project list icons are meaningful, and their meaning is explained in table 1.

Table 1. Project Icons

	Project is closed.
	Project is opened. Its name is displayed under the toolbar together with current working folder.
	Deactivated project. An attempt to create the project failed most likely due to an error in input data. New attempt can be made. Details are here.
	Deactivated project. An error occurred during operation which can break Geometry Database integrity. The project is to be deleted. Details are here.

Program Control

DPM is managed by the main menu commands and commands of context menus of project list, arrival map list and LAM tree. As usual, some main menu commands have matching buttons on the toolbar. The popup menus are discussed in other sections of this and next chapter. Table 2 enumerates main menu commands.

Table 1. Project Manager main menu commands

Команда	Описание
Menu *Working Folder*	
Common Folders	Invokes the dialog for setting common folders (working, export and archive). The command is enabled when all projects are closed.
New Project	Invokes the *Project Properties* dialog permitting to set properties of a new project and to start an attempt of creating it. The command is enabled when all projects are closed.
Add Project From	Adds a new project to current working folder; either it is copied from a network location or it is restored from a specified archive file in the archive folder. Details are here.
Sort Projects by	Sorts out project list either by project name or by creation time. Project creation time is displayed on the status bar when the cursor is hovering over the project name in the list.
Update Project List	Updates project list by reading data from the working folder.
Exit	Terminates the program.

Menu *Project* (enabled if there is an opened project)	
Properties	Displays the *Project Properties* dialog.
Geometry	Launches module Geometry Database Viewer for exploring Geometry Database. Details are here.
Shift Line Origin	Launches module for moving line coordinate system origin. The command is enabled if observation kind is 2.5D or 2D profiling. Details are here.
Wave Manager	Runs Wave Manager providing support of the project wave list. Details are here.
Close project	Closes the project.
Menu *Arrival Maps*	
Check Maps	Checks and updates a number of picked arrivals by rereading arrival map databases.
Clear Maps	Removes picked arrivals from all arrival maps.
Import from DPU 3 Project	Runs module importing specified maps from a DPU 3 project. Details are here.
Import from DPU 2 Project	Runs module importing specified maps from a DPU 2 project (if version 2 is installed on the workstation).
Export	Runs module exporting arrival maps to XTomo-LM 3 or Firstomo. Details are here.
Build Line Arrival Map	Runs module creating new LAM build map from non-empty seismogram maps. Enabled for projects with 2.5D and 2D data. Details are here.
Show Line Map Tree	Switches Project Manager mode from normal to LAM mode and back. The same can be done with two toolbar buttons between double dividers.
Update Tree	Updates LAM tree, reading data from disc.
Menu *Tools*	
Active Module List	Displays list of active modules. See below.

Module Controls

For carrying out processing operations, Project Manager runs executing modules. Each module is a standalone, often very complicated Windows application. Several modules can work at one time or several instances of the same module. The policy of module control is the responsibility of Project Manager. The *Tools|Active Module List* command displays list of active modules (fig. 2) with its context menu.

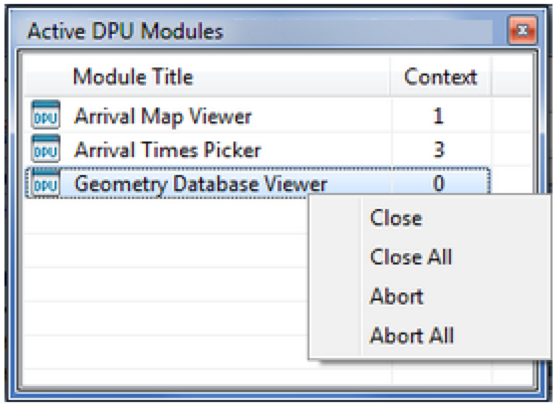


Fig. 2. List of active modules.

The *Context* column cells refers to an object, which a module processes. This is done to distinguish instances of the same module. For example, Arrival Map Viewer refers to a map, and its context is map ordinal number in the list. The dialog is helpful for response to abnormal situations when a module got hung or lost control. The commands *Close* and *Abort* allow terminating module in different ways. *Close* shuts down a module correctly saving all data. *Abort* kills the module's process and frees its resources. Data can be lost or corrupted. One should resort to aborting as the last means.

3 Creating a Project

Common folders – Setting properties for a new projects – Creation – Creation errors – Project properties.

Common folders

Common folders must be selected before creation of the first project. A common folder must not contain another common folder. The *Working Folder|Common folders command*, enabled when there no opened project, invokes the *DPU Common Folders* dialog. Each folder – working, export and archive – can be either selected from a drop-down list or defined in local folder browser. The latter is called with a button to the right of the list.

Setting properties of a new project

The *Working Folder|New Project* is enabled, if only there is no opened project. It displays the *Project properties* dialog with empty fields which are to be filled out following the below guidelines.

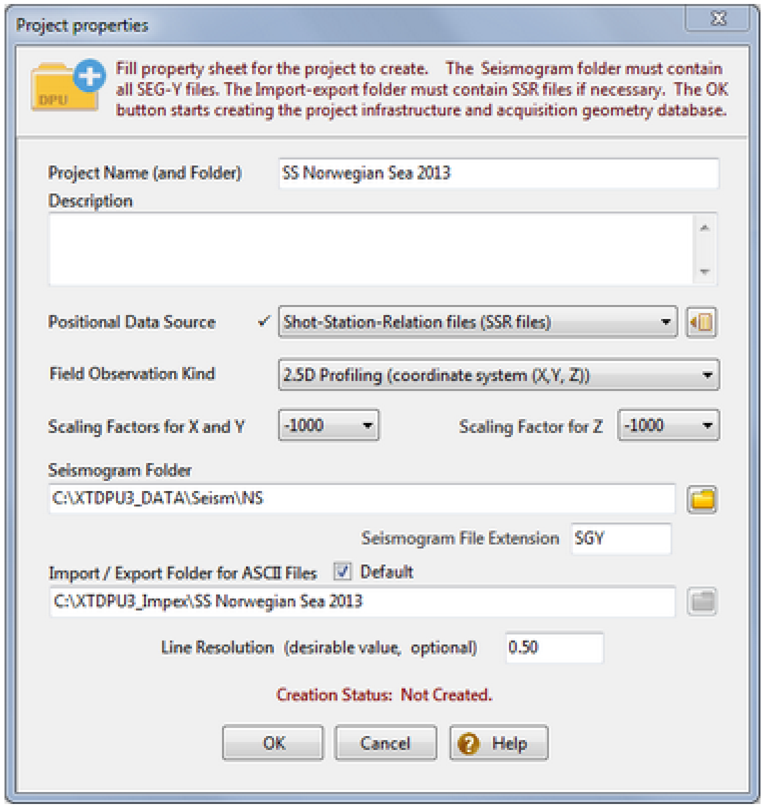


Fig. 1. Dialog for setting properties of a new project.

1. *Project Name (and Folder)*. Project name consists of no more than 25 characters excluding those forbidden in file names and leading or trailing spaces.

2. *Description.* The optional field contains several lines of text about the project; the character "|" is forbidden.

3. *Positional Data Source.* Options to select from are enumerated in the drop-down list: seismogram trace headers; SSR files; modified SSR files. If the first option is selected, DPU extracts positional data from trace headers expecting that they are filled out as described here. If the second option is selected, DPU expects that word 3 of each trace header of every seismogram contains source FID, while SSR files are properly made up, put in one (network) folder and have names satisfying the pattern. If option 3 is chosen, no condition is imposed on seismograms, while SSR(m) files are put in one folder under the required names. If options 2 or 3, are selected the button to the right of the option list gets enabled. It displays the dialog for entering file name prefix. The prefix serves as file filter in the situation when the folder contains different triples of SSR files. After selecting the files, a tick appears to the left of the option list showing that SSR or SSR(m) files are copied to the project folder.

4. *Field Observation Kind* is selected from the drop-down list containing the following options:

- 2.5D Profiling (coordinate system (X,Y, Z));
- 2D Profiling (coordinate system (X, Z));

- 2D Profiling (coordinate system (Y, Z));
- Other 2D Observation (X, Z);
- Other 2D Observation (Y,Z);
- 3D Observations (X, Y, Z).

Comparing the list with what was said in product overview, one notice that in cases of 2D observations the type contains coordinate axis names. DPU must know names under which line coordinates are written in trace headers or SSR files.

5. *Scaling factors* are valid for all coordinate values in trace headers or SSR files as explained hear. Two scaling factor – one for the surface coordinates X, Y and the other for Z – are selected from the drop-down lists. They have the same form as in the SEG-Y Standard: $K = sign(k)\ 10^{|k|}$, where k is integer, $|k| \leq 4$.

6. *Seismogram Folder*. Click on the button to the right of the field and select the required folder in the local folder browser. It is supposed that the seismograms lie in the folder while the user works with the project. But actually, all seismogram must be in the folder only at project create time when they are being registered. If a seismogram is not registered, it not accessible. An individual seismogram must be in the folder at the time of creating, or editing, or viewing its arrival map with modules Arrival Map Viewer or Arrival Time Picker.

7. *Seismogram File Extension* – file extension (without the dot), common for all seismogram, is to be typed in the field. The default extension is SGY.

8. *Import/Export Folder for ASCII Files* – a folder for files which are imported to or exported from the project. If the *Default* box is checked (by default – yes), the required folder with project's name will be created in common import-export folder.

9. *Line Resolution* – value of spatial resolution used when building line geometry. It must be defined for cases of 2.5D and 2D profiling. The value of resolution defines minimal distance between adjacent line stations. The *Desirable* attribute means that DPU can increase it if it is chosen too small.

Creation

A click on the *OK* button starts creation process. It includes two or three stages depending on the observation kind and ends either successfully or by discovering an error in input data. The first stage includes creation of the project infrastructure: folders, seismogram list, databases, wave list and so on. Then the Data Importer module is launched. It processes seismograms, loads SSR files, if necessary, and stores extracted positional data in Geometry Database. The third phase happens for observation of 2.5D and 2D profiling kinds and is performed by Line Geometry Builder. It builds line geometry and saves it to Geometry Database. The name of successfully created project appears in the project list with the *Closed* icon.

Creation errors

If an error occurs in the process of creation, the project appears in the project list as deactivated, with the discolored *Closed* icon. All data entered by the user are kept. The user can do three actions with such project: view creation log, recreate (after correcting the error) and delete. The commands can be found in the project list popup menu, if it is invoked on the deactivated project. The *Create* command invokes the *Project properties* dialog for editing the properties. If SSR or SSR(m) files are used, they must be loaded anew.

Project properties

If a project is successfully created, its properties can be viewed by the *Project|Properties* command. Only three of them can be edited: *Description*, *Seismogram folder* and *Import/Export Folder*. The rest are the project constants. After the seismogram folder has been changed, DPU offers to copy or move all or some seismograms to the new folder. The operation can be performed with the help of the dialog shown on fig. 2

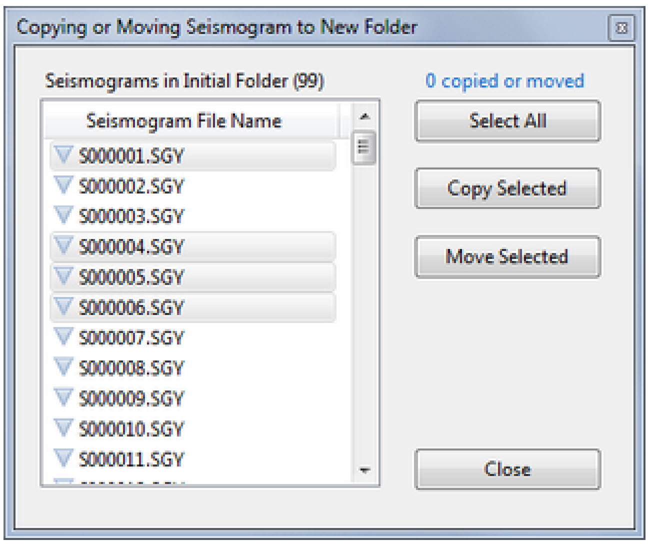


Fig. 2. Dialog for copying or moving seismograms to newly defined folder.

The user have to keep in mind that DPU modules can access only that are seismograms registered at project creation time and located in the folder under question.

Creation logs can be accessed in the way it is done in XTomo-LM: the *Log* button displays the list of logs with names coinciding with the time of attempted creation. A double-click on an item displays the log text. The needless logs can be deleted using a command of the list popup menu.

4 Operations with Projects

Menu

Project list is managed by the commands of popup menu (see table 1). The target of operations is a project currently *selected* in the list. The menu is not accessible for the currently *opened* project.

Table 1. Commands of the project list context menu.

Command	Operation

Open	(= double-click) Opens the selected project. See also the next paragraph..
Rename	Changes project name for a string which the user enters into a dialog. The name must be unique in the list.
Copy To	Copies project folder to a (network) folder, specified by the user. Allows changing project name.
Clone	Creates a copy of a project in current working folder under a new name.
Delete	Removes project folder from disc.
Archive	Creates a project archive file in the common archive folder. Details are below in this section.
Copy Path Name	Puts project folder path name in Windows clipboard. One can copy project name to the clipboard from the panel under the toolbar after selecting it with the mouse.

Deactivated projects

A project can be deactivated on the two reasons: (1) creation of a project was not completed due to an error; (2) operation of batch changes in Geometry Database failed or was interrupted. Deactivated projects have special icons and, if right-clicked, display specific popup menus. In case of (1) it contains the *Create*, *Creation Log*, *Delete* and *Copy Path Name commands.* The first one recreates the project. In case of (2) the commands are *Open*, *Delete*, *Copy Path Name*. The first command does not open the project but allows to read its properties saved to a text file.

Adding a project from a network location

The operation allows creating in the current working folder a copy of a project located at any computer of local network. The operation is initiated by the *Working Folder|Add Project from|Network Location* command, which invokes the dialog shown on fig. 1.

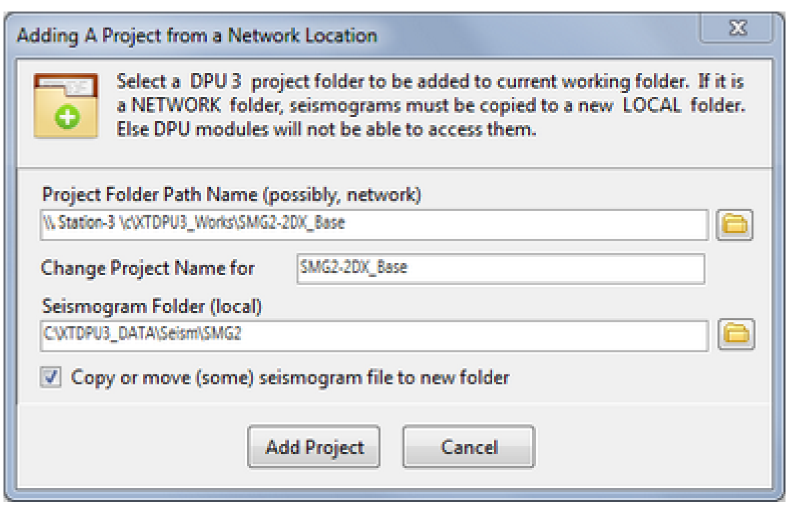
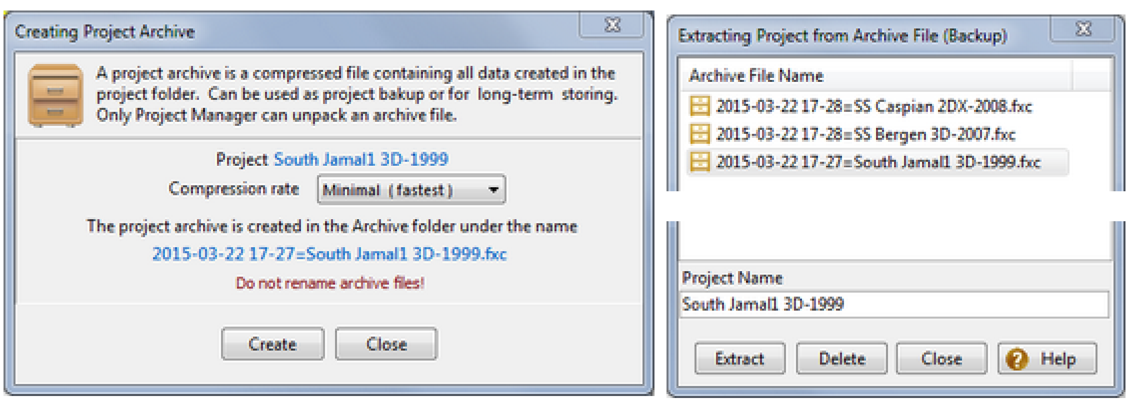


Fig. 1. Adding a project from a network folder.

First, a source project (the *Project Folder Path Name* field) is to be defined. Use the button to the right of the field to display Network folder browser. After selecting the source project folder, its name appears in the *Change Project Name* field, where it can be edited. Transfer of seismograms is an important task of the job because they are not a part of project data. If the source project was found within the *This Computer* node of the folder browser, the *Seismogram Folder* fields displays the word "Same". This means that, by default, the same seismogram folder will be used; at that, the copy check box stay unchecked. If the source project was selected under the *Network* node of the folder browser, the *Seismogram Folder* field stays empty while the copy check box gets checked. In this case, the user must define the new folder for seismograms and copy or move them to the new location. In both cases a click on the *Add Project* button starts the operation. If the copy flag is set, copying or moving seismograms is performed with the dialog shown here.

Archiving

The project archive file is created for warehousing or as a backup copy before "dangerous" operations. The *Archive* command of the project list menu displays the dialog (fig 1a), in which the user should choose degree of compression and click on the *Create* button. The creation time is inversely proportional to compression degree. After the file is created, its name is displayed in the dialog. It must not be changed because its mask is used for decompression.



a b

Fig. 1. Archiving a project.
a – dialog for creating archive file; b – dialog for work with archive files.

The main menu command *Working Folder|Add Project from|Archive file* displays the content of the project archive folder (fig. 1b). To extract a project, select its archive file and click the *Extract* button. The project extracted is placed into the current working folder and appears in the project list. The project name can (and if it duplicates the existing project name – must) be changed. The dialog allows deleting needless files from the folder: select the files in the list and click on the *Delete* button.

A project archive does not contain seismograms. To continue working with a project extracted from an archive, the user has to place the seismograms needed into a local folder and set it as "seismogram folder" in the project properties.

5 Geometry Database

Module GDV – Source-Receiver Configuration – Stations – Info on Line – Problem of Static Corrections – Export – Changing Origin of Line Coordinate System.

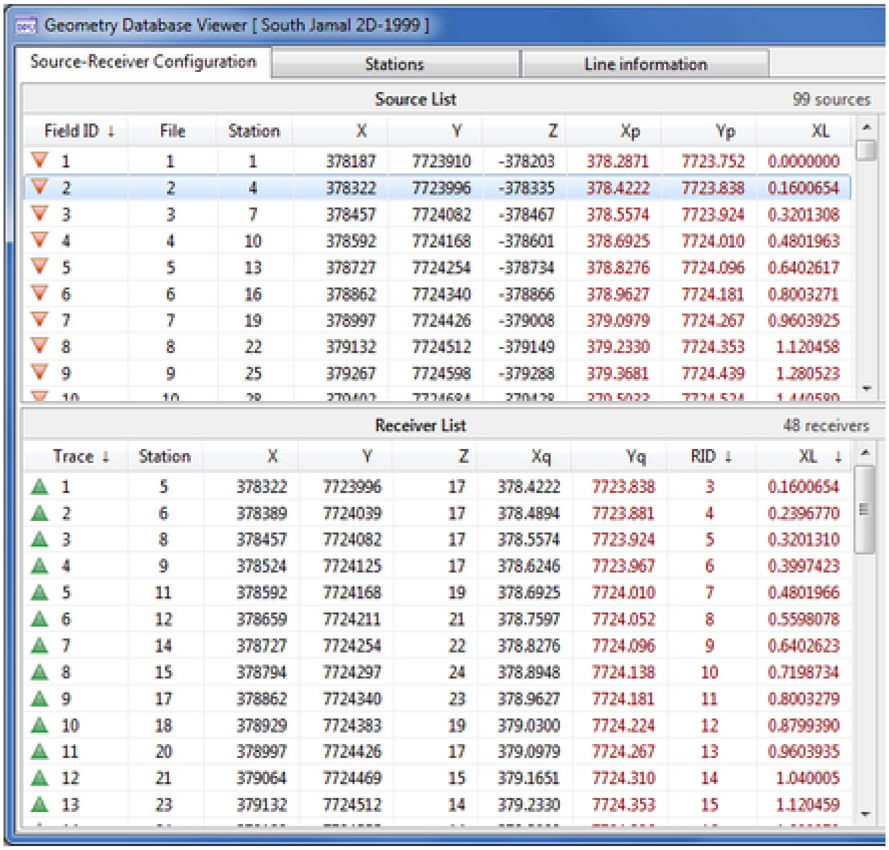
To understand the below text, one has to know the idea of building line geometry for 2.5D observations.

Geometry Database Viewer (GDV)

To explore Geometry Database of an opened project, apply the command of Project Manager main menu *Project|Geometry* or click on the matching toolbar button. It is possible to run several instances of Geometry Database Viewer, if it makes exploring more convenient. The main GDV window contains three tabs: *Source-Receiver Configuration*, *Stations and Line Information*. They represent the entire database content. Additionally, GDV implements four ASCII export operations accessible through the *Export* button on the first tab.

Source-Receiver Configuration

The first tab contains two linked lists. The top one is the source list. It looks like table with 9 columns (fig. 1).



Geometry Database Viewer [South Jamal 2D-1999]

Source-Receiver Configuration | Stations | Line information

Source List — 99 sources

Field ID ↓	File	Station	X	Y	Z	Xp	Yp	XL
1	1	1	378187	7723910	-378203	378.2871	7723.752	0.0000000
2	2	4	378322	7723996	-378335	378.4222	7723.838	0.1600654
3	3	7	378457	7724082	-378467	378.5574	7723.924	0.3201308
4	4	10	378592	7724168	-378601	378.6925	7724.010	0.4801963
5	5	13	378727	7724254	-378734	378.8276	7724.096	0.6402617
6	6	16	378862	7724340	-378866	378.9627	7724.181	0.8003271
7	7	19	378997	7724426	-379008	379.0979	7724.267	0.9603925
8	8	22	379132	7724512	-379149	379.2330	7724.353	1.120458
9	9	25	379267	7724598	-379288	379.3681	7724.439	1.280523

Receiver List — 48 receivers

Trace ↓	Station	X	Y	Z	Xq	Yq	RID ↓	XL ↓
1	5	378322	7723996	17	378.4222	7723.838	3	0.1600654
2	6	378389	7724039	17	378.4894	7723.881	4	0.2396770
3	8	378457	7724082	17	378.5574	7723.924	5	0.3201310
4	9	378524	7724125	17	378.6246	7723.967	6	0.3997423
5	11	378592	7724168	19	378.6925	7724.010	7	0.4801966
6	12	378659	7724211	21	378.7597	7724.052	8	0.5598078
7	14	378727	7724254	22	378.8276	7724.096	9	0.6402623
8	15	378794	7724297	24	378.8948	7724.138	10	0.7198734
9	17	378862	7724340	23	378.9627	7724.181	11	0.8003279
10	18	378929	7724383	19	379.0300	7724.224	12	0.8799390
11	20	378997	7724426	17	379.0979	7724.267	13	0.9603935
12	21	379064	7724469	15	379.1651	7724.310	14	1.040005
13	23	379132	7724512	14	379.2330	7724.353	15	1.120459

Fig. 1. Geometry Database Viewer. Source-receiver configuration.
Receiver List displays ordered set of receivers responsive to source 2 selected in the top list.
The down arrow in headers points to sort key.

The first 6 columns are for the information extracted straight from the input data. The last three columns are filled only for 2.5D and 2D profiling data and relate to line geometry. More exactly:

FID – source/seismogram field ID;

File – internal reference to seismogram file; its name is shown on the right margin of the list;

Station – station number; this is the station matching the shotpoint (see below);

X, Y, Z – shotpoint coordinates;

Xp, Yp – surface coordinates of shotpoint projection onto the seismic line; this is shotpoint in line geometry;

XL – line coordinate of source projection or source in line geometry.

The bottom table displays the set of receivers responsive to the source selected in the top table. It is also a table with 9 columns. Trace number is taken as the table key. First 5 columns are for input data, the rest relates to line geometry and are filled for 2.5D and 2D profiling data only. The table columns are listed below:

Trace – trace number in the seismogram;

Station – station number; this is the station matching receiver position (see below);

X, Y, Z – receiver point coordinates;

Xq, Yq – coordinates of receiver quasi-projections onto the seismic line;

RID – receiver ID = line station number for 2.5D and 2D profiling data; if line resolution is too large, adjacent traces can refer to the same line receiver; in this case duplicate references are marked with the asterisk.

XL – line coordinate of receiver quasi-projection or receiver in line geometry.

Stations

XTomo-LM does not use stations in input data. It uses source-receiver configuration. However, because the SSR model is chosen for input data, Geometry Database contains the list of stations even if positional data are extracted from trace headers. In the latter case, the sequence of stations is created programmatically. The *Stations* tab is shown on fig. 2.

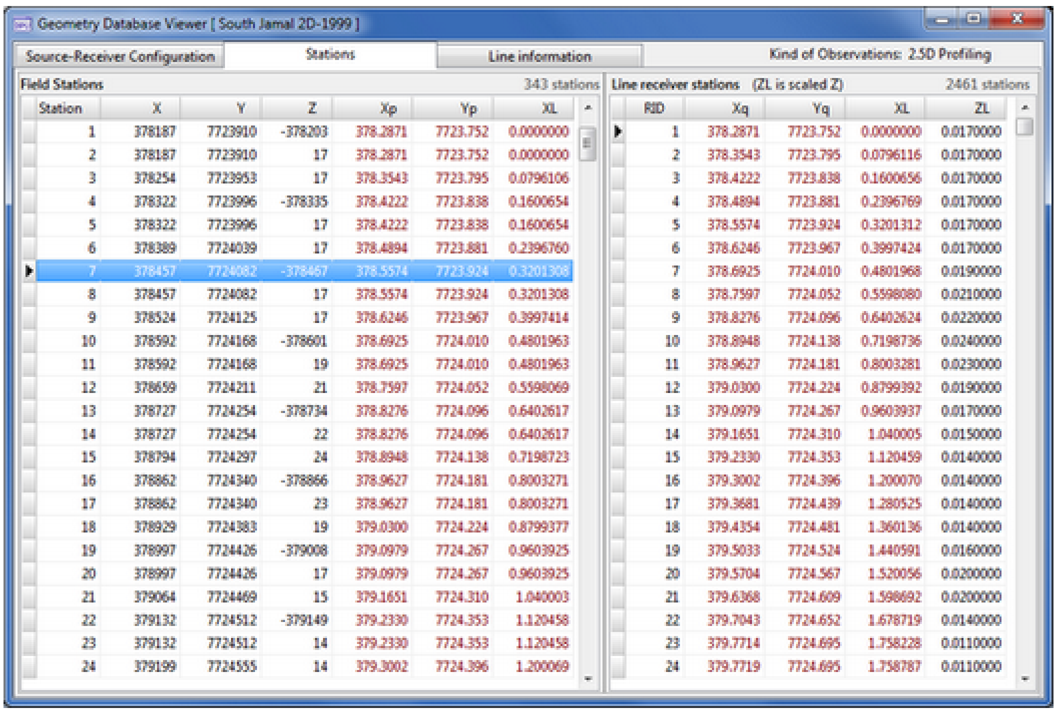


Fig. 2. Geometry Database Viewer. Station lists: stations in input data - on the left, line stations – on the right.

For 2.5D and 2D profiling data, the tab contains two lists. The left one displays the sequence of stations extracted from SSR files or built programmatically. The X, Y and Z columns show station coordinates. The Xp and Yp columns display coordinates of station projections onto the seismic line. They are computed for the problem of introducing statics (see below). The XL column shows the projection line coordinate. The right list represents line geometry stations in the same notations as in the Line Geometry section. For observation kinds Other 2D and 3D, the Xp, Yp and XL columns of the left list and the entire right list are empty.

Information on Seismic Line

The third tab displays information on the seismic line and, in case of 2.5D profiling, – an image showing the set of sources and the line on the (X, Y) plane.

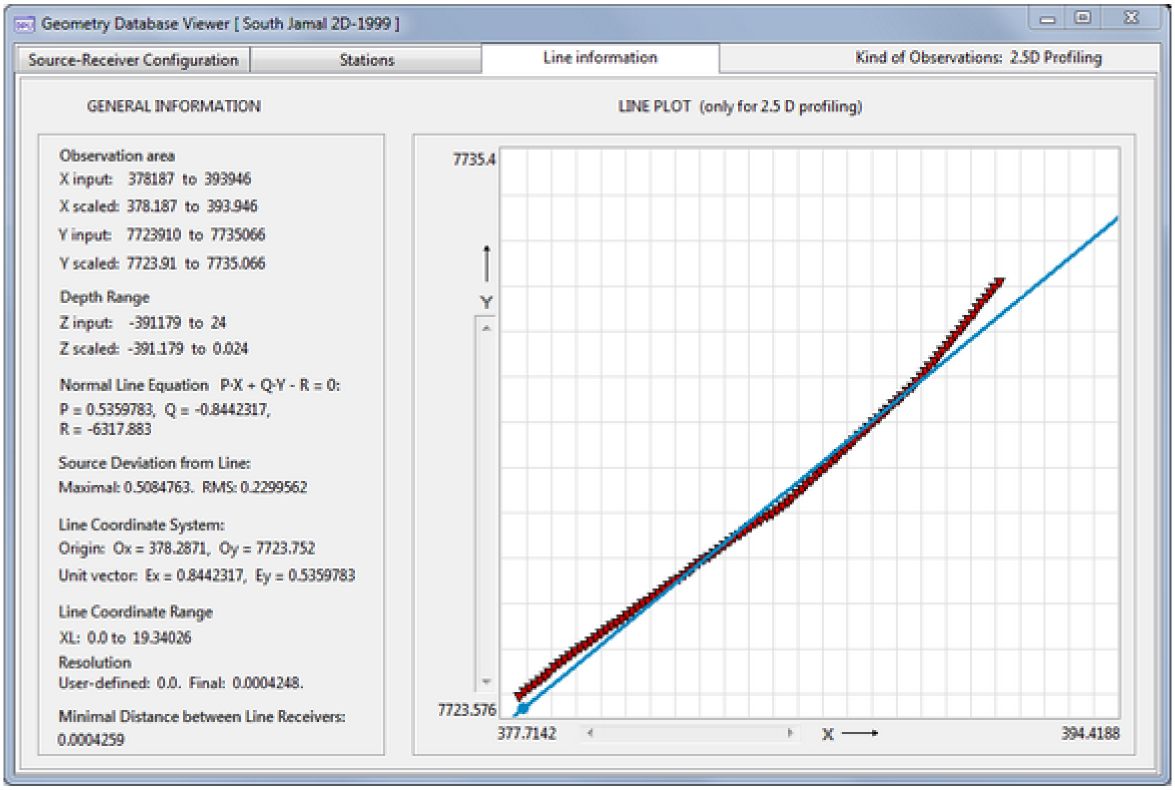


Fig. 3. Geometry Database Viewer: information on the seismic line.

For 2.5D and 2D profiling data information on line includes:

- ranges of coordinates X, Y, Z (initial and scaled);
- coefficients P, Q, R of the line normal equation ($P^2 + Q^2 = 1$);
- maximal and standard deviation of sources from the line;
- line coordinate system: surface coordinates of the origin and the unit vector of the XL axis;
- range of line coordinate XL;
- Resolution: user-defined and actual;
- minimal distance between adjacent line stations.

For observation kinds Other 2D and 3D only coordinate ranges are displayed.

Problem of Static Corrections

In the CDP profiling technology tomography as usually used for studying near-surface layer velocity section followed by referencing positional data to new datum by introducing static corrections. It is possible to use first arrival tomography or attach layered model techniques. Below it is explained how the statics problem is solved by means of the DPU/XTomo-LM software.

First, a DPU project with input data including CSP seismograms and SSR data is created. Arrival maps are picked and exported as SRT file. With this file as input data, the XTomo-LM inversion project is created as a framework for getting velocity section. Then station positions must be passed to XTomo-LM utility called Statics Corrections Calculator. They must be described in the same coordinate system as was used in the SRT file. This can be easily done if we replace stations with their projection onto the seismic line. Projection coordinates (Xp, Yp) and line coordinate XL of projections are stored in Geometry database. They are displayed in station list (fig. 2). Z-coordinate ZL is equal to scaled value of of station z-coordinate. Triples (N, XL, ZL), where N is station number, are exported by GDV (see below) and then imported by the utility. The latter outputs to an ASCII file a set of couples (N, ΔT), where ΔT is time correction, for any user-defined horizontal datum.

Export

The *Export* button on tab 1 drops down the export menu. Its commands are commented on in Table 1.

Table 1. Export commands

Command	Operation
Export Acquisition Geometry to SSR	Exports imported geometry as SSR files irrespective of positional data source.
Export Line Information	Outputs information on the seismic line displayed on tab 3 to text file (for data of 2.5D and 2D observations).
Export Shot Line coordinates	Outputs Source list on tab 1 to text file (for data of 2.5D and 2D observations).
Export Geometry to XTomo-LM (SR file)	Exports line geometry to SR file for using in XTomo-LM modelling project. The command invokes a dialog in which the user defines a sample of sources and receivers for export. GDV ensures that no receiver with duplicate RID is put to the export file. Therefore, import of this file to an XTomo-LM project will be surely successful if only the project's x-resolution is not larger than in current DPU project. The command is disabled for 3D observation.
Export Station Positions (SLS file)	Exports station numbers and line coordinates (N, XL, ZL) for input in the XTomo-LM utility Static Correction Calculator. Accessible for 2.5D and 2D observation data.

Changing Origin of Line Coordinate System

Definition of line coordinate system origin is carried out automatically at project creation time. This point is called the *default origin*. Its position can be changed if found unsatisfactory. The default origin is stored and can be used as such again. Use Project Manager main menu command *Project|Shift Line Origin.* The executing module's main window is shown on fig. 4.

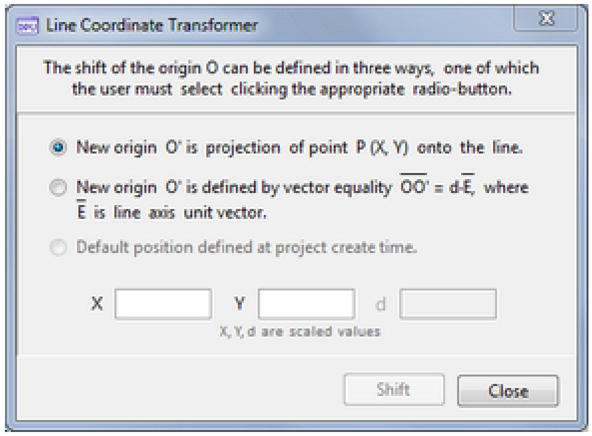


Fig. 4. Main window of Line Coordinate Transformer.

The user either selects one of the two ways to set a new origin O', or requires to go back to the default origin. The latter option makes sense, if operation was already performed once. The ways to define the point O' are:

- O' is a projection of a point P(x,y) onto the line; its coordinates must be typed in the edit fields;
- O' is obtained by a shift *d* of the current origin in the direction of line unit vector *E* or in opposite direction depending on *d* sign; value of *d* must be typed in the field "d".

Pressing the *Shift* button starts the operation. If an error occurs during execution, say, system error, Geometry Database becomes corrupted and the project becomes deactivated.

6 Wave Manager

Project wave list – Work with wave list – Adding a wave – Editing drawing attributes – Replacing waves in arrival maps.

To understand the below text one has to be acquainted with section Waves.

Project wave List

The Wave Manager module differs insignificantly from the program of XTomo-LM bearing the same name. It implements support of the *project wave list.* Any project is provided with the default wave list with one wave – diving (or transient, or first). This is enough for first arrival tomography. In this case Wave Manager is not practically used. But if layered model is going to be used for data interpretation, the user has to add the required set of reflected and head waves to the list and define their drawing attributes using Wave Manager.

The module is launched by the Project Manager main menu command *Project|Wave Manager* or the matching toolbar button. If there are other active modules, changes in the wave list are blocked. The module's main window is shown on fig. 1. The wave list is displayed on the left panel, while the right panel contains *drawing attributes* of the wave currently selected in the list.

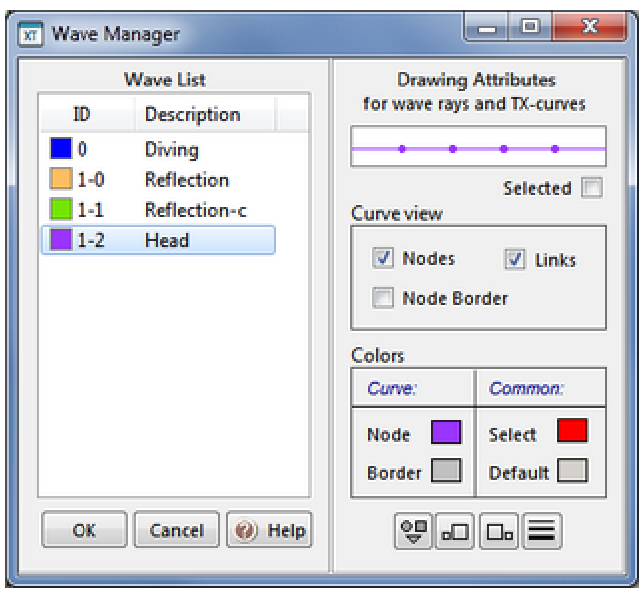


Fig. 1. Wave Manager main window.

Wave List Menu

The list popup menu commands are explained in table 1.

Table 1. Wave list popup menu commands.

Command	Operation
Add	Invokes a dialog for setting properties of a reflection or head wave to add to the list (see below).
Delete	Removes selected wave from the list. After picking has started, the command is disabled while adding new waves is allowed. That's why, the list, usually, contains redundant items.
Export Waves *Import Waves*	The commands allow saving wave list to and importing it from a user file of the UWL type.The import operation is permitted for the default list only.
Replace Waves in Maps	Replaces a specified wave with another specified wave in all seismogram arrival maps (see below).

Adding a wave

The dialog, invoked by the *Add* command is shown on fig. 2. The case of adding a converted reflection generated by horizon 2 is presented.

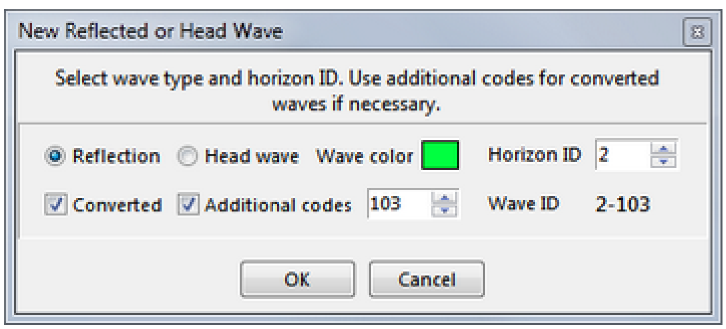


Fig. 2. Adding a wave.

The dialog window contains two lines of controls. The controls of the top line are used for setting wave type (reflection or head wave), its color and ID of the associated horizon. Wave color must be unique as well as wave ID. The latter is composed by the program and displayed in the end of the second line. To define color click the *Wave Color* rectangular. The controls of the bottom line are used to define a converted wave. Begin with checking the *Converted* box. If wave code is one-digit, click on the *OK* button to finish. If it is three-digital, check the *Additional Codes* box, set the code in the spin-edit field and click on the *OK* button. The new wave is added to the list with the default drawing attributes.

Editing curve drawing attributes

A curve images a set of floating-point numbers and consists of *points* or *nodes* matching the numbers and *links* between them. Both nodes and links are optional. Drawing attributes include:

- point flag (if set, nodes are drawn): the *Points|Node* box;
- link flag (if set, links are drawn): the *Points|Links* box;
- point border flag (if set, a point has border): the *Points|Node Border* box;
- point color (= link color = wave color): *Colors|Curve|Node*;
- border color: *Colors|Curve|Border*.
- point shape; this is changed by a button;
- point size; this is changed by a button;
- link width; this is changed by a button;

In the above list, name of panels and controls are printed in italics. The buttons are at the bottom of the right panel. A click on a button changes shape, or size, or width. A sample of curve with the current drawing attributes is shown at the top of the panel. It is redrawn after change of any attribute. The *Colors|Common* panel contains two colors relating to the entire list. *Select* – is color for a curve selected on a picture; *Default* wave color is used in the *New wave* dialog. These colors are reserved and cannot be selected as wave colors.

Replacing waves in arrival maps

The need for such operation is explained here. The *Replace Waves in Maps* command of the list menu displays the text explaining what to do. According to it, the operation is started in the end of drag-and-drop operation with list items. Suppose, wave W1 must be replaced with wave W2 in all arrival maps. Both are in the list. The user has to drag the icon of wave W1 onto the icon of wave W2. At the moment when the left mouse button is released, Wave Manager shuts down, and Project Manager launches the module, which implements replacement after the user's confirmation.

Arrival Maps

1 Introduction

General information

Most of time in work with a DPU project is spent on creation and editing arrival maps. *Arrival map* of a seismogram is a database storing phase lineups picked from the seismogram, that is, an ordered set of triples (*N, S, W*), where *N* is trace number, S is sample number, W is wave ID. A phase lineup represents a TX-curve segment, which explains the term *tx-segment* or, simply, *segment* used in the user interface and the documentation. A triple (*N, S, W*) is also called *segment point* or *arrival*. A segment may consists of one arrival. The word *map* is used because the user views the database content on screen as a set of curves drawn over the seismogram image. For profiling data, seismogram maps can be combined to form the *line arrival map* which is examined in the last two sections of the chapter. In all other sections, "map" always means "seismogram map".

Arrival maps are created by picking arrivals from seismograms with Arrival Time Picker module (ATP, for short). The other way is importing maps from another project if only both projects share a common subset of seismograms. This operation allows creating different projects based on the same input data pool without repeated picking from the same seismograms. One can import maps from DPU 3 and DPU 2 projects.

DPU workflow includes a point of using kinematic modeling as a means of wave field analysis. This possibility is implemented by Arrival Map Viewer (AMV). The module allows building an arrival map based on an XTomo-LM forward problem solution and displaying it over the seismogram image together with the picked map. Clearly, the operation makes sense if XTomo-LM and DPU projects share the same observation system. AMV and ATP are main tools for work with arrival maps. Both are graphic modules according to XTomo-LM terminology.

Arrival Map List. Access to a Map

To access an individual map, one uses *Arrival Map List* displayed on the right panel of Project Manager's window (fig. 1).

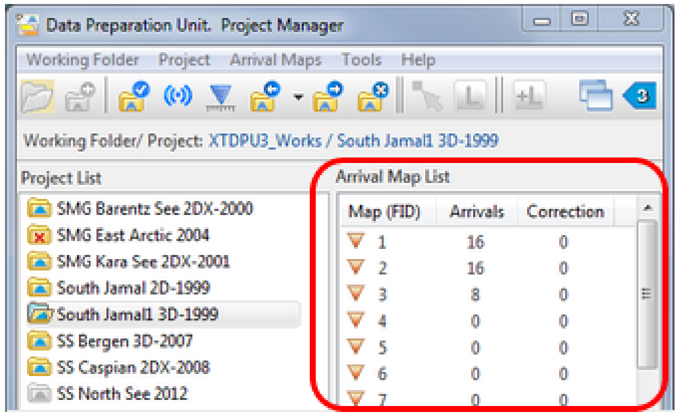


Fig. 1. Arrival Map List is used for access to an individual map with the help of context menu commands.

The list is a table with the three columns: *Map* is map, or source, or seismogram ID; *Arrivals* is total number of arrivals picked; *Correction* is common correction for map arrival times. Need for correction can be caused by a systematic error or delay, common for all seismogram traces. It is measured in a number of samples and is added to all arrival times of a map at export time. It is not used before export. Commands of the list popup menu relates to the map currently selected in the list.

Table 1. Arrival map list popup menu

Command	Operation
View Arrival Map	Runs Arrival Map Viewer (AMV) for viewing a map. One instance can be run for one map, but viewing several map at one time is permitted. AMV can be run by double-clicking a list item.
Pick / Edit Arrivals	Runs Arrival Time Picker (ATP) for creating and editing a map. AMV and ATP can run simultaneously. ATP can be run by double-clicking a list item with the Alt key pressed.
Edit Correction	Allows editing a table cell of the Correction column.
Check Map	Checks total number of arrivals rereading map database.
Clear Map	Clears map database.

Operations with all project maps are started by commands located in section Arrival Maps of main menu.

2 Module AMV: Overview

[Viewing arrival map] – [View parameters] – [Drawing segments] – [Forward problem map] – [Control] – [Mian menu].

Viewing Arrival Map

Module Arrival Map Viewer (AMV) displays arrivals on the seismogram image which implies that it has functionality of a SEG-Y/PC file viewer as minimum. This section presents review of the program's features and a commented list of main menu commands. Further details can be found in the next five sections. Fig. 1 shows the view of a map frame with picked segments of first wave.

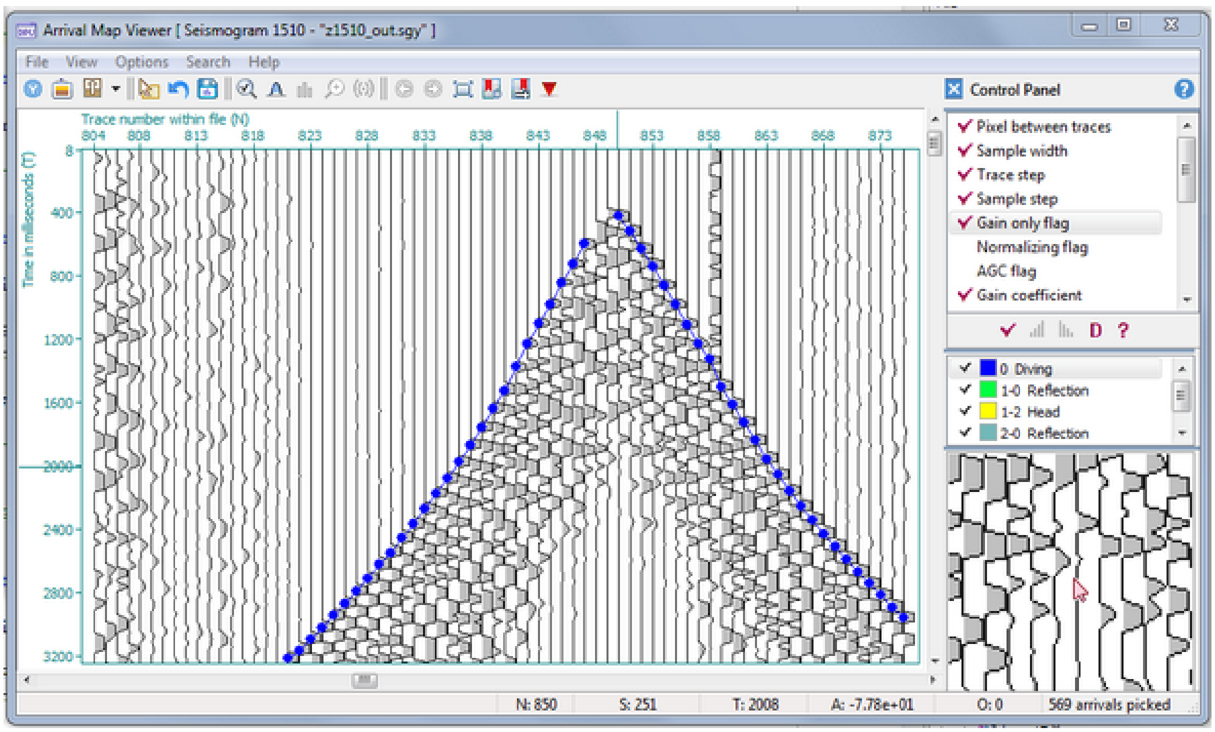


Fig. 1. View of a map on AMV plotting pad.

A part of AMV main window displaying the map image is called the *plotting pad* or the *tablet*, while a part of a map shown on the tablet is called *frame*. Just after AMV is started, it displays a frame containing the trace with minimal offset (*zero-offset trace*). The trace number can be found in the hint window of the button , which scrolls record to the initial frame. A record frame is identified by its *vertex* (N_1, S_1), where N_1 is first trace number, S_1 – first sample number. Time on the vertical axis is measured in milliseconds if sample interval is a multiple of 1000 and in microseconds otherwise. On the status bar at the window bottom, the context information corresponding to the cursor position is displayed in real time. It includes: trace number (N), sample number (S), time value (T), sample value (A), offset of a receiver matching a trace (O), number of picked arrivals. Main control panel is attached to the window right edge.

For data of 2.5D and 2D profiling, offset value is signed difference of receiver and source line coordinate XL; For 3D observations, offset is Euclidean distance between receiver and shot points; for Other 2D observations offset is not computed (zero is displayed).

Record scrolling within the tablet is performed with the following ways:

- by scroll bar buttons and thumb;
- by mouse wheel (with Shift pressed for horizontal scrolling); the tablet must be in focus: click it if turning the wheel has no effect;
- by dragging any record point in the desired direction with the Ctrl key pressed.

There are other ways of displaying specified record frames:

- move to a specified frame;
- using the Back and Forward buttons;
- bookmarks.

View parameters

To adjust a view, one uses two classes of parameters:

- view options (colors, distance between traces, sample width and so on);
- signal preprocessing options (amplification, filtering, time-reducing and so on).

Changing distance between traces and sample pixel width means changing image scale. Faster but rougher way to do that is to drag a record point with the Shift key pressed. If record is dragged horizontally left to right, distance between traces increases, if right to left – it decreases. Vertical scale can be changed similarly.

Signal preprocessing is carried out in a memory buffer just before drawing a trace on the tablet.

By default, when module terminates all parameters are saved to disc and restored in next work session. A set of parameters is, of course, map-specific.

Drawing segments

View of a segment is defined by drawing attributes of a wave a segment belongs to. AMV can access an individual segment on a map using *selection*. A segment or set of segments can be selected with the help of rubber-band. One can get detailed information on each selected segment and even a list of its arrivals. AMV can filter map by waves, i.e., make visible or invisible segments associated with a specified subset of waves. On fig. 1, all waves, but the diving, are filtered off.

Forwad Problem Map

If modeling is used at picking arrivals time, AMV provides for imaging forward problem solution on the seismogram. To do that, AMV converts a part of ray catalog database into the arrival map format and then draws this map over the seismogram together with picked arrivals.

Control

The AMV user interface offers different methods of tuning the image. Additionally to main menu and tablet context menu, one can use floating control panels and main control panel. To work with segments, one applies rubber-band and the rubber-band menu. In this section, only main menu commands are listed and explained. Other means of control are examined in next sections of the chapter.

Main menu

Table 1. AMV main menu commands.

Command	**Operation**
Menu *File*	
SEG-Y Headers	Invokes the dialog permitting to view general file properties, binary and textual header and any trace header. In order to display the header of a trace on the image, right-click the tablet near the trace zero-amplitude line and select the *View Trace SEG-Y Header* command in the popup menu.
Create Raster File	Runs the module implementing export of map image to a graphic file. Details are here.
Exit	Shuts down AMV.
Menu *View*	
Show Status Info as Hint	A switch; if on, a part of context information in status bar is displayed in the hint window under the cursor.
Show Control Panel	A switch; if on, the main control panel is displayed attached to the window right edge. Details are here.
Show View Options Console	Displays *View Options Console* – a floating control panel for modifying view and signal parameters.
Show Wave Filter	Displays the *Wave Filter* panel over the tablet. Details are here.
Show Magnifying Glass	Displays the floating *Magnifying Glass* panel over the tablet. Details are here.
Update	Repaints the current frame anew extracting it from the map database. If AMV works together with Arrival Time Picker, the command is used to sync map views in both modules.
Hide Arrival Map	A switch; if on, the picked map is not shown on the tablet.
Create FP Solution Map	Creates arrival map based on the specified forward problem solution. Details are here.
Show FP Solution Map	A switch; if on, forward problem map is shown on the image.

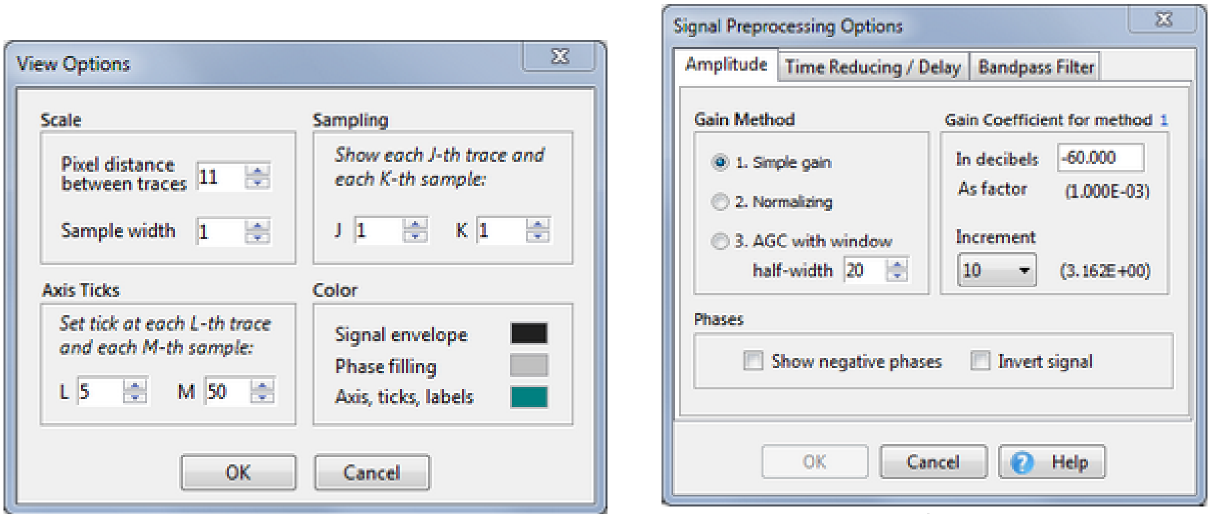
Menu *Options*	
View Options	Displays the *View Options* dialog for editing image view options. Details are here.
Signal Preprocessing Options	Displays a dialog for changing signal preprocessing parameters. Details are here.
Apply Options: Default Saved	Changes current view parameters for the defaults or for those that have been lately saved to disc (in this or previous work session).
Cancel Last Option Change	Restores map view that was on the tablet before last change of a parameter.
Save Options Now	Saves current view parameters to disc.
Do Not Save Options at Exit	A switch; if on, view parameters will not be saved at exit the program.
Menu *Search*	
Go to Frame	Permits to move to a specified frame. The user specifies a frame in a dialog, typing in its vertex, i.e. first trace and first sample (or its time).
Bookmark Frame	Creates a bookmark for the current frame. The user is offered to type in comment to facilitate later frame search in the bookmark list.
Go to Bookmark	Scrolls record to the specified frame. The user specifies frame in a dialog containing the bookmark list.
Show Zero-offset Trace	Scrolls record to the frame containing the zero-offset trace (the zero-offset trace number can be found in the hints to the menu command or the toolbar button).

3 AMV: View Parameters

Classification – View options – Signal preprocessing options – Comment

Classification

One has to distinguish two classes of parameters: *view options* (table 1) and *signal preprocessing parameters* (table 2). Access to all parameters of each class and their editing is carried out in two dialogs (fig. 1). They are invoked by the commands of the *Options* menu. Most parameters can be also edited in the floating control panel called *View Options Console* (see the next section.)



a b

Fig. 1. View parameter dialogs.
a - View Options dialog; each panel corresponds a group in table 1.
b - Signal Processing Options dialog; each tab corresponds to a block of table 2.

View Options

Table 1.

Group	Parameter	Description
Scale	Pixel distance between traces	Defines horizontal scale of the image.
	Sample width	A number of pixels taken up on screen by one sample. The default is 1. Defines vertical scale of the image.
Sampling	J	Step of sampling traces; if J = 1 all traces are drawn, else only traces with numbers J, 2J, 3J and so on.
	K	Step of sampling signal samples; if K = 1 all samples are drawn, else only samples with numbers K, 2K, 3K and son.
Axis ticks	L	Ticks and labels are set at every L-th trace starting from the first.
	M	Ticks and labels are set at every M-th sample starting from the first.
Color	Signal envelope	Color of signal envelope.
	Phase Filling	Color of filling positive phases.
	Axis ticks and labels	Color of axis line and label font.

Signal Preprocessing Options

Terms and comments follow table 2.

Table 2.

Parameter	Description
	Amplitude Control
Amplitude control Method	Amplitude control methods are distinguished by their numbers: 1. Simple gain. 2. Normalizing (amplitude equalization). 3. Automatic Gain Control (AGC).
AGC window half-with	Half-width of averaging window (interval) measured in a number of samples.
Gain coefficient for method…	Gain coefficient is defined for each method of amplitude control.
Increment	Increment of gain coefficient (see the comment).
Show negative phases	By default, instead of real signal, its positive part $S^{+}(t) = max(0, S(t))$ is drawn. If the flag is set, negative signal phases are drawn as well.
Invert signal	This a flag; if set, signal is drawn inverted: -S(t) instead of S(t).
	Time Reducing / Delay
Transform Record	This is a flag; if set, record is undergone *time-reducing transformation*. It shifts each trace upward to implement time mapping $T \rightarrow T - D/V$, where D is trace offset, V is reduction velocity. If the flag is on, status bar fields S and T displays two values for sample and time: visible/actual.
Reduction velocity	Value of reduction velocity.
Increment	Reduction velocity increment.
Apply delay	Delay flag; if set, traces are shifted by a specified constant C: $T \rightarrow T - C$.
Delay value	Delay C measured in number of samples. If $C > 0$ trace are shifted upward, else – downward.
Increment	Delay increment.
	Bandpass Filter
On	Filtration flag; if set, record is filtered.
Low-frequency cutoff	Low-frequency cutoff value.

High-frequency cutoff	High-frequency cutoff value.
Increment	Frequency increment.
Response function window half-width	Controls filter quality: the wider window, the higher quality.

Comment

Increment is a value by which parameter is changed on a control panel by a click on a button. Amplitude equalization suggests dividing each sample by maximal amplitude value in trace which makes maximal amplitudes of each trace equal to 1. AGC transformation models an amplifier with feedback loop. Applying AGC means dividing a sample $S(t)$ by the mean value of $|S(\tau)|$ in the interval [t – w, t + w]. Value of w is AGC window half-with. After setting any method of amplitude control, the signal can be amplified using its own gain coefficient.

Time-reducing transformation is helpful when large seismograms are viewed or picked from. For example, ocean bottom station record may contain thousands of traces. The transformation decreases time at large offsets considerably and straightens phase lineups.

Among different bandpass filters the fastest is used in order not to slow down imaging of a map. it is not, however, zero-phase which results in shifting phases. One has to take that into account when picking.

4 AMV: Control panels

The *View Options* and *Signal Preprocessing Options* dialogs provides full control of all view parameters, but they are not convenient for quick tuning, just because they are dialog windows blocking access to the image. Control panels floating over the tablet or fixed main control panel are more comfortable in use. There are three such panels: *View Options Console*, *Wave Filter* and *Magnifying Glass* (fig. 1).

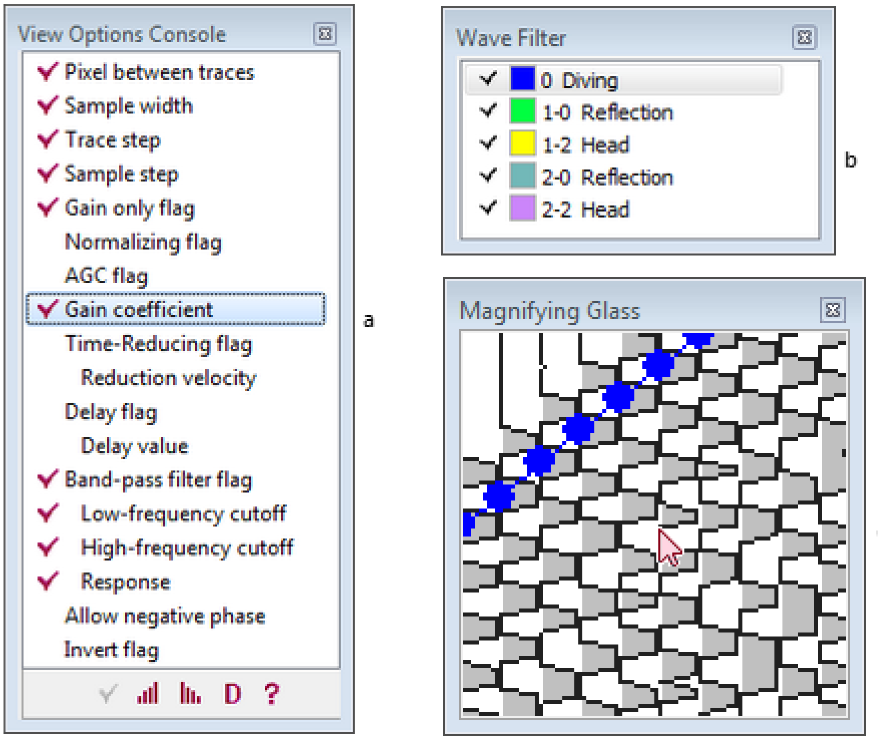


Fig. 1. Control panels: a – View Options Console; b – Wave Filter; c – Magnifying Glass.

View Options Console

The panel is invoked by the AMV main menu command *View|Show View Options Console*. The console (fig. 1a) displays a subset of view options and signal preprocessing options in one list view. Each list item represents a parameter, which can be either a flag or numeric value. Some of items have a tick icon. For a flag, it means that it is set (turned on); for a value item, it signals that it can be modified. For example, if the Band-pass filter flag is set, all filter parameters can be changed.

Buttons under the list operate on the selected item. The operations are listed in table 1.

Table 1. Console button functions

Button	Operation	Shortcut
✓	Enabled for a flag. Flips flag from on to off and back.	double-click
	Enabled for a value item. Increases the value by its increment, if possible.	double-click
	Enabled for a value item. Decreases the value by its increment, if possible.	Ctrl + double-click
D	Assigns the default values to all parameters.	

A parameter-value is changed by its increment defined in the options dialog or by 1. At each click on a button, the image is repainted. The current parameter value can be seen on the item hint window.

Wave Filter

The panel is invoked by the *View|Show Wave Filter* command. It displays the project wave list (fig.1b) with check boxes. If an item box is checked, segments of the wave are visible on the map, else they are hidden. The list has a popup menu with the commands *Check/Uncheck*, *Check All*, *Uncheck All*.

Magnifying Glass

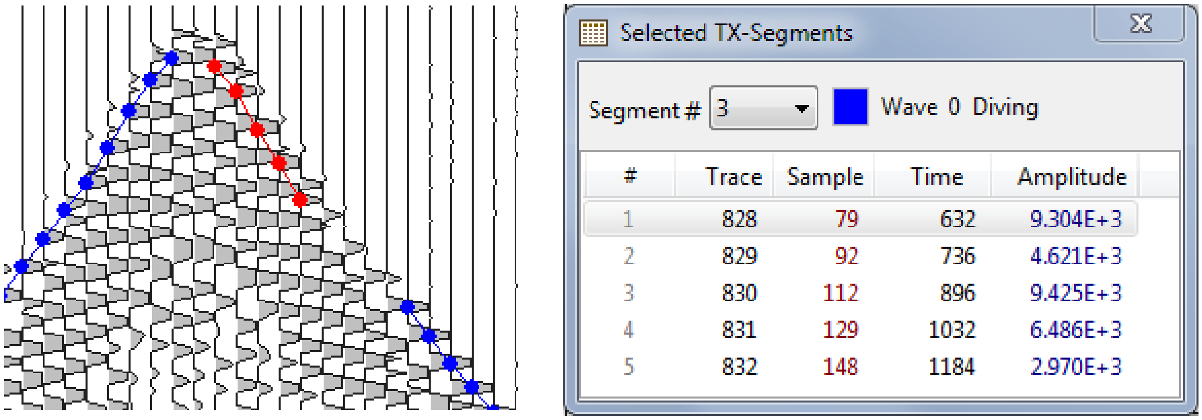
The panel is invoked by the *View|Show Magnifying Glass* command. This is a window (fig. 1c), in which a square with the center, currently pointed by the cursor, is displayed 2 or 4 times magnified as a raster. The magnified view is displayed only if the cursor is over the record frame. Magnifying Glass has a popup menu with commands *Switch Zoom* and *Disconnect.* The former switches the magnifying factor, the latter blocks displaying the raster.

Main Control Panel

The main control panel displays all three panels without window title bars (fig. 1).). Panel sizes are set and changed automatically when the AMV window is resized. Magnifying Glass always has full size. The panel is invoked by the main menu command or toolbar button with icon . Before it appears on screen, all floating panels close. The *View Options* and *Signal Preprocessing Options* are accessible at any time, irrespective of activity of control panels.

5 AMV: Access to Segments

AMV not only draws tx-segments, but provides access to an individual segment. This is necessary for editing maps. And though editing is not an AMV function, access tools are included with the aim to ensure getting information on each segment. Access to a segment is implemented by means of its *selecting*. A selected segment (or segments) are drawn in special color which is defined in Wave Manager as *select color* (fig. 1a). To point to a required segment one uses *rubber-band* – a rectangular which is drawn by dragging an image point. When the left mouse button is released, the rectangle disappears, if no arrival got inside it, or fixes its last position and throws out the *rubber-band menu* (table 1).



a b

Fig. 1. Selecting segments: a – selected segment; b – information on a selected segment.

Table 1. Rubber-band menu commands.

Command	Operation
Select Segment	The command is enabled if there is no selection. Selects one segment, whose points are captured by rubber band. If arrivals of several segments got inside, selects the segment whose arrival is nearest to the left side. If several arrivals are equally close to the left side, the one with minimal time defines the selected segment.
Select Subsegment	The command is enabled when exactly one segment is selected. The operation deselects all points of the segment that do not get into trace interval defined by rubber-band.
Select All Captured Segments	The command is enabled if there is no selection. Makes selected all segments having at least one arrival inside rubber-band.
Rubber-band properties	Displays a dialog, in which one adjust contour line width and two colors: drag color and draw color. The former is used at dragging stage, the latter for final draw.

To cancel selection, apply the *Unselect* command of the tablet context menu or double-click the tablet at any point. To get details on selected segments or on a subsegment, apply the *Display Selected as Table* command of the same menu. It displays a dialog shown on fig. 1b. The drop-down list at the top-left contains internal numbers of the selected segments. Information in the dialog concerns the segment chosen in that list. To the right of it, the wave to which the segment belongs is shown. The table contains arrival list, each arrival being described by trace number, sample number/time value and amplitude of the associated phase.

6 AMV: FP Arrival Map

In the problem of layered model interpretation, wave field analysis and fitting a model are two sides of the process, in which DPU is responsible for work with seismic records while XTomo-LM serves as a means of interpretation. In order that both software systems work with the same data, observation geometry must be extracted from DPU Geometry Database and imported in an XTomo-LM project. If it is a modeling project, geometry is exported by the GDV as an SR file; if it is an inversion project, geometry is passed through an SRT file. The backward data transfer – from XTomo-LM to DPU – is realized as imaging of forward problem solution on a seismogram in a DPU project. The latter problem is solved by AMV. The shortcuts *FP* and *fp* are used for forward problem.

Creation of FP-Map

The AMV main menu command *View|Create FP Solution Map* launches module FP Map Builder, which, for given FP solution and seismogram, builds a database having the same structure as an arrival map. It is called *fp-map*. Module's main window is shown on fig. 1a. If fp-map for the seismogram was once built, the window displays XTomo-LM processing tree, in which the f-node used earlier as the source of FP solution, is selected and printed in bold. Otherwise, the tree window is empty, and the user has to select an XTomo-LM project using local folder browser button. After it is done, the module displays the project's processing tree.

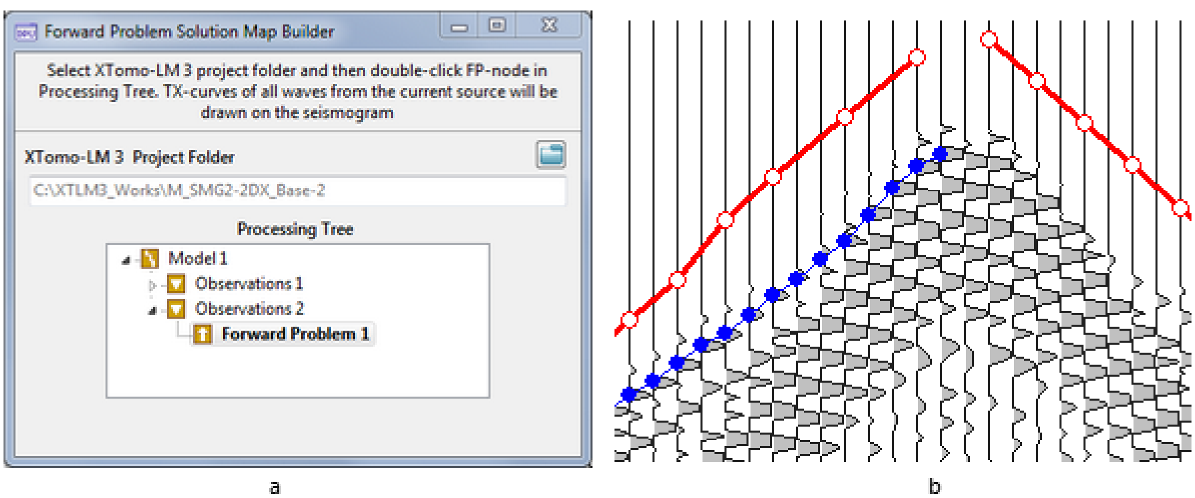


Fig. 1. Building and drawing fp-map: a – main window of FP Map Builder; b – a fragment of fp-map.

Once processing tree is displayed, the only thing the user has to do is to double-click the required f-node. If operation is a success, the module is closed and fp-map is drawn on the AMV tablet (fig. 1b). FP Map Builder identifies the source and receivers in DPU and XTomo-LM projects by their IDs and line coordinates. if the source of the current seismogram is not found in the f-node ray catalog or more than 10% of the receivers from ray catalog are not found in Geometry Database, the operation fails.

Viewing fp-map

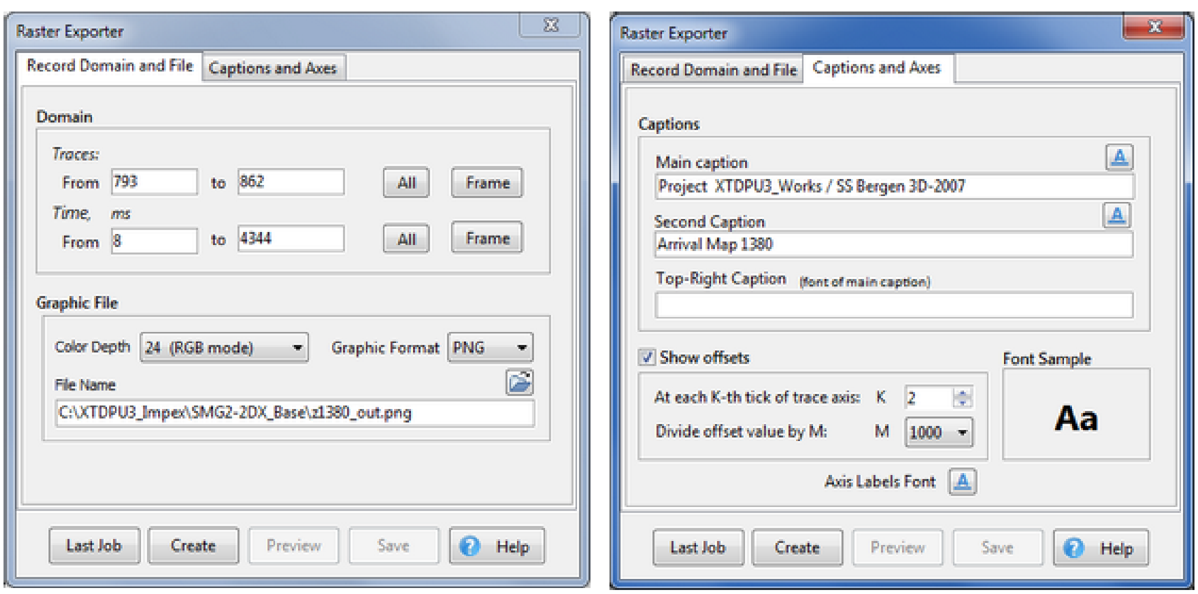
Segments of fp-map are TX-curves. They are drawn with specific drawing attributes that are not used for picked segments. Segments of different waves are drawn with the same attributes and cannot be distinguished by view. However, there is a way to view any wave in fp-map, while the rest are hidden. It is explained below.

The *View|Create FP Solution Map* command has a duplicate toolbar button . The button has the down arrow which drops down the menu. The menu lists fp-map waves defined in the XTomo-LM project. Each command is a switch "show/hide". Thus, the menu works as a wave filter for fp-map. It is not supposed that wave lists of DPU and XTomo-LM projects somehow correspond to each other. The menu contains the *Show All Waves* command as well.

FP-map can be examined together with the picked map or without it. Each map can be shown or hidden using two switch commands of the *View* menu: *Hide Arrival Map* and *Show FP Solution Map*.

7 AMV: Graphic Export

Graphic export is organized in the same way as in XTomo-LM. First, set image features you want to have in exported file using AMV tools. Then apply the *File|Create Raster File* command to start the Raster Exporter module, executing the operation. Its main window is shown on fig. 1. The user job is to define additional properties of the would-be image.



a b

Fig. 1. Raster Exporter.
a – tab 1 (map domain, export file); b – tab 2 (headings, offsets, fonts).

On tab 1, the user defines map rectangle domain as well as format and path name of export file.

To define a domain means to specify its trace range and time range. By default, the domain coincides with the current record frame on the AMV tablet. The *All* and *Frame* buttons set trace and time ranges so as to produce the entire seismogram or the current frame, respectively.

The target graphic file can have one of the following formats: BMP, GIF, PNG, JPG. Color depth can be chosen as 1, 4, 8, 16 or 24 bits. The JPG format requires color depth 24. Format and file path name can be selected after image is created and previewed.

On tab 2 (fig.1b), the user defines optional image captions: main, second and top-right. Captions fonts can be adjusted using the buttons A. When the cursor hovers over the button, the panel *Font Sample* displays "Aa" printed with the selected font. If the *Show Offsets* flag is set, offsets will be printed along the trace number axis N. One defines the frequency of offset labels with respect to axis ticks and, optionally, scales offsets by dividing their values by a degree of 10. On fig. 1b offsets are printed at each second tick of the N axis, while offset values are divided by 1000.

After filling out the required dialog fields, one clicks on the *Create* button to start creating the image. After it is finished, the *Preview* button gets enabled. Clicking on it, one can view the result displayed by the program fixed for viewing BMP files in Windows. If the view is OK, one selects the export file and clicks on *Save*. It is possible to save the created image in all available formats. The current job is automatically saved when the module shuts down. The *Last Job* button loads the last job of the previous module session.

8 Picking Arrival Maps

Approach – Methods of prediction and refinement – Process of picking – Elaboration

Approach

Wave arrival is associated with signal phase. The user finds a (positive) phase on the record and point to it by a double-click. Then the arrival time T is defined by the first phase sample S, whose value is not less than $q \cdot A$, where A is phase amplitude (maximal sample), $0 < q \leq 1$. The program stores the arrival as point (N, S) on seismogram image. Here N is trace number. In the user interface, parameter q, called *first break factor*, is defined as percentage with the default value 100, which means that the arrival time corresponds to phase maximum.

The previous paragraph describes elementary action in the process of picking. One can then pass to the next trace and repeat the action and so on. One does just that, indeed, to pass through incoherent record block, but, normally, the *phase correlation* approach is applied. It is based on the fact that arrivals of the same wave have similar phase form on neighbouring traces, while arrival time changes in regular way. In other words, arrival time is *predictable.* Instead of programmatic analysis of phase shapes, usually unreliable and strongly dependant on the recording quality, DPU uses the following *interactive* procedure, based on geophysicist's ability to easily identify a phase lineup visually.

One finds a part of phase lineup and reports to the program its start and end phases $\boldsymbol{P}_i$ and $\boldsymbol{P}_e$ by double-clicks. $\boldsymbol{P}_i$ and $\boldsymbol{P}_e$ are called *checkpoints*. The program (1) defines arrivals at the checkpoints; (2) computes predicted arrivals times on each intermediate trace; and (3) refines them to get true arrivals; (4) displays picked arrivals for approval. Simple and fast algorithms are used for prediction and refinement. The set of arrivals between checkpoints is called a *link.* A link is a part of a tx-segment.

Methods of Prediction and Refinement

The user can select methods of prediction and refinement of arrival times from the options in table 1:

Table 1. Methods of prediction and refinement

Prediction method	Refinement method
1. Local	1. By nearest phase
2. Linear	2. Maximal sample in search interval
3. None	3. None

Each method of prediction (the first column) can be combined with a method of refinement (with one exception). The simplest and most frequently used prediction method is *linear*: predicted times on traces between $\boldsymbol{P}_i$ and $\boldsymbol{P}_e$ are defined by samples belonging to strait line joining arrivals at the checkpoints. The most natural way of refining the predicted time *T'* is to find the nearest phase and determine the arrival time as in the first paragraph of the section. This is refinement *by nearest phase.* Combination 2-1 can be used in most cases (it is highlighted in table 1). However, a number of necessary checkpoints may increase due to peculiarities of the record. That's why other methods are offered.

If record quality is low, phase shape changes significantly, and search of the nearest phase becomes problematic. In this situation, the refinement method 2 may prove to be a better choice. It works this way: if S' is the predicted sample on a trace, then the arrival is defined by the sample with maximal value in interval *[S' – m, S' + m]*, where *m* is a parameter. This interval is called *search interval*.

If a phase lineup has significant curvature and the record is well-resolved (as refraction arrivals in near zone), *local* prediction is applied which is combined only with refinement method 1. The local method uses the end checkpoint $\boldsymbol{P}_e$ not for calculation of predicted times but only for testing. Predicted time *T'* on trace *N* is computed using arrival times on the *K* previous traces *N–1, N–2, … N–K*. The integer *K* which is called *prediction base* is a parameter.

The prediction method 3 means that no prediction is used at all. A segment consists of the only point *(N, S)*, obtained at double-clicking on the phase as in the first paragraph. The refinement method 3 means that no refinement is done: arrival time is equal the predicted time.

Combination 2-3 reduces phase correlation to linear interpolation between arrival times at checkpoints; it is used for passing through intervals of incoherent recording.

Process of Picking

After the starting checkpoint is double-clicked, the picking is developing by steps, each step being initiated by double-clicking the next checkpoint, possibly, moving to the next frame, possibly increasing gain, while the phase lineup is perceptible (fig. 1). On each step, prediction times are calculated using the last and the previous checkpoints.

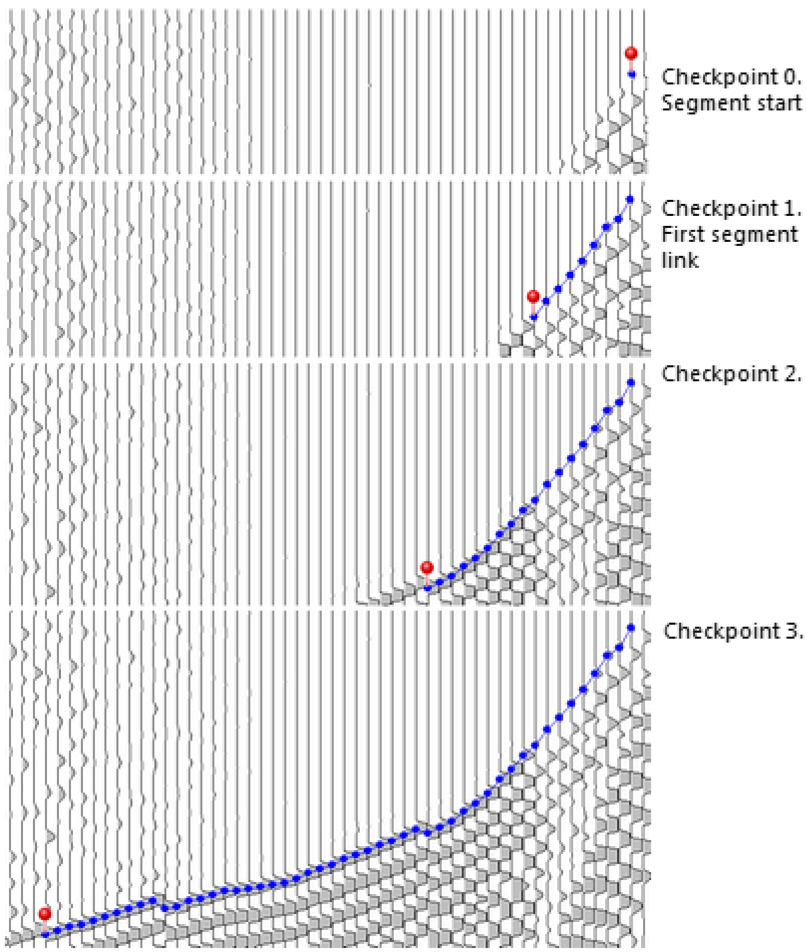


Fig. 1. Picking a segment. The red pin points to the last checkpoint. Record quality is not high, so checkpoints are set frequently enough.

Elaboration

The following statements give further details of the process.

1. Before picking, the wave to which the future segment(s) belongs must be set.
2. Picking goes in the direction ***from*** the zero-offset trace. Arrival picked on this trace belongs to the segment heading to the right.
3. Record is shown in the mode when only positive phases are visible. All checkpoints must

be positive phases. Options of displaying negative phases and inverting signal are blocked.

4. Picking is performed within *picking session*, which begins with the *Start* command and ends by the *Save* or *Cancel* commands During session, one can change view and signal preprocessing options, cancel the last link and switch methods of prediction and refinement with the only exception (see p. 5). One should be careful about turning filtering on/off during session, because the filter used can shift phases.
5. Selecting method of prediction 3 (rejecting prediction) switches on the special picking mode: *picking a sequence of arrivals* as opposed to *picking a segment*. One cannot switch between the modes during session. Picking sequence can be called *picking by one arrival*. In this mode, each picked arrival is regarded as a separate segment.

9 Arrival Time Picker

To understand the below text one has to be acquainted with Picking arrival maps.

Module ATP

The ATP module looks like Arrival Map Viewer and inherits all its functionality but the fp-map and graphic export features. Both programs can work with the same map: ATP carries out picking, while AMV provides for optimal map view. Changes made in the map become visible in AMV after applying the *View|Update* command.

ATP maintains the means of picking from and editing an arrival map. During work session, ATP provides for map backup: on the user command, it creates a copy of the current map and then, by another command, loads it to replace the current one. These commands can be found in the *File* menu and at left edge of the toolbar. A new section of main menu *Pick/Edit* contains ATP-specific commands.

Wave filter has an additional function in ATP. It is used for setting *target wave*, i.e. wave which is the object of an operation. For example, to define the wave owning segments to be picked, one has to set it as the target in Wave filter. Of course, target wave must be visible. To set target wave, select the *Mark as Target* command in the Wave filter popup menu. Target wave is highlighted with bold typeface.

Picking Console

This is a control panel for managing picking. It permits to select prediction and refinement methods and change picking parameters. As a floating panel, it can be invoked by the *Pick/Edit Arrivals| Display Picking Console* command. As a part of the main control panel, it is placed at the top. The upper console section Tracking method (fig. 1). contains, in the shortened form, table 1 of the previous section. Method selection is made by radio-buttons.

The method parameter section is just below. There are only two method parameters. For local prediction method 1-1, this is *Prediction base K*. The more *K* is, the more conservative (smoothing sharp changes) prediction is. For methods with refinement 2, *Search interval half-width* is displayed and modified on the panel.

Still below, the common parameters section is placed. There are two common parameters: maximal phase length in number of samples and first break factor. Maximal phase length is used to single out phases on the record. First break factor is explained [here](). The default value of 100 means that arrival time is defined by the maximal sample of the phase.

The picking toolbar at attached to console bottom. Commands matching the buttons are described in table 1.

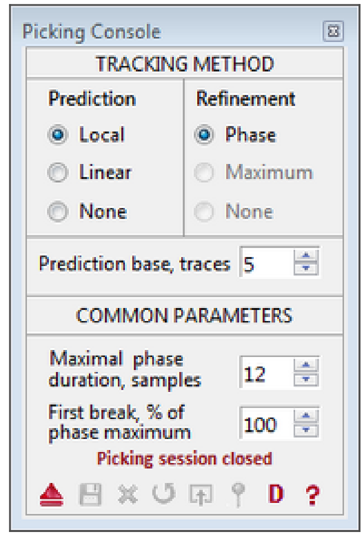


Fig. 1. Picking control panel.

Table 1. Picking Console buttons.

Button	Operation
Open Session	Opens picking session. If prediction method is set to None, picking a sequence is started, else — picking a segment. The command produces no visible effects: the program is waiting for the initial checkpoint to be double-clicked. Before clicking the button the target wave must be set in Wave Filter.
Close and Save	Closes session and saves the picked segment or sequence of arrivals to the map database.
Close	Closes session without saving and wipes out whatever has been picked from the map.
Cancel Link	Cancels last link. The command is recursive: one can cancel the whole segment link after link.
Continue on Next Frame	Scrolls record to the next frame. The command differs from the regular means of scrolling in that it chooses the next frame in most appropriate way to continue picking.
Show Checkpoint	Scrolls record back to the frame containing the last checkpoint if it is lost from view.

The console buttons have their clone commands in the tablet context menu. Beyond session, only the *Start Session command* is visible, but once the session has begun, all of them appear in the menu.

Errors of Picking

If tracking the next link failed, ATP displays an error message. Error messages have non-standard view shown on fig. 2. There is a sort of arrow at the bottom-right corner that points exactly to the record point at which the error has been discovered.

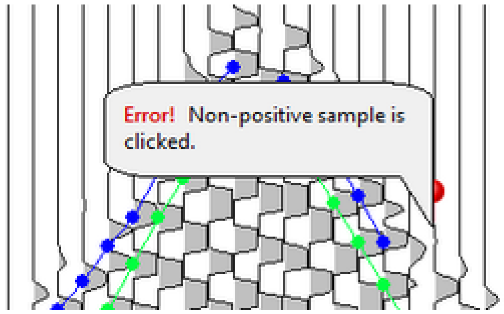


Рис. 2. Сообщение об ошибке считывания.

To hide the error message window, click on message text.

10 Editing Maps

To understand the below text one has to reread the section Access to segments.

Editing is enabled beyond picking sessions. There are only two edit operations: changing wave and deleting. Both operations can work with following sets of arrivals: selected segments; a subsegment; segments associated with the same wave; all map segments. Commands relating to a selection are contained in the tablet popup menu. The rest can be found in the *Pick/Edit* section of main menu. Changing or replacing a wave means that arrivals participating in the operation will be associated with the target wave defined in Wave Filter. Therefore, before issuing the command, one has to set the required wave in Wave Filter using context menu. Table 1 gives the detailed command description.

Table 1. Edit commands and operations

Command	Operation
Tablet context menu (there is a selection on the map)	
Set Wave for Selected	Associates all selected arrivals with the target wave set in Wave Filter. If a subsegment is selected, it is turned out into a separate segment as well as the the remaining parts of the segment.
Replace Wave	The command is enabled if exactly one segment is selected. If it belongs to the wave *W*, then all segments belonging to *W* will be associated with the target wave.
Delete Selected	Removes the selected segments from the map. If a subsegment has been removed, the remaining parts are turned into segments.

Menu *Pick/Edit*	
Delete wave Arrivals	Removes all arrivals of the target wave from the map.
Clear Map	Removes all arrivals from the map.

11 Importing Maps

Arrival maps can be imported from another project if both are based on the same field seismograms, at least, in part. No correspondence between seismogram (and map) IDs in both projects is supposed. The import operation is important because it solves the problem of repeated picking from the same seismograms. For example, creating several projects (= variants of processing) of the same field data requires basic picking to be made in one project only. Map import is provided from projects of versions 3 and 2. Because ways of storing data in version 3 and 2 are different, the job is carried out by different modules. They are launched by different commands and have quite different "internals", but similar user interface. That makes it sufficient to explain only the case of version 3.

Module Arrival Map Importer (AMI) is launched by the *Arrival Maps|Import from DPU 3 Project* main menu command. Its main window is shown on fig. 1.

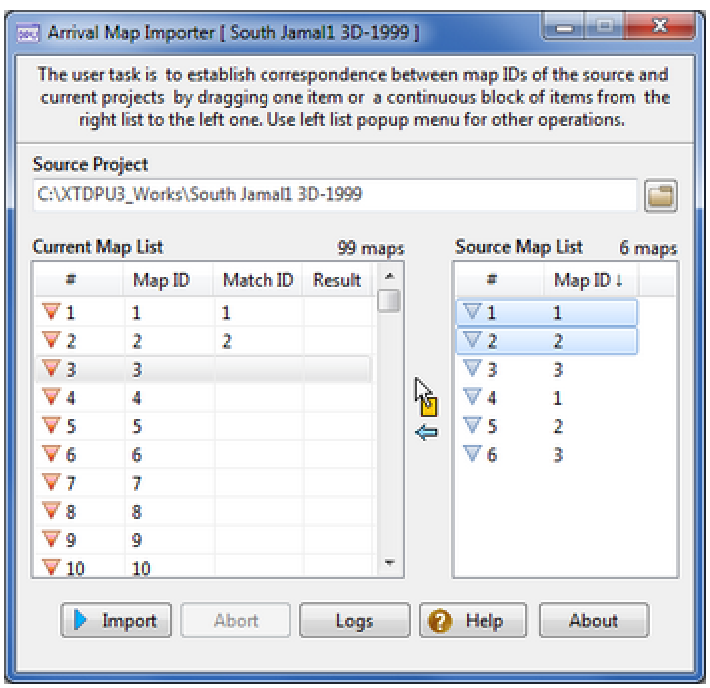


Fig. 1. Arrival Map Importer main window.

On the left, the full map list of the current project is shown. The first user action is to select the source project. To do that, select the required project's folder in the local folder browser clicking on the folder button. The list of non-empty maps of the source project appears in the right table. The user task is to determine (1) which IDs to import and (2) which IDs the imported map must have in the current project to refer the same seismograms.

Correspondence between maps is shown in the columns *Map ID* and *Match ID* of the left list. The latter column is empty at program start. One must fill it, at least in part, with IDs from the right list. One does it by dragging an ID right to left and dropping it on the matching item. One can drag one item or a contiguous block of selected items. In the latter case, the mouse left button must be released over the starting item of the block in the left list.

The left list owns context menu with commands explained in table 1.

Table 1. Commands of the context menu of the current map list.

Command	Operation
Match Maps with Same IDs	Matches maps with the same IDs, filling out the *Match ID cells*. No drag-drop is needed.
Clear Match IDs in Selected	Clears the *Match* cells of the selected items.
Clear All Match IDs	Clears the entire *Match* column.
Reset	Resets the results for repeated import in the same session.

After matching map IDs, click on the *Import* button to start the operation. On termination, the *Result* column will contain "OK" or "Fail". If a map is not imported, the reason can be found in the operation log invoked by the *Log* button. Typical error arises from different project wave lists: a map to import contains a wave not found the current project wave list. In this case, the absent wave should be added, and import run anew.

12 Exporting Maps

In projects with 2.5D, 2D and Other 2D data observation kinds, arrival maps are exported to SRT files for input into XTomo-LM. In projects with 3D data, arrival maps are exported to #DT file which are imported by 3D tomography system Firstomo. Export is implemented by different modules. Project Manager launches appropriate module depending on dimension of data. The launching command is *Arrival Maps|Export.*

Export to XTomo-LM

The module's main menu is shown on fig. 1.

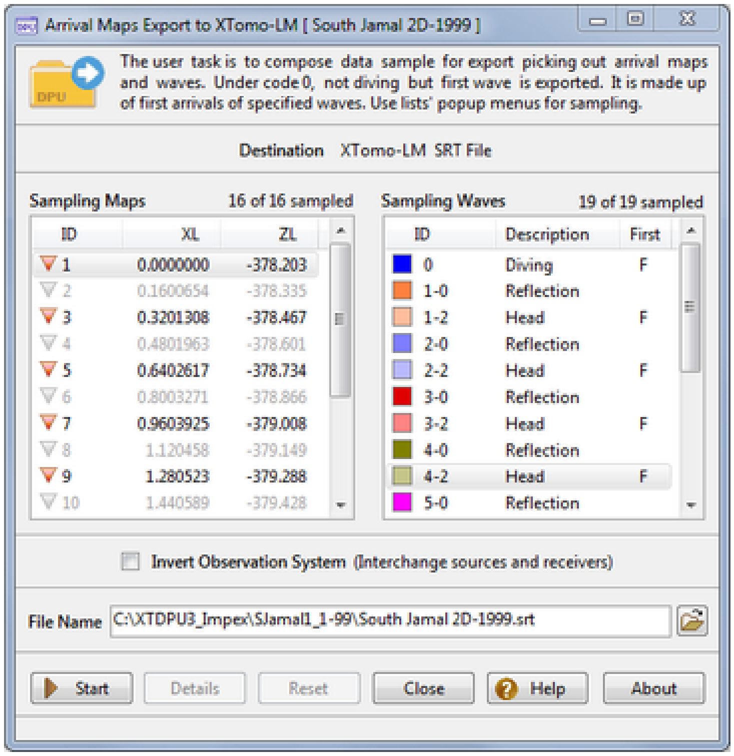


Fig. 1. Map Exporter to XTomo-LM

The user task is to define a sample of data to export. Objects for sampling are maps and waves. Additional option is inverting observation system. This means that in SRT file receivers will be used as sources and vice-versa. Including this option is caused by the rigid requirement for input seismic records to be common source seismograms. This restriction is discussed here.

Sampling maps

The map list is displayed as list of sources with their line coordinates. By default, all maps are to be exported or, in other words, are included in the data sample. The user can judge on whether a map is included or not by its icon: ▼ means included, ▽ – excluded. Because the list allows multiple selection, an arbitrary subset of maps can be included in the sample using item selecting with the modifier keys Ctrl and Shift and the context menu commands (table 1).

Table 1. Command of the map list context menu.

Command	Operation
Include Selected *Exclude Selected*	Includes in (excludes from) the sample the items selected in the list.
Include All *Exclude All*	Includes in (excludes from) the sample all list items.
Map Sequence	Includes in (excludes from) the sample a subsequence of maps (see below)

A double-click on an item toggles its state. The *Map Sequence* command invokes a dialog shown on fig. 2.

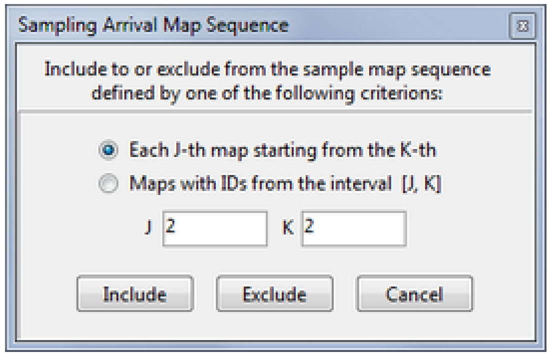


Рис. 2. Definition of map subsequence.

A sequence is defined either by the condition *Each J-th map, starting from the K-the* (this option is selected on fig. 2 with J = K = 2), or by requirement of falling map FID into interval [J, K]. In both cases values of J and K are to be typed in the edit fields. The *Include* or *Exclude* buttons execute the operation. The *Include* command includes the sequence excluding nothing. The same way, strictly following its name, acts the *Exclude* command.

Sampling Waves. Export of First Wave

The project wave list on the right allows selecting waves for export in similar way. However, the list view has additional feature: it presents the interface for export of first wave. According to what was said in section Waves, first wave may consist of arrivals of waves of different origin. The user defines first wave makeup by setting the F flag in the *First* list column. That is done with a context menu command or a double-click on an item with the Alt key pressed. Such waves are called F-waves, for brevity. Diving wave is always an F-wave. The user must follow these guidelines:

(1) if diving wave is included in the sample, first wave is exported instead of diving;

(2) first wave consists of arrivals of F-waves; a reflected or head F-wave contributes in first wave always, irrespective of whether it is included in the sample or not;

(3) the export module forms first wave from arrivals of F-waves, *excluding second and later arrivals*.

It often happens that one picks several segments of the same wave from the same traces which differ in time. One does that just in case, putting off the final choice till the moment when technical work is finished. One has to keep in mind that when the wave is exported, and two or more wave arrivals are discovered on the same trace, *only the one with minimal time is exported*; the second and later arrivals are ignored.

Case of 3D observations

In this case only first wave can be picked, therefore the export module displays only map list (fig. 3.). Sampling maps is similar to the case of 2D.

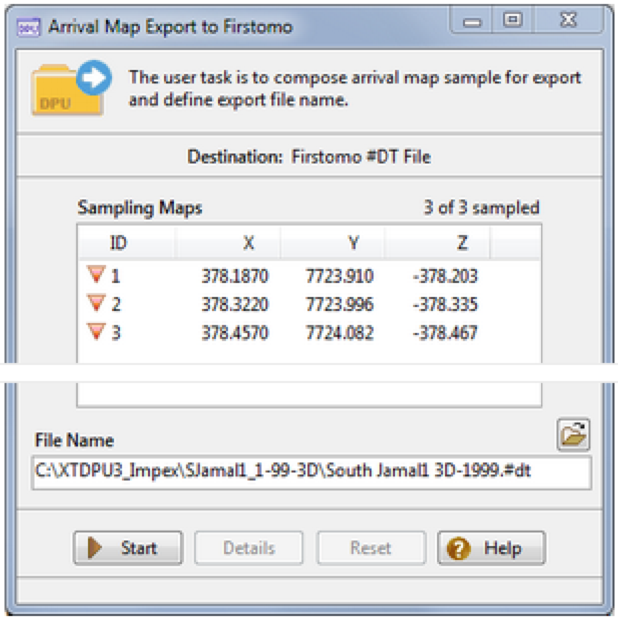


Fig. 3. Export of 3D data to to Firstomo.

Executing. Secure Resolution

A click on the *Start* button starts the export operation. It is performed so that maps are processed by concurrent threads, so the processing is fast enough. After it is finished with errors reported, the *Details* button displays additional information on errors. The *Reset* button switches the program in initial state allowing the user to repeat the operation.

In the cases of 2.5D and 2D profiling, the minimal distance between receivers exceeds the resolution value by the way of building line geometry. Theoretically, it is possible that adjacent traces match the receivers that are "glued together". The export module guarantees that arrivals breaking unambiguity of the observation system will NOT be written to the export file. Therefore, when the file is imported to XTomo-LM, the resolution errors will be excluded, if only x-resolution in XTomo-LM project is no greater than in the DPU project.

13 Line Arrival Map

LAM

LAM means Line Arrival Map in the user interface and the documentation. Line arrival map is a database combining all currently non-empty seismogram arrival maps. It is built for projects with 2.5D and 2D profiling data when the user needs a broader view at all picked arrivals for correct wave identification. Exploring LAM includes viewing the maps, comparing apparent velocity of segments, editing segments similar to ATP and exporting to XTomo-LM. Versions of LAM may be created more than once during process of picking.

LAM Tree

DPU provides storing and access to any number of LAM versions. Project Manager represents them in the form of a tree. After the first version is created, LAM tree appears in Project Manager main window replacing arrival map list. Since then, to switch between LAM tree and arrival map list, use the *Arrival Maps|Show Line Map Tree* command or a couple of toolbar buttons(fig. 1).

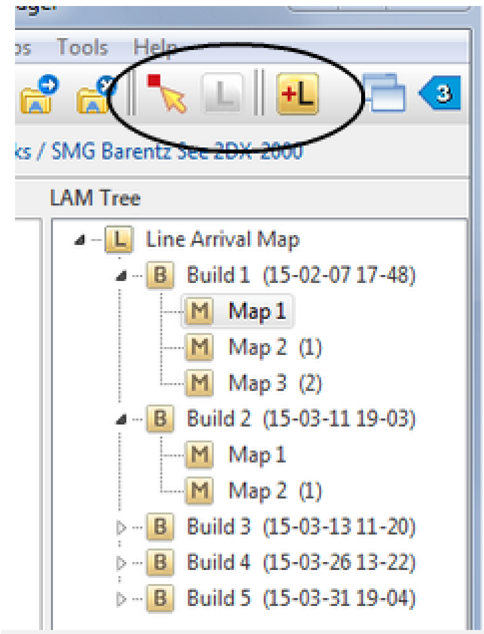


Fig. 1. LAM Tree.
The Black contour outlines control buttons: *Switch to arrival map list*, *Switch to LAM tree*, *Create LAM build.*

The tree has three levels. The root node Line Arrival Map is simply a heading without any functional load. The second level is occupied by *Build* nodes. Build is a LAM version, the result of new LAM building. It is created by the *Arrival Maps|Build Line Arrival Map* command. Builds are numbered automatically. After removing a build, its number is not used any longer.

The third level is populated with line arrival maps. The first map of a build is called *Map 1*. Because maps can be edited, the problem of maintenance of different map version arises. It is solved in the following way: each map can be copied, and editing may be continued in the copy. A map copy stays on the same level, but its name points to its source. Map names follow the pattern "Map N (P)", where N is map ordinal number generated automatically, while P is parent map number. Thus, map hierarchy is supported at the expense of naming without growth number of levels. The first map *Map 1* cannot be changed as an original of the build.

LAM Tree Menu

The set of the menu commands depends on the node selected, as shown in table 1.

Table 1. Commands of LAM tree context menu

Command	Node	Operation
Explore *Explore/ Edit*	Map	Launches module Line Map Explorer for exploring and editing the selected line arrival map. The first command relates to *Map 1,* which cannot be edited.
Copy	Map	Creates a copy of the selected map.
Delete	Build Map	Deletes the selected node. The Build node is removed with all child maps. The map is deleted alone, parent-child relationship is ignored. Map databases are wiped out from disc.
Expand Tree	Any	Entirely expands the tree.

Collapse Tree	Any	Folds the tree up to the Build list.

14 Exploring LAM

Module LME – Filters – Zoom – First wave mode – Information on selected segments – Comparing apparent velocities – Edit operations – Graphic export – Export to XTomo-LM.

Line Map Explorer (LME)

Graphic module LME displays the set of segments picked from all project seismograms on the tablet with horizontal axis X = XL (line coordinate) and vertical axis T (time in seconds). Module's main window is shown on fig. 1.

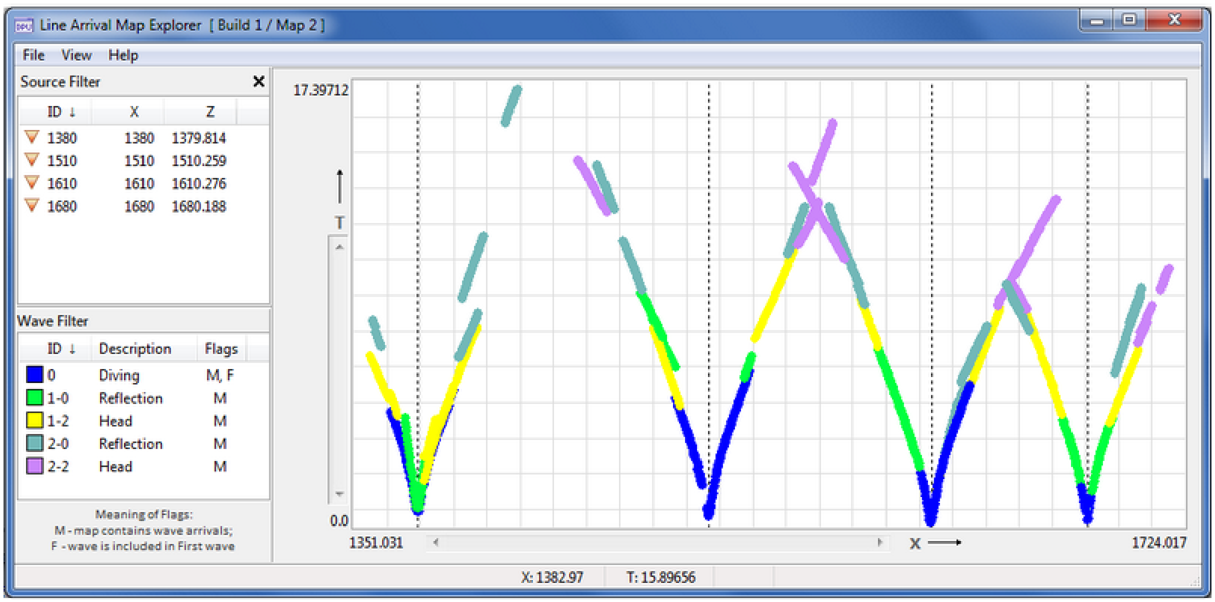


Fig. 1. Line Map Explorer main window.

The left panel displays source and wave lists. Each list is, functionally, a filter (see below). It can be hidden to let the tablet take up all the window client area. Segments are drawn with attributed of the waves they belong to. Vertical dotted lines pass through the shotpoints. They can be hidden using the *View* menu command. If one clicks on the tablet to the left of a vertical with the Alt key down, the matching source becomes the selected item in the source list.

In many features LME is similar to the other two graphic modules AMV and ATP: the same way of access to segments (selecting), the same editing operations, similar wave filters and so on. The fact that AMV and ATP draw segments over the seismogram image, while LME draws them on (X,T) plain, doesn't affect the basic similarity. On this reason, we limit ourselves to short LME overview lingering only over differences and new features.

Filters

The source filter hides seismogram maps, corresponding to sources that are filtered off. A double-click on an item switches its state. Context menu commands hide/show segments pertaining to the selected items, or show only selected maps, or subsequence of maps (each second, each third, fourth or fifth).

The wave filter contains the additional Flags column. There are three flags: M, F and T. If a flag is set, a column cell displays its character. M means that a wave arrivals are found on the map; F means that a wave arrivals are included in first wave; T means that the wave is set as the *target* of an edit operation, as in ATP. Flags F and T are managed by the user with the help of context menu, while the M flag is controlled by the program.

Zoom

In AMV, image scale is defined by view options. In LME, rubber-band is used for magnifying the image, as in XTomo-LM. The rubber-band menu command *Zoom in* stretches the inside of rubber-band so that it takes up the entire tablet. This works if there is at least one arrival inside the contour. The operation is recursive: it can be applied more than once to attain the necessary magnification. When magnified, the image can be scrolled within the tablet as a record frame in AMV: by scroll bars, by mouse wheel (horizontally – with Shift pressed) or by dragging an image point with Ctrl pressed. To zoom out, use the tablet menu commands *Decrement Zoom* and *Zoom out* = Ctrl+Z. Usually one works with magnified image to make arrivals look separated from each other (they are simply not observable on fig. 1).

First wave mode

LME can export first wave instead of diving in the same way as Export module does. Moreover LME allows the user to examine it on the tablet., if only diving wave is not filtered off. First wave makeup is defined by the F flags. Diving wave is always an F-wave. Other F-waves participate even if they are filtered off. To view first arrivals, one turns on the F mode by the main menu command *View|Show First Wave*. First arrivals are drawn over image in the select color without links. Links keep their native color and can point to component waves. When first wave is displayed, the wave filter is still enabled but not for diving wave. The same command hides first wave. Switching to F-mode deselects whatever has been selected on the map. Selecting is blocked in F-mode.

Information on Selected Segments

It can be obtained by the *Selected in Detail* command of the plotting pad context menu. It invokes the dialog that differs from that of AMV (fig. 2).

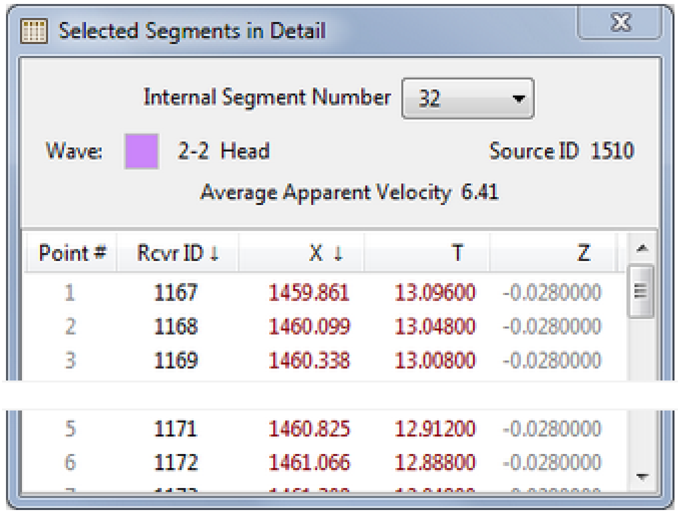


Fig. 2. Information displayed for each of the selected segments.

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For each selected segment (their drop-down list is at the top), the following properties are displayed: internal segment number; wave it is associated with, source FID, average apparent velocity and list of arrivals. The latter is represented by a table with columns: arrival ordinal number (Point #), receiver ID (Rcvr ID), line coordinate XL (X), time (T) and z- coordinate (Z).

Comparing Segment Apparent Velocity

This operation is especially useful for identification of head waves. During work session, LME supports the list of (sub)segments with their apparent velocities. The list is formed by the user. To add a segment to it, select a segment and apply the *Compare Apparent Velocity* command of the tablet context menu. It invokes the dialog *Apparent Velocity Compare List* (fig. 3).

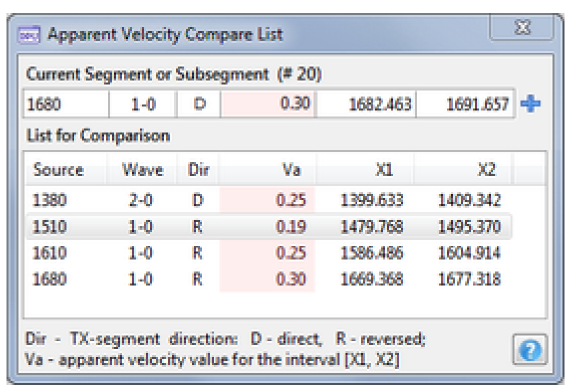

Fig. 3. Apparent velocity compare list.

Information on the segment is displayed in the line at the top. The line fields match the columns of the list. The button adds the content of the line to the list. The list context menu allows sorting its items by source FID or wave ID and delete needless records. A subsegment can be added to the list too. First select a segment, then point subsegment x-range by rubber-band and apply the *Compare* command of the rubber-band menu.

Edit Operations

As in ATP, there are two operations: changing segment wave association and deleting. Operation objects are: a set of selected segments or a set of segments belonging to the same wave. Commands can be found in the tablet context menu. The *Set Wave for Selected* command associates the selected segments with the target wave marked by the T flag in the wave filter. The *Replace wave* command associates all segments, belonging to the same wave as the selected one, with the target wave. The *Delete Selected* command removes the selected segments from the map.

The service operation of turning subsegment into segment allows expanding the edit operations down to each arrival. To perform it, select a segment; then point x-range of the would-be subsegment by rubber-band an apply the *Turn Subsegment into Segment* command of the rubber-band menu. It breaks the segment into two or three subsegments, one of which is the required.

Graphic Export

The dialog for graphic export somewhat differs from that of AMV. It is invoked by the *File|Export Image To Graphic File* command. On tab 1 (fig. 4a), one defines a rectangle subdomain of the map in (X, T) coordinates. By default, it coincides with the (sub)domain in the plotting pad.

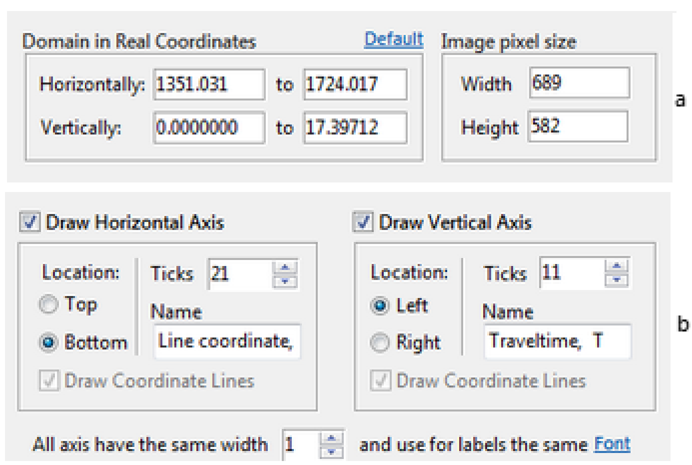

Fig. 4. Line arrival map export to graphic file.
a – fragment of tab 1: subdomain of the map and pixel picture size;
b – fragment of tab 1: setting axis properties.

On the right panel, one defined the pixel size of the future image. By default, it coincides with the tablet size. Tab 2 is for setting axis properties and captions (fig. 4b). For example, horizontal axis has the following properties: the Draw Horizontal Axis flag (draw or not), Location (top or bottom), Ticks (number of ticks), Name, axis pixel width and label font. The selected font can be viewed in hint widow of the *Font* hyperlink. Graphic formats and captions are defined as in AMV. Color depth is not set: it is equal to 24 bit. The control buttons and the order of user actions are the same as in AMV.

Export to XTomo-LM

LME implements export to XTomo-LM through creating an SRT file as an alternative to seismogram map export. LME replaces sampling of sources and waves with filtering, so that data sample is defined by the state of source and wave filters. If diving wave is not filtered off, first wave is exported instead of the diving, and it must be displayed on the tablet before export. The export command is *File|Export Map to XTomo-LM SRT File*. Inverting the observation system is also available: before export, set the flag *File|Invert Observation System at Export*. Thus, exporting includes one to three actions: (1) set F-mode, if diving wave is checked; (2) set inversion flag in the File menu, if the observation system is to be inverted; (3) apply export command in the File menu.

Appendix: SEG-Y Headers

1 File Binary Header Layout

Binary File Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based n – information words interpreted at file opening.		
Слово	**Байты**	**Описание**
1	3201-3204	Job identification number.
2	3205-3208	Line number. For 3-D poststack data, this will typically contain the in-line number.
3	3209-3212	Reel number.
4	3213-3214	Number of data traces per ensemble. *Mandatory for prestack data.*
5	3215-3216	Number of auxiliary traces per ensemble. *Mandatory for prestack data.*
6	3217-3218	Sample interval in microseconds (μs). *Mandatory for all data types.*
7	3219-3220	Sample interval in microseconds (μs) of original field recording.
8	3221-3222	Number of samples per data trace. *Mandatory for all types of data.* Note: The sample interval and number of samples in the Binary File Header should be for the primary set of seismic data traces in the file.
9	3223-3224	Number of samples per data trace for original field recording.
10	3225-3226	Data sample format code. *Mandatory for all data.* 1 = 4-byte IBM floating-point 2 = 4-byte, two's complement integer 3 = 2-byte, two's complement integer 4 = 4-byte fixed-point with gain (obsolete) 5 = 4-byte IEEE floating-point 6 = Not currently used 7 = Not currently used 8 = 1-byte, two's complement integer
11	3227-3228	Ensemble fold — The expected number of data traces per trace ensemble (e.g. the CMP fold). *Highly recommended for all types of data.*
12	3229-3230	Trace sorting code (i.e. type of ensemble) : -1 = Other (should be explained in user Extended Textual File Header stanza) 0 = Unknown

Binary File Header Layout According to SEG-Y Standard Revision 1 (2002)
Byte numbering is 1-based
n – information words interpreted at file opening.

Слово	Байты	Описание
		1 = As recorded (no sorting) 2 = CDP ensemble 3 = Single fold continuous profile 4 = Horizontally stacked 5 = Common source point 6 = Common receiver point 7 = Common offset point 8 = Common mid-point 9 = Common conversion point *Highly recommended for all types of data.*
13	3231-3232	Vertical sum code: 1 = no sum, 2 = two sum, …, N = M-1 sum (M = 2 to 32,767)
14	3233-3234	Sweep frequency at start (Hz).
15	3235-3236	Sweep frequency at end (Hz).
16	3237-3238	Sweep length (ms).
17	3239-3240	Sweep type code: 1 = linear 2 = parabolic 3 = exponential 4 = other
18	3241-3242	Trace number of sweep channel.
19	3243-3244	Sweep trace taper length in milliseconds at start if tapered (the taper starts at zero time and is effective for this length).
20	3245-3246	Sweep trace taper length in milliseconds at end (the ending taper starts at sweep length minus the taper length at end).
21	3247-3248	Taper type: 1 = linear 2 = cos2 3 = other
22	3249-3250	Correlated data traces: 1 = no 2 = yes
23	3251-3252	Binary gain recovered: 1 = yes

Binary File Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based n – information words interpreted at file opening.		
Слово	**Байты**	**Описание**
		2 = no
24	3253-3254	Amplitude recovery method: 1 = none 2 = spherical divergence 3 = AGC 4 = other
25	3255-3256	Measurement system: *Highly recommended for all types of data.* If Location Data stanzas are included in the file, this entry must agree with the Location Data stanza. If there is a disagreement, the last Location Data stanza is the controlling authority. 1 = Meters 2 = Feet
26	3257-3258	Impulse signal polarity 1 = Increase in pressure or upward geophone case movement gives negative number on tape. 2 = Increase in pressure or upward geophone case movement gives positive number on tape.
27	3259-3260	Vibratory polarity code: Seismic signal lags pilot signal by: 1 = 337.5° to 22.5° 2 = 22.5° to 67.5° 3 = 67.5° to 112.5° 4 = 112.5° to 157.5° 5 = 157.5° to 202.5° 6 = 202.5° to 247.5° 7 = 247.5° to 292.5° 8 = 292.5° to 337.5°
	3261-3500	Unassigned
28	3501-3502	SEG Y Format Revision Number. This is a 16-bit unsigned value with a Q-point between the first and second bytes. Thus for SEG Y Revision 1.0, as defined in this document, this will be recorded as 010016. *This field is mandatory for all versions of SEG Y, although a value of zero indicates “traditional” SEG Y conforming to the 1975 standard.*
29	3503-3504	Fixed length trace flag. A value of one indicates that all traces in this SEG Y file are guaranteed to have the same sample interval and number of samples, as specified in Textual File Header bytes 3217-3218 and 3221-3222. A value of zero indicates that the length of the traces in the file may vary and the number of samples in bytes 115-116 of the Trace Header must be examined to determine the actual length of each trace. *This field is*

Binary File Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based n – information words interpreted at file opening.		
Слово	**Байты**	**Описание**
		mandatory for all versions of SEG Y, although a value of zero indicates "traditional" SEG Y conforming to the 1975 standard.
30	3505-3506	Number of 3200-byte, Extended Textual File Header records following the Binary Header. A value of zero indicates there are no Extended Textual File Header records (i.e. this file has no Extended Textual File Header(s)). A value of -1 indicates that there are a variable number of Extended Textual File Header records and the end of the Extended Textual File Header is denoted by an ((SEG: EndText)) stanza in the final record. A positive value indicates that there are exactly that many Extended Textual File Header records. Note that, although the exact number of Extended Textual File Header records may be a useful piece of information, it will not always be known at the time the Binary Header is written and it is not mandatory that a positive value be recorded here. *This field is mandatory for all versions of SEG Y, although a value of zero indicates "traditional" SEG Y conforming to the 1975 standard.*
	3507-3600	Unassigned

2 Trace Header Layout

Trace Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based. n – information words interpreted at reading trace. n – information words relating to positional data and shot time		
Слово	**Байты**	**Описание**
1	1-4	Trace sequence number within line — Numbers continue to increase if the same line continues across multiple SEG Y files. *Highly recommended for all types of data.*
2	5-8	Trace sequence number within SEG Y file — Each file starts with trace sequence one.
3	9-12	Original field record number. *Highly recommended for all types of data.*
4	13-16	Trace number within the original field record. *Highly recommended for all types of data.*
5	17-20	Energy source point number — Used when more than one record occurs at the same effective surface location. It is recommended that the new entry defined in Trace Header bytes 197-202 be used for shotpoint number.
6	21-24	Ensemble number (i.e. CDP, CMP, CRP, etc)

Trace Header Layout According to SEG-Y Standard Revision 1 (2002)

Byte numbering is 1-based.

n – information words interpreted at reading trace.

n – information words relating to positional data and shot time

<table>
<tr><th>Слово</th><th>Байты</th><th colspan="2">Описание</th></tr>
<tr><td>7</td><td>25-28</td><td colspan="2">Trace number within the ensemble — Each ensemble starts with trace number one.</td></tr>
<tr><td>8</td><td>29-30</td><td colspan="2">Trace identification code:
-1 = Other
0 = Unknown
1 = Seismic data
2 = Dead
3 = Dummy
4 = Time break
5 = Uphole
6 = Sweep
7 = Timing
8 = Waterbreak
9 = Near-field gun signature
10 = Far-field gun signature
11 = Seismic pressure sensor
12 = Multicomponent seismic sensor - Vertical component
13 = Multicomponent seismic sensor - Cross-line component
14 = Multicomponent seismic sensor - In-line component
15 = Rotated multicomponent seismic sensor - Vertical component
16 = Rotated multicomponent seismic sensor - Transverse component
17 = Rotated multicomponent seismic sensor - Radial component
18 = Vibrator reaction mass
19 = Vibrator baseplate
20 = Vibrator estimated ground force
21 = Vibrator reference
22 = Time-velocity pairs
23 … N = optional use, (maximum N = 32,767)
Highly recommended for all types of data.</td></tr>
<tr><td>9</td><td>31-32</td><td colspan="2">Number of vertically summed traces yielding this trace. (1 is one trace, 2 is two summed traces, etc.)</td></tr>
<tr><td>10</td><td>33-34</td><td colspan="2">Number of horizontally stacked traces yielding this trace. (1 is one trace, 2 is two stacked traces, etc.)</td></tr>
<tr><td>11</td><td>35-36</td><td colspan="2">Data use:
1 = Production
2 = Test</td></tr>
<tr><td>12</td><td>37-40</td><td colspan="2">Distance from center of the source point to the center of the receiver group (negative if opposite to direction in which line is shot).</td></tr>
<tr><td>13</td><td>41-44</td><td>Receiver group elevation (all elevations above the Vertical datum are positive and below are negative).</td><td rowspan="4">The scalar in Trace Header bytes 69-70 applies to these values. The units are feet or meters as specified in Binary File Header bytes 3255-3256). The Vertical Datum should be defined through a Location Data stanza</td></tr>
<tr><td>14</td><td>45-48</td><td>Surface elevation at source.</td></tr>
<tr><td>15</td><td>49-52</td><td>Source depth below surface (a positive number).</td></tr>
<tr><td>16</td><td>53-56</td><td>Datum elevation at receiver group.</td></tr>
</table>

Trace Header Layout According to SEG-Y Standard Revision 1 (2002)

Byte numbering is 1-based.

n – information words interpreted at reading trace.

n – information words relating to positional data and shot time

Слово	Байты	Описание	
17	57-60	Datum elevation at source.	
18	61-64	Water depth at source.	
19	65-68	Water depth at group.	
20	69-70	Scalar to be applied to all elevations and depths specified in Trace Header bytes 4168 to give the real value. Scalar = 1, +10, +100, +1000, or +10,000. If positive, scalar is used as a multiplier; if negative, scalar is used as a divisor.	
21	71-72	Scalar to be applied to all coordinates specified in Trace Header bytes 7388 and to bytes Trace Header 181-188 to give the real value. Scalar = 1, +10, +100, +1000, or +10,000. If positive, scalar is used as a multiplier; if negative, scalar is used as divisor.	
22	73-76	Source coordinate – X	The coordinate reference system should be identified through an extended header Location Data stanza (see section D-1). If the coordinate units are in seconds of arc, decimal degrees or DMS, the X values represent longitude and the Y values latitude. A positive value designates east of Greenwich Meridian or north of the equator and a negative value designates south or west.
23	77-80	Source coordinate – Y	
24	81-84	Group coordinate – X	
25	85-88	Group coordinate – Y	
26	89-90	Coordinate units: 1 = Length (meters or feet) 2 = Seconds of arc 3 = Decimal degrees 4 = Degrees, minutes, seconds (DMS) Note: To encode ±DDDMMSS bytes 89-90 equal = ±DDD*10^4 + MM*10^2 + SS with bytes 71-72 set to 1; To encode ±DDDMMSS.ss bytes 89-90 equal = ±DDD*10^6 + MM*10^4 + SS*10^2 with bytes 71-72 set to -100.	
27	91-92	Weathering velocity. (ft/s or m/s as specified in Binary File Header bytes 3255-3256)	
28	93-94	Subweathering velocity. (ft/s or m/s as specified in Binary File Header bytes 3255-3256)	
29	95-96	Uphole time at source in milliseconds.	Time in milliseconds as scaled by the scalar specified in Trace Header bytes 215-216.
30	97-98	Uphole time at group in milliseconds.	
31	99-100	Source static correction in milliseconds.	
32	101-102	Group static correction in milliseconds.	
33	103-104	Total static applied in milliseconds. (Zero if no static has been applied,)	
34	105-106	Lag time A — Time in milliseconds between end of 240byte trace identification header and time break. The value is positive if time break occurs after the end of header; negative if time break occurs before the end of header. Time break is defined as the initiation pulse that may be recorded on an auxiliary trace or as otherwise specified by the recording system.	

Trace Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based. n – information words interpreted at reading trace. n – information words relating to positional data and shot time		
Слово	**Байты**	**Описание**
35	107-108	Lag Time B — Time in milliseconds between time break and the initiation time of the energy source. May be positive or negative.
36	109-110	Delay recording time — Time in milliseconds between initiation time of energy source and the time when recording of data samples begins. In SEG Y rev 0 this entry was intended for deep-water work if data recording does not start at zero time. The entry can be negative to accommodate negative start times (i.e. data recorded before time zero, presumably as a result of static application to the data trace). If a non-zero value (negative or positive) is recorded in this entry, a comment to that effect should appear in the Textual File Header.
37	111-112	Mute time — Start time in milliseconds.
38	113-114	Mute time — End time in milliseconds.
39	115-116	Number of samples in this trace. *Highly recommended for all types of data.*
40	117-118	Sample interval in microseconds (μs) for this trace. The number of bytes in a trace record must be consistent with the number of samples written in the trace header. This is important for all recording media; but it is particularly crucial for the correct processing of SEG Y data in disk files If the fixed length trace flag in bytes 3503-3504 of the Binary File Header is set, the sample interval and number of samples in every trace in the SEG Y file must be the same as the values recorded in the Binary File Header. If the fixed length trace flag is not set, the sample interval and number of samples may vary from trace to trace. *Highly recommended for all types of data.*
41	119-120	Gain type of field instruments: 1 = fixed 2 = binary 3 = floating point 4 … N = optional use
42	121-122	Instrument gain constant (dB).
43	123-124	Instrument early or initial gain (dB).
44	125-126	Correlated: 1 = no 2 = yes
45	127-128	Sweep frequency at start (Hz).
46	129-130	Sweep frequency at end (Hz).
47	131-132	Sweep length in milliseconds.
48	133-134	Sweep type: 1 = linear

Trace Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based. n – information words interpreted at reading trace. n – information words relating to positional data and shot time		
Слово	**Байты**	**Описание**
		2 = parabolic 3 = exponential 4 = other
49	135-136	Sweep trace taper length at start in milliseconds.
50	137-138	Sweep trace taper length at end in milliseconds.
51	139-140	Taper type: 1 = linear 2 = cos2 3 = other
52	141-142	Alias filter frequency (Hz), if used.
53	143-144	Alias filter slope (dB/octave).
54	145-146	Notch filter frequency (Hz), if used.
55	147-148	Notch filter slope (dB/octave).
56	149-150	Low-cut frequency (Hz), if used.
57	151-152	High-cut frequency (Hz), if used.
58	153-154	Low-cut slope (dB/octave)
59	155-156	High-cut slope (dB/octave)
60	157-158	Year data recorded — The 1975 standard is unclear as to whether this should be recorded as a 2-digit or a 4-digit year and both have been used. For SEG Y revisions beyond rev 0, the year should be recorded as the complete 4-digit Gregorian calendar year (i.e. the year 2001 should be recorded as 2001_{10} ($7D1_{16}$)).
61	159-160	Day of year (Julian day for GMT and UTC time basis).
62	161-162	Hour of day (24 hour clock).
63	163-164	Minute of hour.
64	165-166	Second of minute.
65	167-168	Time basis code: 1 = Local 2 = GMT (Greenwich Mean Time) 3 = Other, should be explained in a user defined stanza in the Extended Textual File Header 4 = UTC (Coordinated Universal Time)
66	169-170	Trace weighting factor — Defined as 2N volts for the least significant bit. (N = 0, 1, …, 32767)
67	171-172	Geophone group number of roll switch position one.
68	173-174	Geophone group number of trace number one within original field record.
69	175-176	Geophone group number of last trace within original field record.

Trace Header Layout According to SEG-Y Standard Revision 1 (2002)
Byte numbering is 1-based.
n – information words interpreted at reading trace.
n – information words relating to positional data and shot time

Слово	Байты	Описание
70	177178	Gap size (total number of groups dropped).
71	179-180	Over travel associated with taper at beginning or end of line: 1 = down (or behind) 2 = up (or ahead)
72	181-184	X coordinate of ensemble (CDP) position of this trace (scalar in Trace Header bytes 71-72 applies). The coordinate reference system should be identified through an extended header Location Data stanza (see section D-1).
73	185-188	Y coordinate of ensemble (CDP) position of this trace (scalar in bytes Trace Header 71-72 applies). The coordinate reference system should be identified through an extended header Location Data stanza (see section D-1).
74	189-192	For 3-D poststack data, this field should be used for the in-line number. If one in-line per SEG Y file is being recorded, this value should be the same for all traces in the file and the same value will be recorded in bytes 3205-3208 of the Binary File Header.
75	193-196	For 3-D poststack data, this field should be used for the cross-line number. This will typically be the same value as the ensemble (CDP) number in Trace Header bytes 21-24, but this does not have to be the case.
76	197-200	Shotpoint number — This is probably only applicable to 2-D poststack data. Note that it is assumed that the shotpoint number refers to the source location nearest to the ensemble (CDP) location for a particular trace. If this is not the case, there should be a comment in the Textual File Header explaining what the shotpoint number actually refers to.
77	201-202	Scalar to be applied to the shotpoint number in Trace Header bytes 197-200 to give the real value. If positive, scalar is used as a multiplier; if negative as a divisor; if zero the shotpoint number is not scaled (i.e. it is an integer. A typical value will be -10, allowing shotpoint numbers with one decimal digit to the right of the decimal point).
78	203-204	Trace value measurement unit: -1 = Other (should be described in Data Sample Measurement Units Stanza) 0 = Unknown 1 = Pascal (Pa) 2 = Volts (v) 3 = Millivolts (mV) 4 = Amperes (A) 5 = Meters (m) 6 = Meters per second (m/s) 7 = Meters per second squared (m/s2) 8 = Newton (N) 9 = Watt (W)
79	205-210	Transduction Constant = The multiplicative constant used to convert the Data Trace samples to the Transduction Units (specified in Trace Header bytes 211-212). The constant is encoded as a four-byte, two's complement integer (bytes 205-208) which is the mantissa and a two-byte, two's complement integer (bytes 209-210) which is the power of ten exponent (i.e. Bytes 205-208 * 10**Bytes 209-210).
80	211-212	Transduction Units — The unit of measurement of the Data Trace samples after they

Trace Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based. n – information words interpreted at reading trace. n – information words relating to positional data and shot time		
Слово	**Байты**	**Описание**
		have been multiplied by the Transduction Constant specified in Trace Header bytes 205-210. -1 = Other (should be described in Data Sample Measurement Unit stanza) 0 = Unknown 1 = Pascal (Pa) 2 = Volts (v) 3 = Millivolts (mV) 4 = Amperes (A) 5 = Meters (m) 6 = Meters per second (m/s) 7 = Meters per second squared (m/s2) 8 = Newton (N) 9 = Watt (W)
81	213-214	Device/Trace Identifier — The unit number or id number of the device associated with the Data Trace (i.e. 4368 for vibrator serial number 4368 or 20316 for gun 16 on string 3 on vessel 2). This field allows traces to be associated across trace ensembles independently of the trace number (Trace Header bytes 25-28).
82	215-216	Scalar to be applied to times specified in Trace Header bytes 95-114 to give the true time value in milliseconds. Scalar = 1, +10, +100, +1000, or +10,000. If positive, scalar is used as a multiplier; if negative, scalar is used as divisor. A value of zero is assumed to be a scalar value of 1.
83	217-218	Source Type/Orientation — Defines the type and the orientation of the energy source. The terms vertical, cross-line and in-line refer to the three axes of an orthogonal coordinate system. The absolute azimuthal orientation of the coordinate system axes can be defined in the Bin Grid Definition Stanza. -1 to -n = Other (should be described in Source Type/Orientation stanza) 0 = Unknown 1 = Vibratory - Vertical orientation 2 = Vibratory - Cross-line orientation 3 = Vibratory - In-line orientation 4 = Impulsive - Vertical orientation 5 = Impulsive - Cross-line orientation 6 = Impulsive - In-line orientation 7 = Distributed Impulsive - Vertical orientation 8 = Distributed Impulsive - Cross-line orientation 9 = Distributed Impulsive - In-line orientation
84	219-224	Source Energy Direction with respect to the source orientation — The positive orientation direction is defined in Bytes 217-218 of the Trace Header. The energy direction is encoded in tenths of degrees (i.e. 347.8º is encoded as 3478).
85	225-230	Source Measurement — Describes the source effort used to generate the trace. The measurement can be simple, qualitative measurements such as the total weight of explosive used or the peak air gun pressure or the number of vibrators times the sweep duration. Although these simple measurements are acceptable, it is preferable to use

Trace Header Layout According to SEG-Y Standard Revision 1 (2002) Byte numbering is 1-based. n – information words interpreted at reading trace. n – information words relating to positional data and shot time		
Слово	**Байты**	**Описание**
		true measurement units of energy or work. The constant is encoded as a four-byte, two's complement integer (bytes 225-228) which is the mantissa and a two-byte, two's complement integer (bytes 209-230) which is the power of ten exponent (i.e. Bytes 225-228 * 10**Bytes 229-230).
86	231-232	Source Measurement Unit — The unit used for the Source Measurement, Trace header bytes 225-230. -1 = Other (should be described in Source Measurement Unit stanza) 0 = Unknown 1 = Joule (J) 2 = Kilowatt (kW) 3 = Pascal (Pa) 4 = Bar (Bar) 4 = Bar-meter (Bar-m) 5 = Newton (N) 6 = Kilograms (kg)
	233-240	Unassigned — For optional information.

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