Nankai 3D Seismic Processing Summary

By Zhiyong Zhao

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1. Field Data

We have total 122 field lines in segy format on 21 DLT tapes. After examining these data, we made a few corrections to our field record regarding these tapes. The revised information for these tapes is summarized in Table 1 below.

We actually used 111 field lines in our 3D seismic processing. The rest of the lines are either out of our 3D grid or duplicated. Table 2 lists all the lines we actually used in our 3D seismic processing.

Table 1. SEG-Y Tape Information from Nankai 3-D Survey

Tape#	File#	Line#	Start Day & Time		END Day & Time		# of Shots	File Size
1	1	nan-1	171	18:01:50	171	19:43:30	306	920059920
	2	40	171	19:47:30	171	23:12:42	588	1727876880
	3	141	171	23:15:45	172	09:07:21	1560	4581818596
	4	42	172	09:07:51	172	12:36:26	358	1052008080
	5	50	172	15:08:06	172	19:47:22	719	2112828240
2	1	104	176	18:22:54	177	03:46:23	1791	5262964560
	2	106	177	18:01:44	178	03:19:13	1791	5262964560
	3	136	176	06:32:06	176	16:55:06	1599	4698761040
	4	138	177	05:43:26	177	16:11:47	1552	4560648720
	5	140	178	05:38:43	178	16:47:00	1599	4698761040
3	1	100a	174	05:29:13	174	15:24:32	1763	5180684880
	2	102	175	19:03:33	176	04:37:22	1791	5262964560
	3	108	178	18:22:14	179	03:56:57	1713	5033756880
	4	132	173	18:25:32	174	04:01:54	1580	4642928400
	5	134	174	17:12:14	175	17:38:12	1539	4522447440
4	1	110	179	20:11:59	180	05:34:00	1799	5286473040
	2	112	181	21:29:07	182	06:11:46	1600	4701699600
	3	142	179	05:52:48	179	18:22:07	1553	4563587280
	4	144a	181	09:19:36	181	19:58:13	1601	4704638160
	5	144	180	12:01:32	180	16:36:13	453	1331171280
5	1	114	182	20:28:28	183	05:14:17	1601	4704638160
	2	116	183	20:25:52	184	04:43:10	1586	4660559760
	3	146	182	07:30:00	182	18:37:06	1600	4701699600
	4	148	183	06:58:16	183	18:41:20	1597	4692883920
	5	150	184	06:45:02	184	16:50:13	1601	4704638160
6	1	118	184	18:36:20	185	03:08:43	1601	4704638160
	2	120	185	15:27:56	186	00:23:39	1601	4704638160
	3	122	186	12:45:06	186	21:17:50	1601	4704638160
	4	152	185	05:12:04	185	13:46:23	1600	4701699600
	5	154	186	02:24:36	186	10:25:15	1470	4319686800
	6	154x	186	10:29:06	186	11:20:19	120	352630800
7	1	124	187	10:06:43	187	18:34:30	1601	4704638160

	2	126	188	07:45:14	188	14:48:16	1289	3787807440
	3	126a	189	06:05:46	189	08:29:20	300	881571600
	4	156	186	23:27:49	187	08:33:59	1601	4704638160
	5	158	187	20:29:50	188	05:53:59	1601	4704638160
	6	160	189	10:27:06	189	20:20:27	1601	4703854544
8	1	128	189	22:01:32	190	06:56:20	1601	4704638160
	2	130	190	20:08:37	191	04:28:49	1601	4704638160
	3	101	191	17:52:01	192	03:10:35	1791	5262964560
	4	162	190	08:51:46	190	18:31:22	1601	4704638160
	5	164	191	06:05:42	191	15:37:36	1601	4704589184
9	1	96	192	16:09:56	193	01:30:57	1801	5292350160
	2	98	193	14:16:17	193	23:58:48	1728	5077063908
	3	133	192	05:01:54	192	14:37:10	1600	4701699600
	4	137	193	03:15:09	193	12:32:57	1601	4704638160
	5	143	194	01:26:54	194	11:39:50	1601	4704638160
10	1	103	194	13:21:58	194	22:43:17	1801	5292350160
	2	107	195	12:00:12	195	21:23:34	1801	5292350160
	3	111	196	10:59:52	196	19:36:26	1601	4704638160
	4	151	195	23:02:25	196	09:11:35	1601	4704638160
	5	147	195	00:45:11	195	10:23:50	1601	4704638160
11	1	115	197	09:40:29	197	18:18:48	1601	4704638160
	2	119	198	07:03:06	198	16:13:23	1601	4704638160
	3	155	196	21:27:29	197	07:48:36	1601	4704638160
	4	159	197	20:09:36	198	05:25:13	1601	4703903520
	5	163	198	18:01:33	199	03:31:37	1588	4663620760
	6	101a	199	04:56:16	199	06:08:20	235	690565200
	7	114a	199	06:40:13	199	09:44:23	596	1751385360
12	1	169	203	01:11:13	203	10:48:25	1601	4704638160
	2	131	203	12:19:07	203	20:21:23	1601	4704638160
	3	168	203	22:21:01	204	08:23:43	1600	4701699600
	4	129	204	09:58:18	204	18:50:42	1601	4704638160
	5	167	204	20:11:27	205	05:58:26	1601	4704638160
13	1	127	205	07:16:15	205	15:23:27	1601	4704638160
	2	166	205	16:44:44	206	02:59:50	1601	4704638160
	3	125	206	05:20:26	206	14:03:32	1601	4704638160
	4	165	206	15:22:56	207	00:20:12	1412	4149250320
	5	135	208	18:18:20	209	04:56:46	1600	4701699600
14	1	97	209	06:55:39	209	16:22:26	1671	4910337360
	2	139	209	17:22:56	210	02:58:25	1600	4701699600
	3	99	210	04:43:07	210	13:32:20	1662	4883890320
	4	145	210	14:34:45	211	00:06:04	1601	4704638160
	5	105	211	01:40:27	211	11:13:01	1802	5295288720
15	1	149	211	12:57:28	211	22:29:21	1601	4704638160
	2	109	212	00:41:43	212	10:15:18	1767	5192439120
	3	153	212	11:54:30	212	21:08:41	1592	4678191120
	4	113	212	23:20:18	213	07:54:59	1600	4701699600
	5	135a	213	09:43:58	213	10:10:09	83	243904080

	6	108a	213	11:57:51	213	13:01:06	191	561268560
16	1	157	213	14:14:22	213	23:52:54	1587	4663498320
	2	117	214	01:28:51	214	10:23:21	1591	4675252560
	3	161	214	12:11:51	214	21:54:10	1601	4704638160
	4	121	214	23:37:35	215	08:43:28	1601	4704638160
	5	167a	215	10:05:17	215	11:00:45	172	505435920
	6	141c	215	12:07:41	215	16:12:51	751	2206862160
	7	165a	215	17:31:51	215	18:57:17	235	690565200
17	1	123	215	20:56:26	216	05:50:38	1509	4433237656
	2	138a	216	07:50:17	216	09:15:42	255	749336400
	3	134b	216	09:43:46	216	16:08:03	1082	3179525520
	4	34	219	09:32:20	219	12:49:21	593	1742569680
	5	135b	219	12:54:47	219	17:43:08	810	2380237200
	6	156a	219	18:48:39	219	20:06:46	213	625916880
	7	154a	219	20:35:32	219	22:44:45	328	963851280
18	1	113b	220	00:31:33	220	03:20:07	508	1492792080
	2	126b	220	06:01:56	220	08:11:55	400	1175427600
	3	160a	220	09:35:39	220	18:31:34	1452	4266792720
	4	117a	220	20:15:39	221	04:51:33	1601	4704638160
	5	161a	221	06:31:11	221	15:25:50	1592	4678191120
	6	111a	221	18:40:05	221	19:55:51	238	699380880
	7	122a	221	21:27:44	221	23:43:18	442	1298847120
	8	143a	222	02:13:13	222	08:42:22	1152	3385224720
19	1	151a	222	17:25:54	222	17:49:58	61	179255760
	2	119a	222	21:23:10	222	22:05:13	133	390832080
	3	97a	222	10:26:46	222	14:29:47	808	2374360080
	4	117b	222	23:33:31	223	00:31:55	182	534821520
	5	123a	223	01:27:36	223	01:58:38	98	287982480
	6	142a	223	05:33:46	223	06:19:37	130	382016400
	7	151b	223	09:04:40	223	10:06:16	171	502497360
	8	169a	223	11:01:37	223	13:36:29	401	1178366160
20	1	95	223	15:39:28	224	00:07:17	1655	4863320400
	2	170	224	01:41:16	224	07:16:29	967	2841591120
	3	170a	224	17:35:48	225	02:46:50	1394	4096356240
	4	94	225	04:43:35	225	14:04:46	1665	4892706000
	5	171	225	15:33:24	226	00:53:53	1594	4684068240
	6	93	226	02:33:06	226	11:24:20	1664	4889767440
21	1	172	226	13:06:25	227	00:01:28	1601	4704638160
	2	92	227	01:54:47	227	10:28:35	1665	4892706000
	3	157a	227	11:58:39	227	21:20:55	1601	4703866788
	4	121a	227	22:42:37	228	07:06:52	1599	4698761040
	5	20	228	07:07:10	228	08:26:00	248	728766480
	6	19	228	08:26:00	228	10:00:08	293	861001680
Total	**122**						**153612**	**451.41 gbyte**

Table 2. Field Seismic Lines Included in the 3D Seismic Processing

92	109	122	136	151b	165a
93	110	122a	137	152	166
94	111	123	138	153	167
95	111a	123a	138a	154	167a
96	112	124	139	154a	168
97	113	125	140	155	169
97a	113b	126	141	156	169a
98	114	126b	141c	156a	170
99	114a	127	142	157	170a
100a	115	128	142a	157a	171
101	116	129	143	158	172
101a	117	130	143a	159	
102	117a	131	144a	160	
103	117b	132	145	160a	
104	118	133	146	161	
105	119	134	147	161a	
106	119a	134b	148	162	
107	120	135	149	163	
108	121	135a	150	164	
108a	121a	135b	151	165	

2. 3D Binning

Base on the field tests done by Sean, we set our 3D grid origin in UTM coordinates at x = 505537.5 and y = 3562005. Inline orientation is -45.85° N and xline 44.15° N.

In order to improve seismic images and reduce smearing, we tried two different bin sizes. The first bin size was 25 m in the inline direction and 50 m in the xline direction. For this bin size, the inline number ranges from 180 to 360 and the xline number from 1 to 3710. Base on test results, we chose a bin extension of 70% in both the inline and the xline directions, an ellipse shape for the extended bins, a maximum fold of 60 and a 100-m offset interval with a maximum of 4 traces in each interval. The extended bin size was 60 m by 120 m. For this binning, the distribution of trace distances from mid-points to bin centers peaks at 15-16 m and there is only an insignificant number of traces with a distance larger than 25 m. Table 3 lists the trace utilization in this binning:

Table 3. Trace Utilization (First binning)

# of Times Used	0	1	2	> 2
% of Total	28.7	45.5	23.4	2.4

See Figures 1-10 in the Figure section for more details about the coverage of this binning. We abbreviate the binning parameters as 0.7-4-100 in these figures.

We did a second binning with bin size of 12.5 m in inline direction and 25 m in xline direction. The inline number ranges from 360 to 720 and xline number from 1 to 7420 in this binning. We also revised the maximum fold to 20, the bin extension to 200%, the offset interval to 400 m with a maximum 4 traces per offset interval. The extended bin size was 62.5 m by 125 m. The distribution of trace distances from mid-points to bin centers peaks at 8-9 m for the second binning and there is only an insignificant number of traces with a distance larger than 15 m. Table 4 lists the trace utilization in the second binning:

Table 4. Trace Utilization (Second Binning)

# of Times Used	0	1	2	3	>3
% of Total	19.0	40.8	33.5	3.3	3.4

See Figures 11-20 for more details about the coverage of the second binning. We abbreviate the binning parameters as 2-4-400 in those figures.

3. Processing Flow

We followed a standard 3D seismic processing flow as shown in the processing flow chart below. One of the outstanding problems in this 3D processing was insufficient disk space to hold two copies of our prestack data (one for the input and one for the output). Though it was possible to use a tape drive to hold a copy of input or output data, it would significantly reduce processing speed. In this processing, we adopted a dynamic approach, that is, we constantly check available disk space during the processing and delete the input lines that have been processed when available disk space is below a certain level.

Our Focus projects and lines for the processing are NK3D and 3D for the first binning and NANKAI3D and 3D for the second binning. The following is a detailed description of the processing flow chart.

Field Seismic Data

See section 1 Field Data for details.

Trace Edit & Band-pass Filter

We omitted those traces/shots specified in /d5/nk21/headblock/line#/line#.kill prepared by Jim. We also omitted traces that were rejected in Ucooa generation as recorded in the log file (/d5/nk21/ukooa/edit.17/log). In addtion, Line 103 was upward shifted 12 ms.

Base on the test done by Sean, we applied a band-pass file on the field data. The bandpass frequency is 5-8-65-80.

Focus job files associated with this processing are:
/d5/protape/line#.protape.dat (First Binning)
/d5/protape2/line#.protape.dat (Second Binning)
/d5/ebapply2/line#.ebapply.dat (First Binning)
/d5/ebapply3/line#.ebapply.dat (Second Binning)

Ukooa Files:

We used ukooa version 17 prepared by Mark as navigation input to define receiver and shot location. The ukooa files are in the directory:

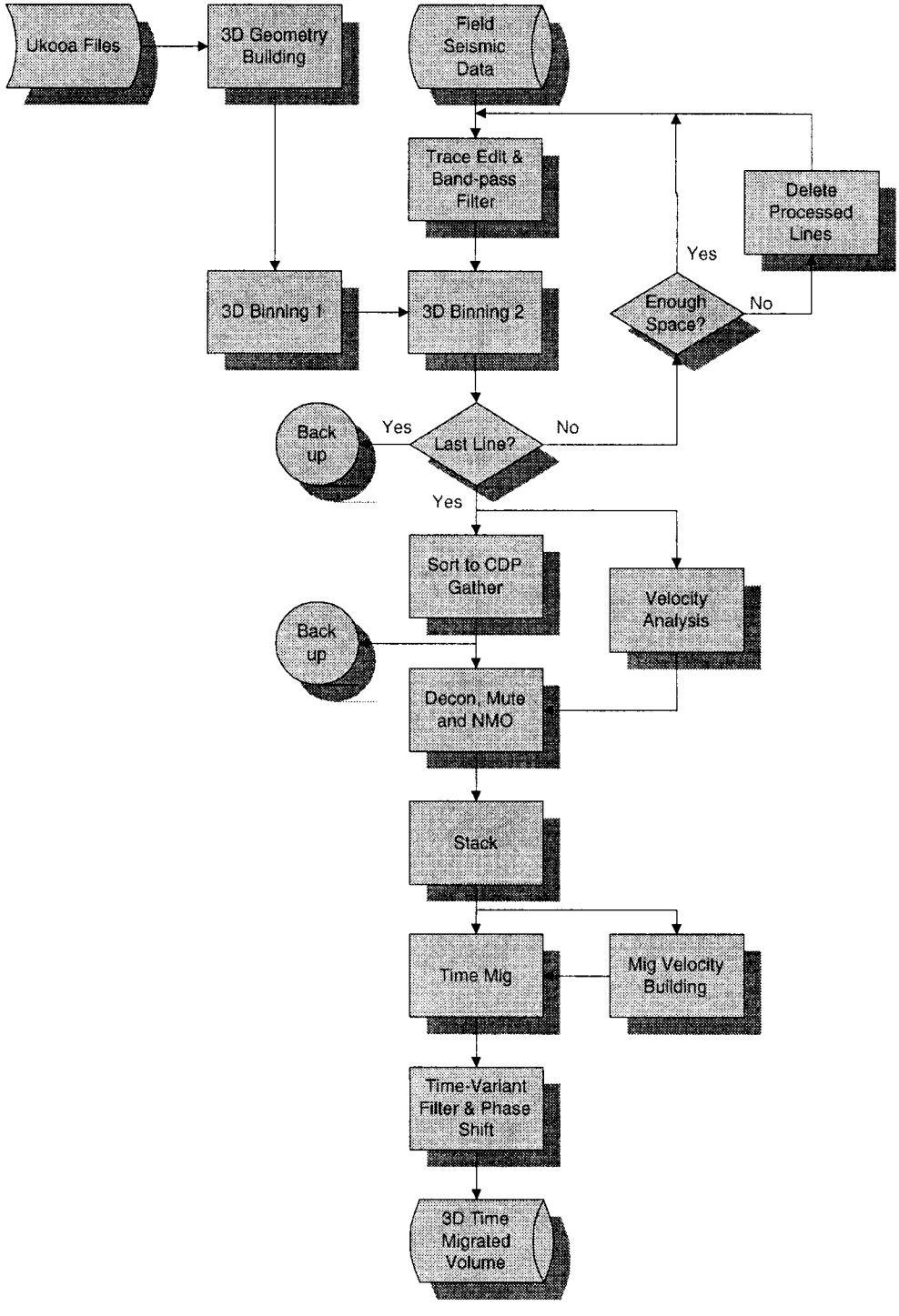
/d5/nk21/ukooa/edit.17.

3D Geometry Building

See the binning section above. Focus job files involved in this process are:

/d5/navdata/line3d_stn.dat (First binning)

3D Seismic Processing Flow Chart



/d5/navdata/line3d_cdp.dat (First binning)
For the second binning, those job files were created by Sean

3D Binning 1.

This processing is basically to generate several database files from navigation data and these files will be used in 3D binning 2. Focus job files associated with this processing are:

/d5/navdata/navrd.dat
/d5/navdata/pltcdp.dat (First binning)
/d5/navdata/ebload.dat (First binning)
For the second binning, the above two job files were created by Sean
/d5/ebapply2/extbin.dat (First Binning)
/d5/ebapply3/extbin.dat (Second Binning)

3D Binning 2.

This part of binning includes writing geometry information into trace headers, duplicating certain traces and assigning them to neighbor bins. Focus job files associated with this processing are:

/d5/protape/line#.protape.dat (First binning)
/d5/protape2/line#.protape.dat (Second binning)
/d5/ebapply2/line#.ebapply.dat (First binning)
/d5/ebapply3/line#.ebapply.dat (Second binning)

Backup

We have two versions of the 3D data backed up on tapes for the first binning (25X50). Both sets of tapes were written by "dd" command. The first version backed up on tapes (labeled as Protape) is the data output from PROTAPE (before bin extension) with editing and filtering applied. The following is the tape information for this backup. Note that there is only one file on each tape.

```
Protape 1: 92 93 94 95 96 97 97a
Protape 2: 98 99 100a 101 101a 102 103
Protape 3: 104 105 106 107 108 108a 109
Protape 4: 110 111 111a 112 113 113b 114 114a 115
Protape 5: 116 117 117a 117b 118 119 119a 120 121 121a
Protape 6: 122 122a 123 123a 124 125 126 126b 127
Protape 7: 128 129 130 131 132 133 134
Protape 8: 134b 135 135a 135b 136 137 138 138a 139 140
Protape 9: 141 141c 142 142a 143 143a 144a 145 146
Protape 10: 147 148 149 150 151 151b 152
Protape 11: 153 154 154a 155 156 156a 157 157a
Protape 12: 158 159 160 160a 161 161a 162
Protape 13: 163 164 165 165a 166 167 167a 168 169
Protape 14: 169a 170 170a 171 172
```

The second backup version is sorted CDP gathers (labeled as Bin). The following is a list of files on tapes:

```
Bin1: CDPLBLX1-400.ebapply.focus
Bin2: CDPLBLX401-650.ebapply.focus
Bin3: CDPLBLX651-900.ebapply.focus
Bin4: CDPLBLX901-1150.ebapply.focus
Bin5: CDPLBLX1151-1400.ebapply.focus
Bin6: CDPLBLX1401-1650.ebapply.focus
Bin7: CDPLBLX1651-1900.ebapply.focus
Bin8: CDPLBLX1901-2150.ebapply.focus
Bin9: CDPLBLX2151-2400.ebapply.focus
Bin10: CDPLBLX2401-2650.ebapply.focus
Bin11: CDPLBLX2651-2900.ebapply.focus
Bin12: CDPLBLX2901-3150.ebapply.focus
Bin13: CDPLBLX3151-3400.ebapply.focus
Bin14: CDPLBLX3401-3710.ebapply.focus
```

Velocity Analysis

We extracted a grid of super bins for velocity analysis after binning. The super bin grid spacing is 10 inlines and 40 xlines. Super bin pattern is a cross with 5 bins in each super bin. Most velocity analysis was done by Sean et al. The Focus job used to extract super bins is:

/d5/velocity/vel3d.dat

Sort to CDP Gathers

The sorted CDP gathers for the first binning have been backed up on tapes (see backup subsection).

The sorted CDP gathers for the second binning are currently on disk. These files are:

/d5/sort/ CDPLBLX1-800.ebapply.focus
/d5/sort/ CDPLBLX801-1150.ebapply.focus
/d5/sort/ CDPLBLX1151-1500.ebapply.focus
/d5/sort/ CDPLBLX1501-1850.ebapply.focus
/d5/sort/ CDPLBLX1851-2200.ebapply.focus
/d5/sort/ CDPLBLX2201-2550.ebapply.focus
/d5/sort/ CDPLBLX2551-2900.ebapply.focus
/d5/sort/ CDPLBLX2901-3250.ebapply.focus
/d5/sort/ CDPLBLX3251-3600.ebapply.focus
/d5/sort/ CDPLBLX3601-3950.ebapply.focus
/d5/sort/ CDPLBLX3951-4300.ebapply.focus
/d5/sort/ CDPLBLX4301-4650.ebapply.focus
/d5/sort/ CDPLBLX4651-5000.ebapply.focus

/d5/sort/ CDPLBLX5001-5350.ebapply.focus
/d5/sort/ CDPLBLX5351-5700.ebapply.focus
/d5/sort/ CDPLBLX5701-6050.ebapply.focus
/d5/sort/ CDPLBLX6051-6400.ebapply.focus
/d5/sort/ CDPLBLX6401-6750.ebapply.focus
/d5/sort/ CDPLBLX6751-7100.ebapply.focus
/d5/sort/ CDPLBLX7101-7420.ebapply.focus

Decon, Mute and NMO

We applied a prestack decon with Focus module MCDECON. Earlier tests of the decon were done by Steffen and Sean.

Three types of mutes were applied on the prestack 3D data. First, we applied a 10-percent stretch mute on the version with bin size of 25 X 50 and 15-percent of stretch mute on the version with bin size of 12.5 X 25. We also applied a bottom mute to far-offset traces (half of a gather) to attenuate multiples. The bottom mute time was defined as double seafloor reflection time minus 300 ms. Finally, we applied a surgical mute 100 ms above and 500 ms below the oceanic crust on far-offset traces (half of a gather) to reduce dispersion noise. The surgical mute was applied only to xline under 2100 for the first binning and 4200 for the second binning.

NMO is a standard normal moveout correction with stacking velocity NKVLALL8 for the first binning and VEL10 for the second binning.

Focus job files for the above processing are:

/disk/nk2/stack2/stack.dat (First binning)
/d5/stack3/stack.dat (Second binning)

Stack

We applied a standard stack with stack normalization by number of live samples. Two versions of stacked volumes are currently stored in the following files:

/disk/nk2/stack2/stack.lod (First binning)
/d5/stack3/stack.lod (Second binning)

Focus job files for the stack are the same as the job files for decon, mute and NMO.

Mig Velocity Building

We are still trying to build a better velocity model. Currently, we have two migration velocity models, that is, VELINT2 and Tom's velocity model. The VELINT2 was generated on the structural frame defined by the seafloor and the basement horizons

(see Figure 21). We divided our 3D volume into five units: above the seafloor, below the basement and additional 3 units between the seafloor and the basement. The velocity between the seafloor and the basement has two components: base velocity and a gradient velocity from the seafloor. The velocity model was determined by try and error. Table 5 lists the parameters used to build velocity model VELINT2.

Table 5. Parameters for Velocity Model VELINT2.

Units	Thickness in % of the thickness between the sf and the bmt	Velocity (m/s)	Base-velocity (m/s)	Gradient (m/s^2) from the seafloor
Above the seafloor		1500		
1	60		1530	2000
2	20		1570	2000
3	20		1600	2000
Below the basement		500 m transition then 2500		

Time Mig

We are still trying different migration algorithms to improve our 3D seismic images. So far, we tested all 3 poststack time migration algorithms included in Focus. These algorithms were MIGFK3D (two-pass F-K), MIGFX3D (one-pass omega-x) and MIGX3D (two-pass finite difference). We also tried post-stack Kirchhoff time migration with Geodepth. Relatively, the migration with Geodepth produced a better image than the migration with Focus. For the Kirchhoff time migration, we used an aperture of 200 traces in inline direction and 20 traces in xline direction with the migration velocity of VELINT2 for the first binning and 400 traces in inline direction and 50 traces in xline direction with Tom's velocity for the second binning. We realized that the aperture along the xline direction seemed too small, however, it did produce a better image. The migration on the data with the second binning is still running under the Geodepth project Nankai12x25.

Time-Variant Filter & Phase Shift

A spatial variant band-pass filter was applied to the post-stack migrated data with the first binning to suppress multiples. We applied a band-pass filter of 5-8-60-70 Hz to the data 500 ms above the first seafloor multiple and a filter of 5-8-25-35 Hz to the data below. We also applied a 90° phase shift to convert a reflection waveform to nearly zero-phase.

The Focus job file for the above processing is
/disk/nk2/stack2/filt.dat

3D Time Migrated Volume

The final migrated 3D volume from the first binning is currently in the file:
/disk/nk2/stack2/3dmig.segy

Figures

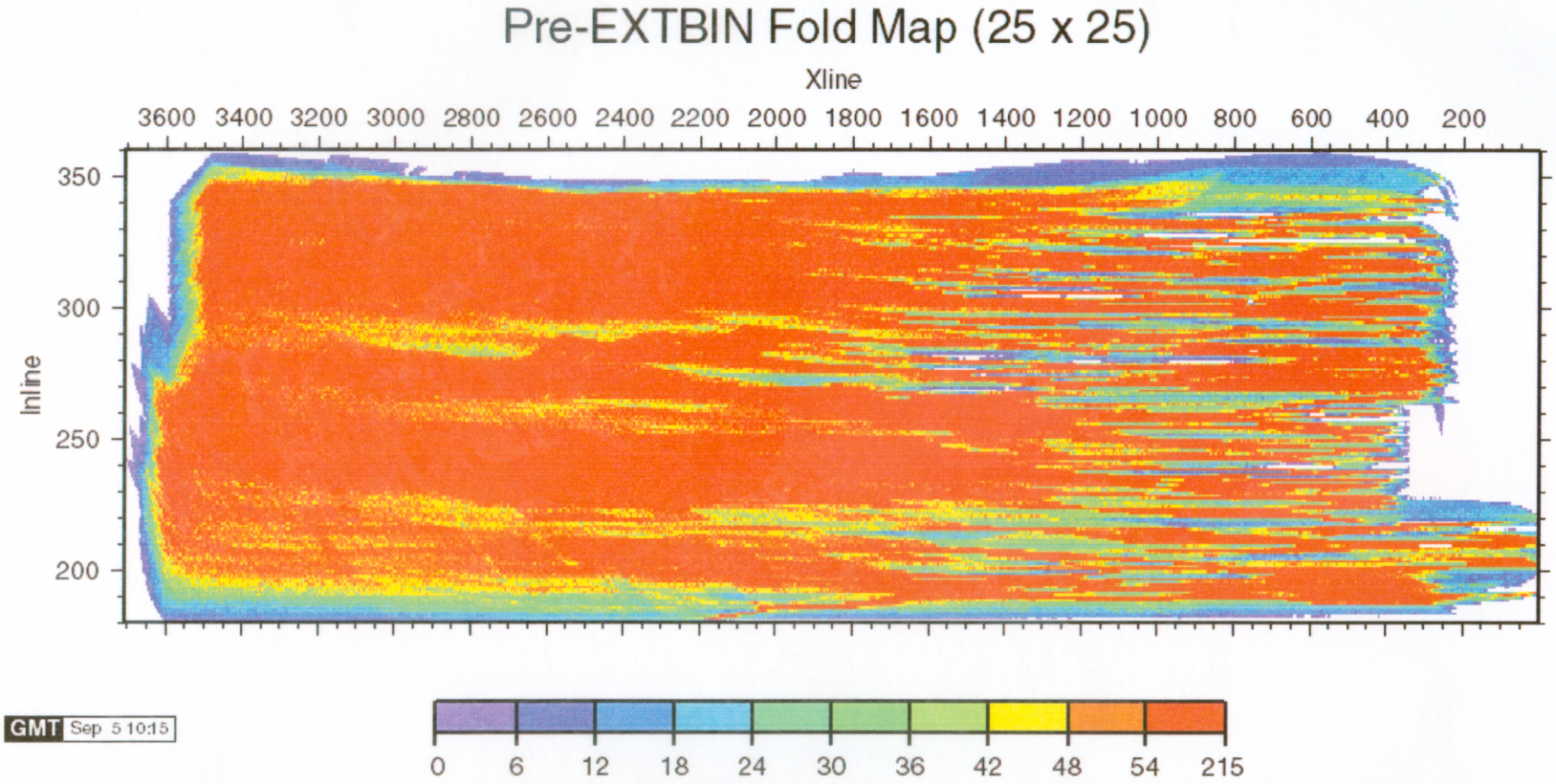


Figure 1. Fold map without bin extension. Bin size is 25 m by 50 m

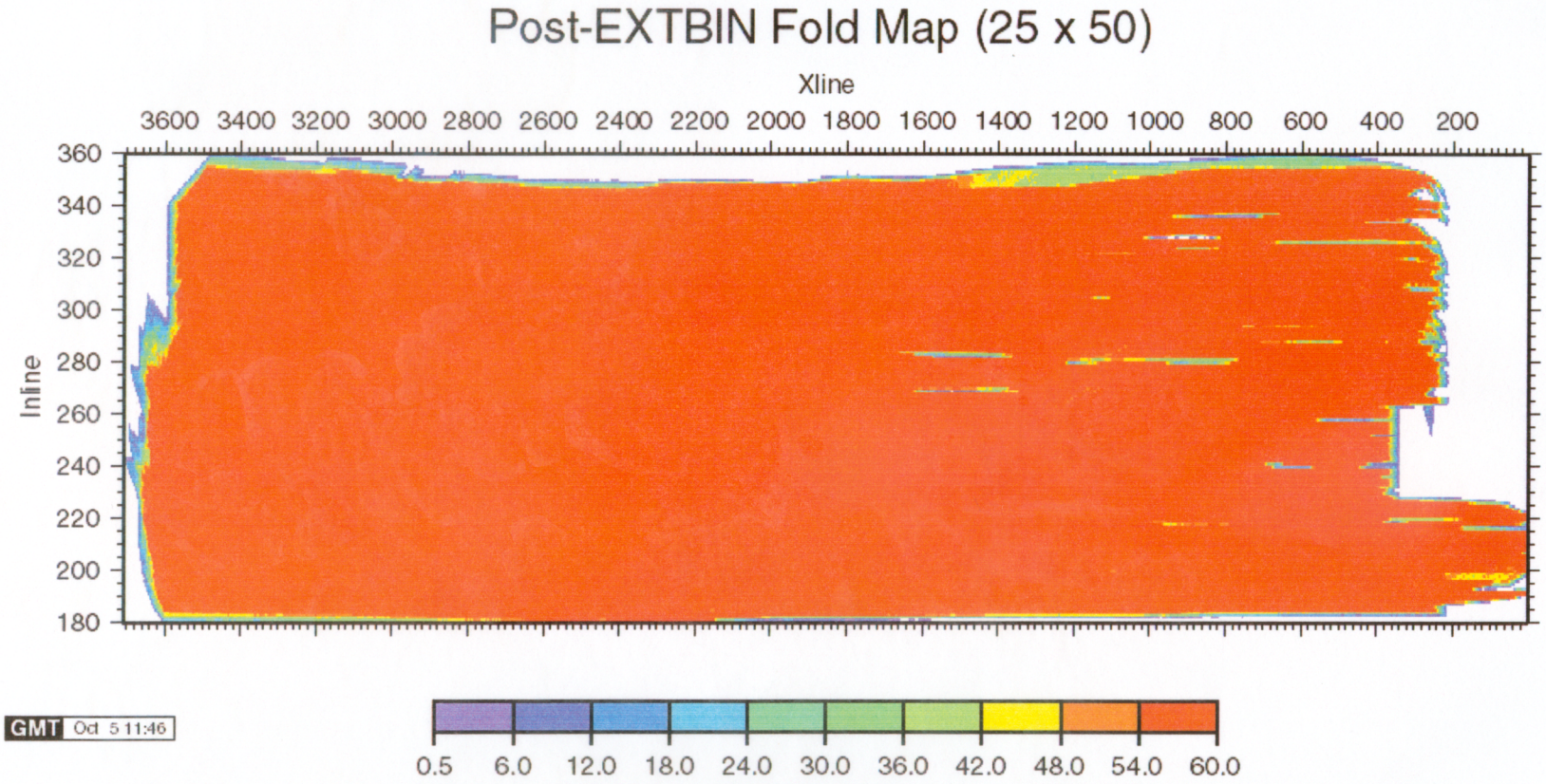


Figure 2. Fold map with binning parameters 0.7-4-100. The bin size is 25 m by 50 m

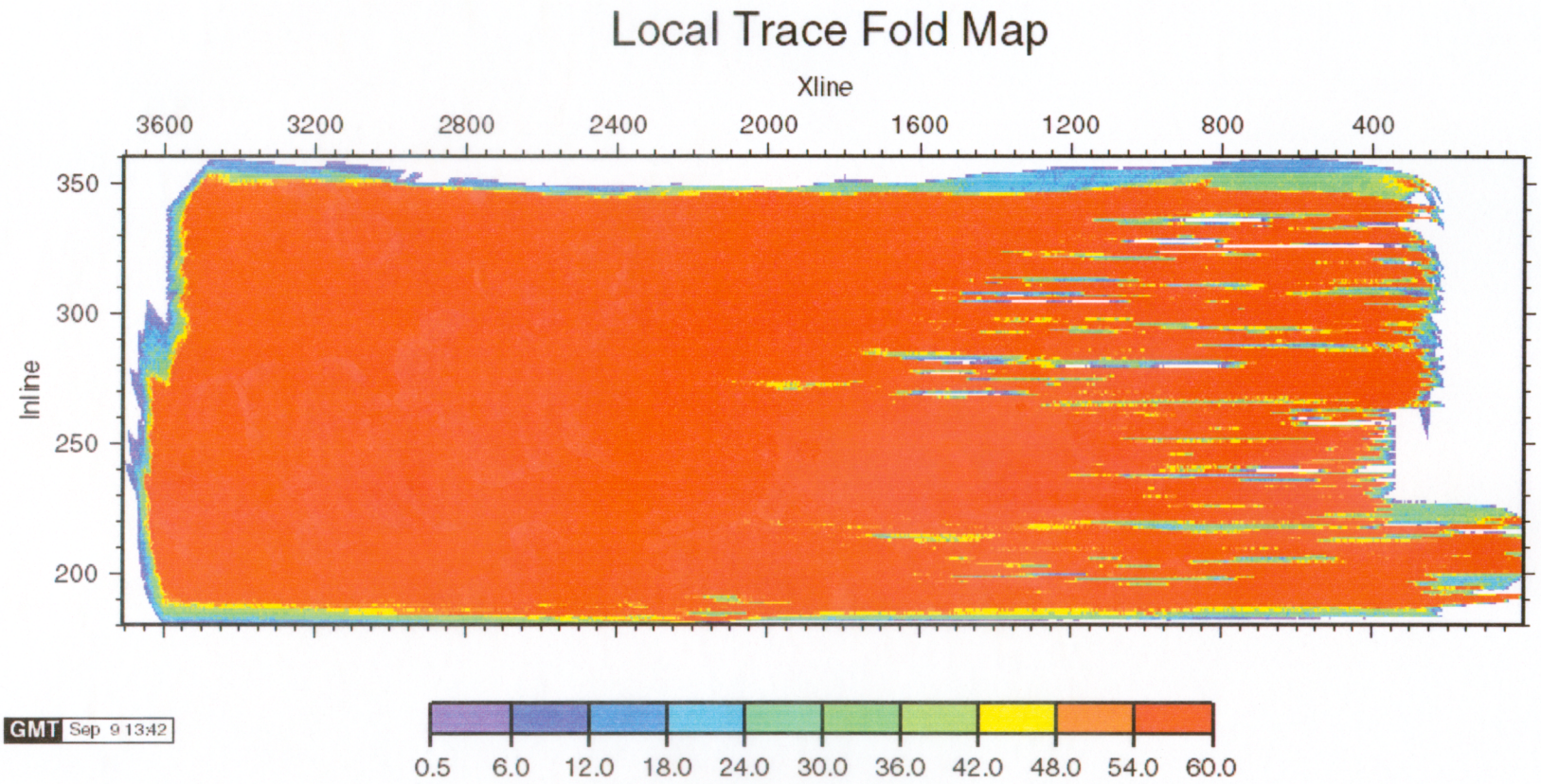


Figure 3. Fold map of traces within 28 m to bin centers. Binning parameters are 0.7-4-100. The bin size is 25 m by 50 m

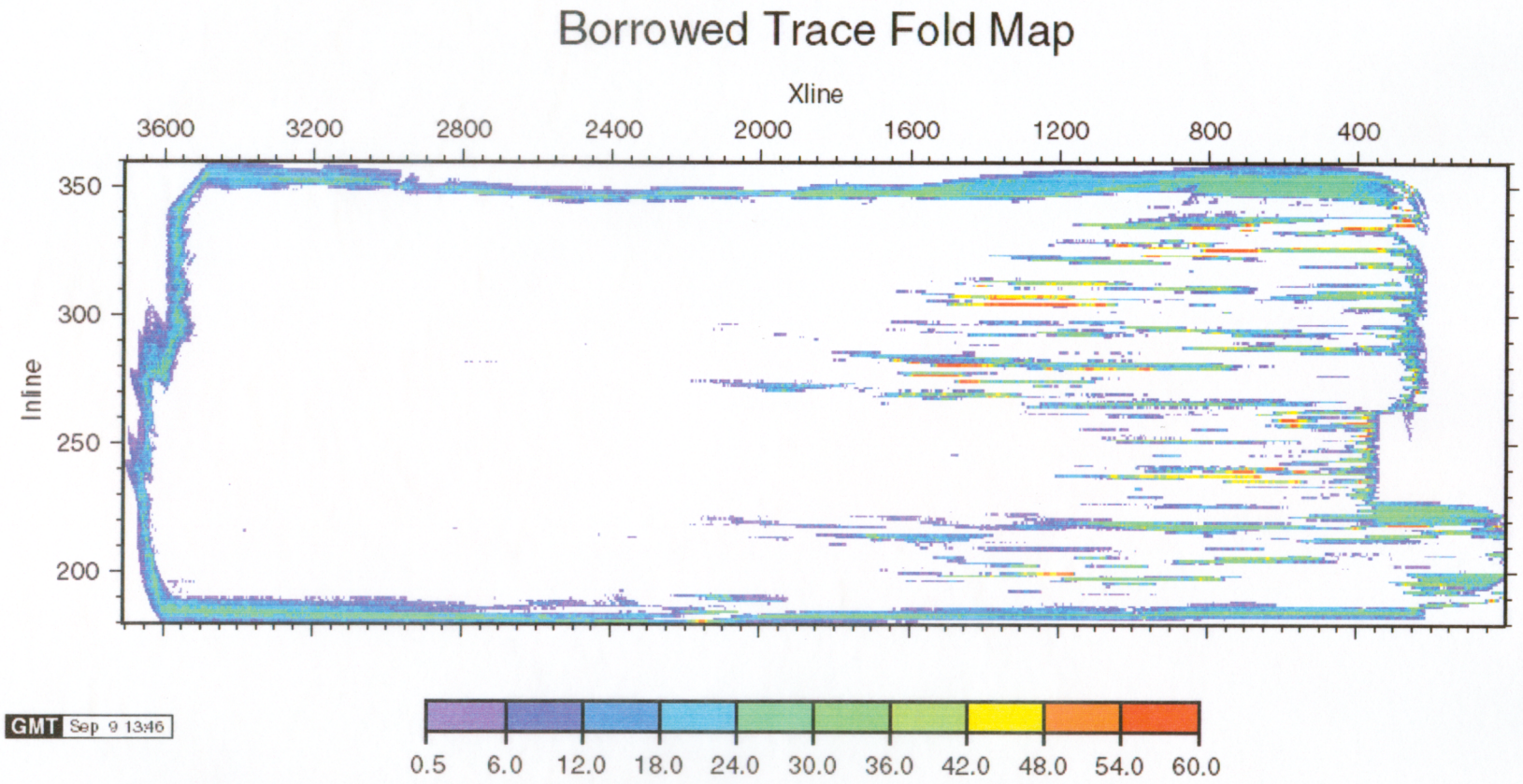


Figure 4. Fold map for traces within a distance of 28 - 60 m to bin centers. Binning parameters are 0.7-4-100 and the bin size is 25 m by 50 m.

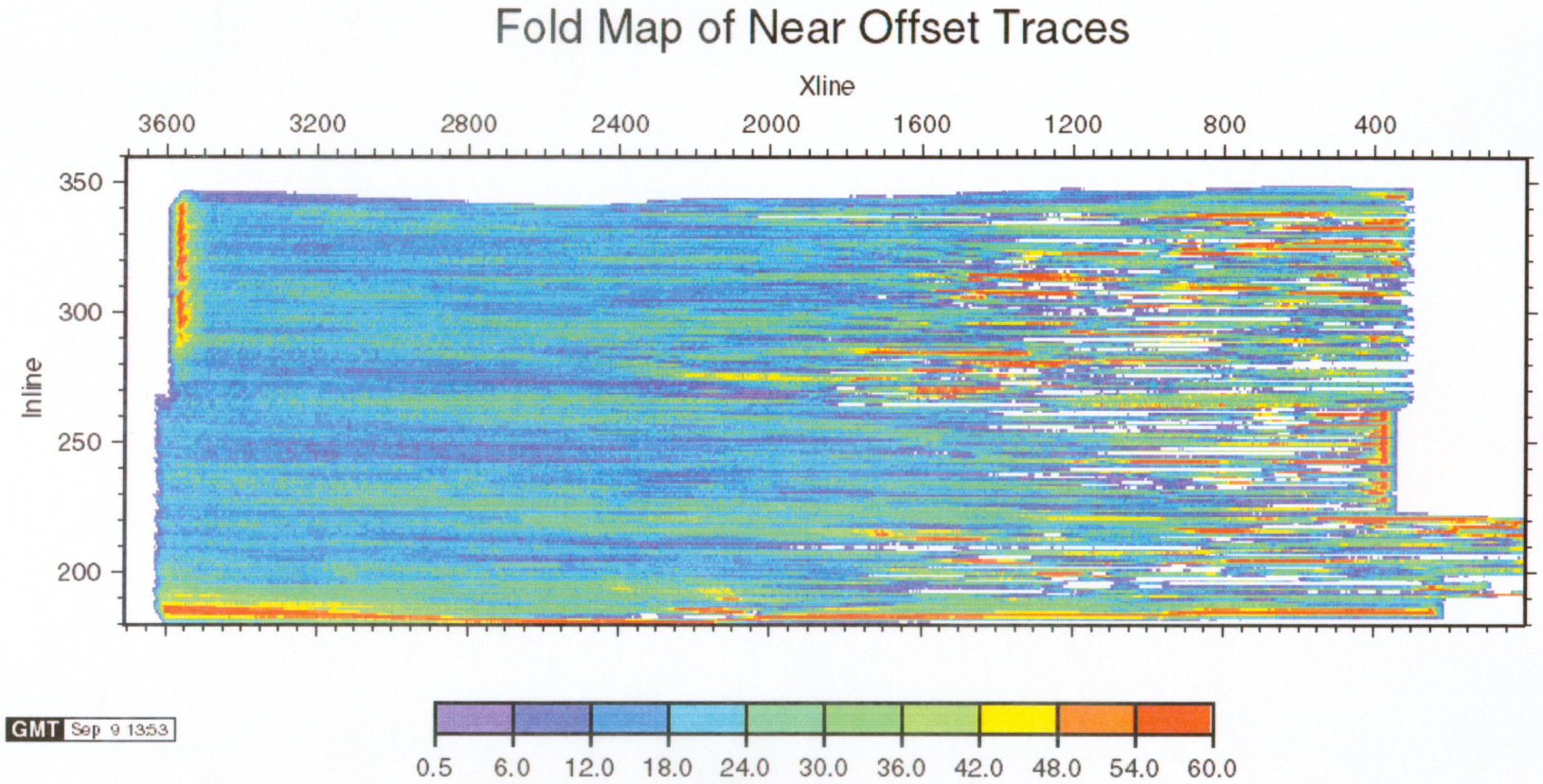


Figure 5. Fold map of traces with offsets 0 - 2000 m. Binning parameters are 0.7-4-100. The bin size is 25 m by 50 m.

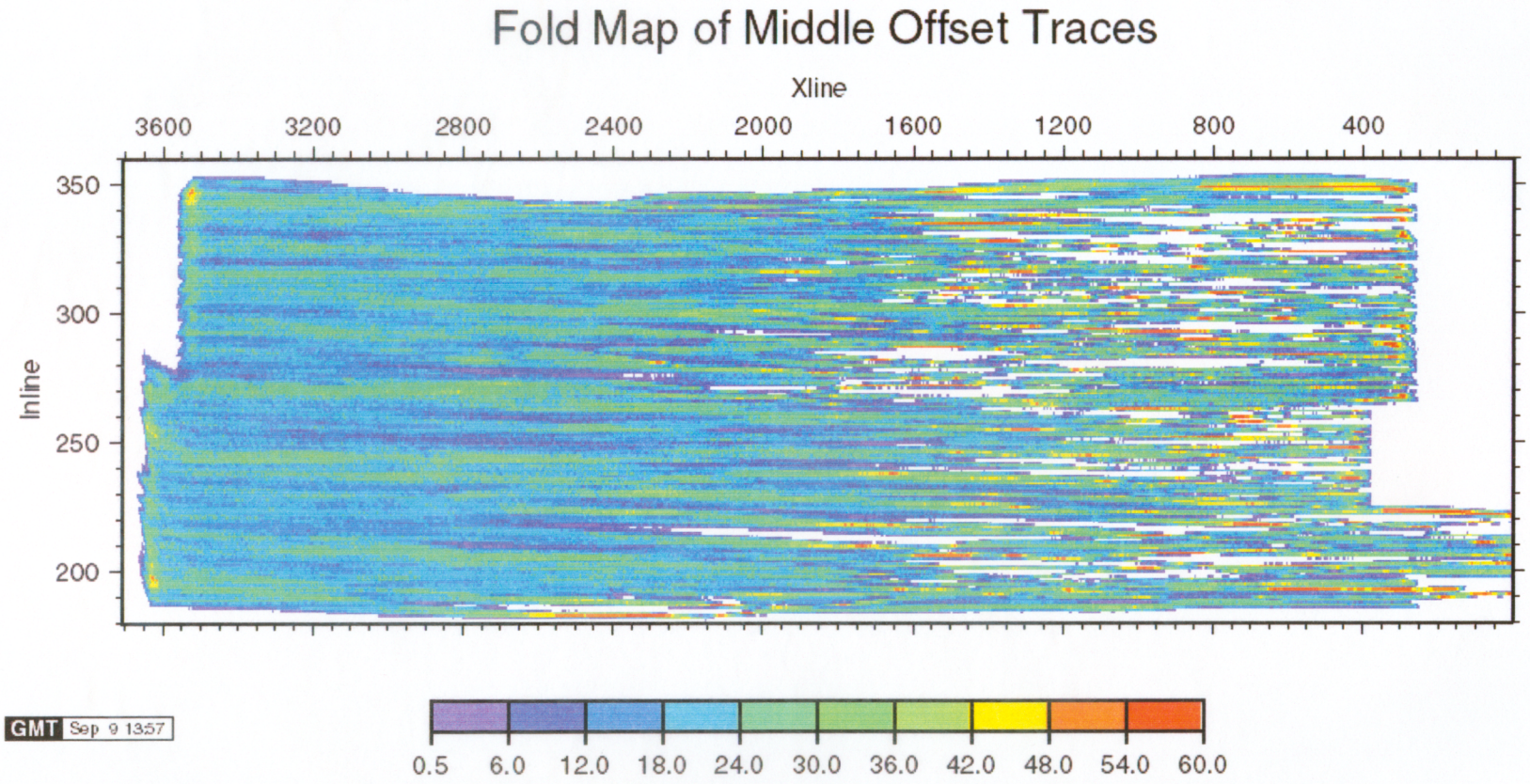


Figure 6. Fold map of traces with offsets 2000 - 4000 m. Binning parameters are 0.7-4-100. The bin size is 25 m by 50 m.

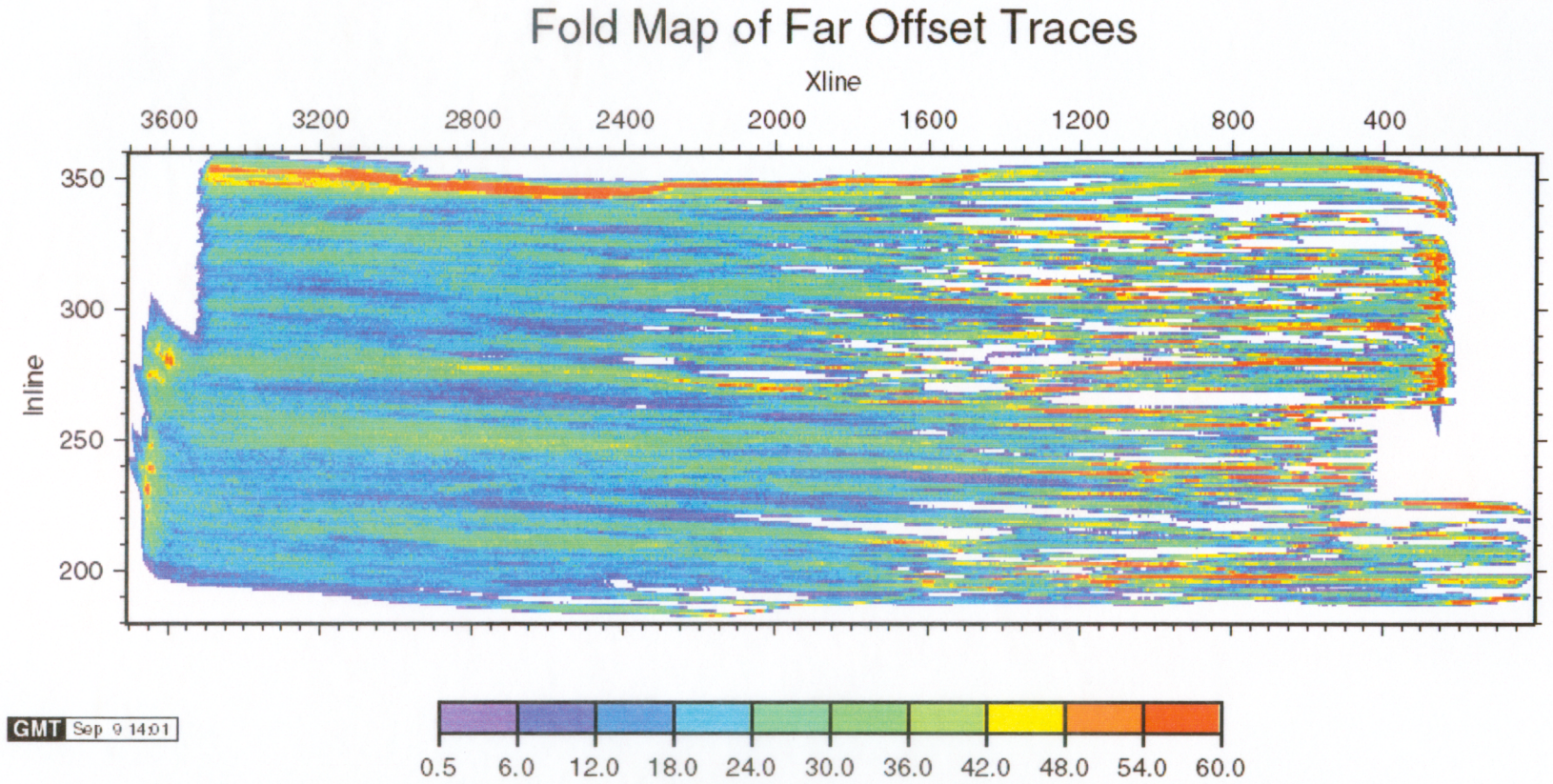


Figure 7. Fold map of traces with offsets 4000 - 6200 m. Binning parameters are 0.7-4-100. The bin size is 25 m by 50 m.

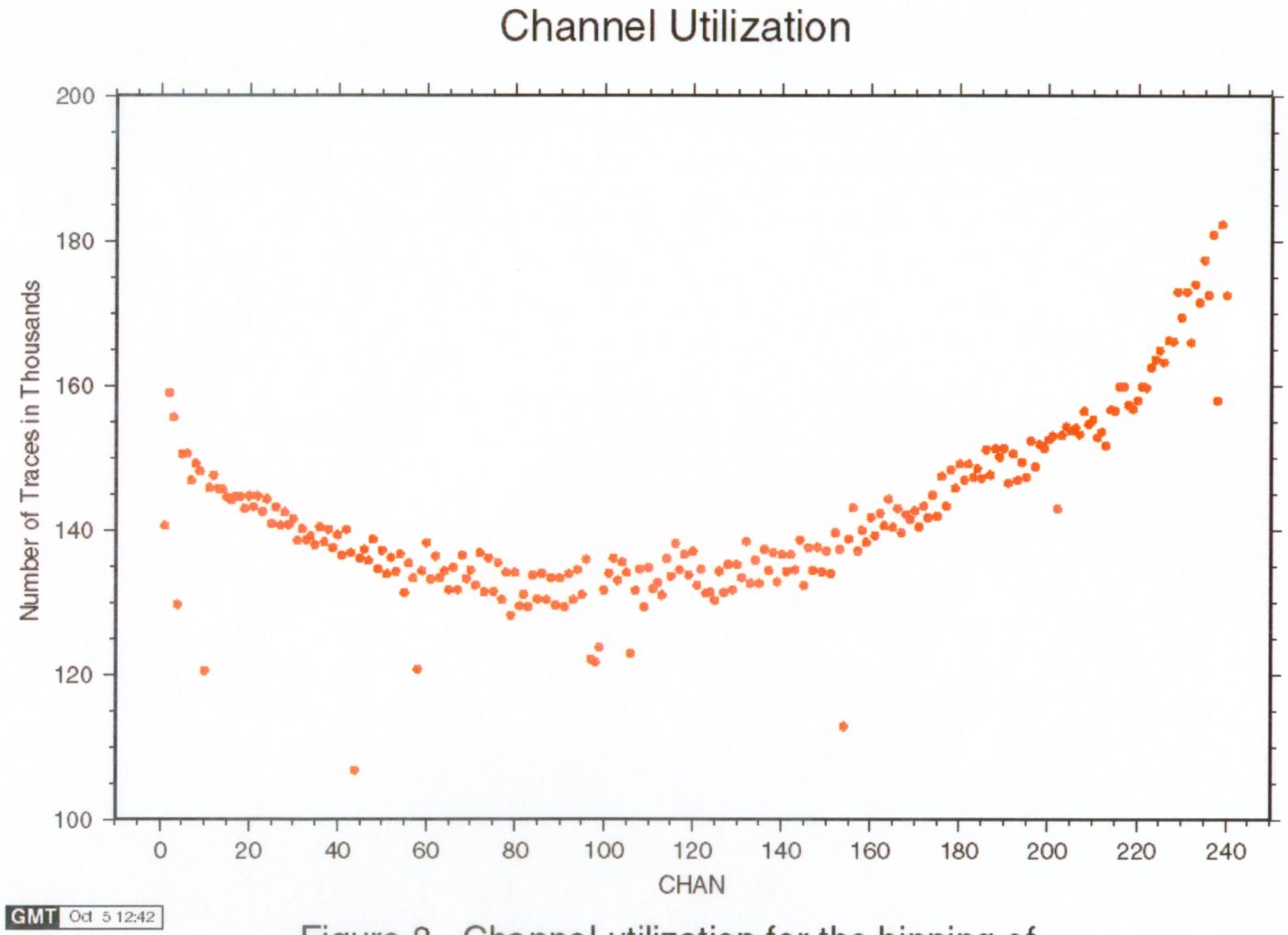


Figure 8. Channel utilization for the binning of 0.7-4-100. The bin size is 25 m by 50 m.

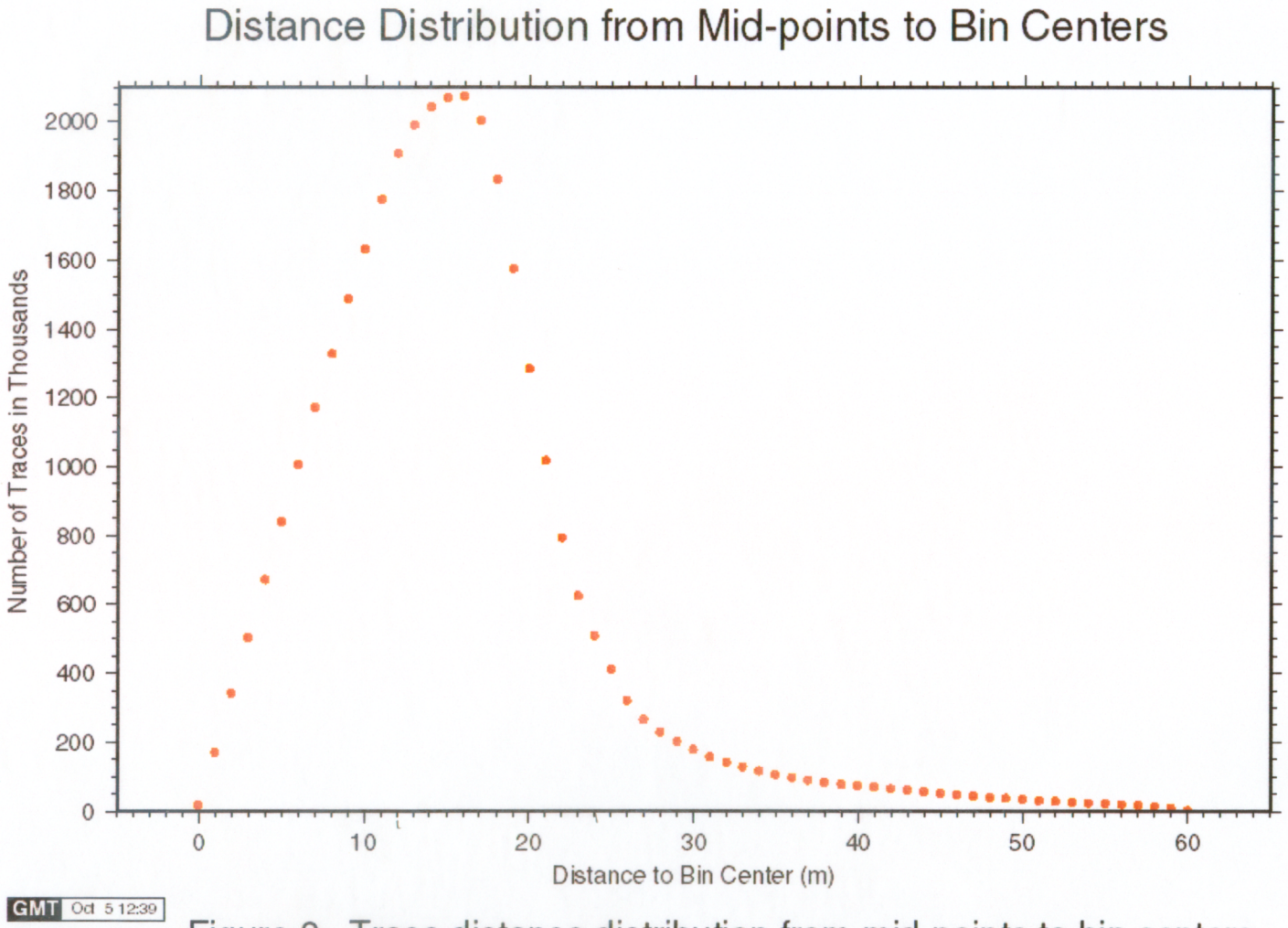


Figure 9. Trace distance distribution from mid-points to bin centers. Binning parameters are 0.7-4-100. The bin size is 25 m by 50 m.

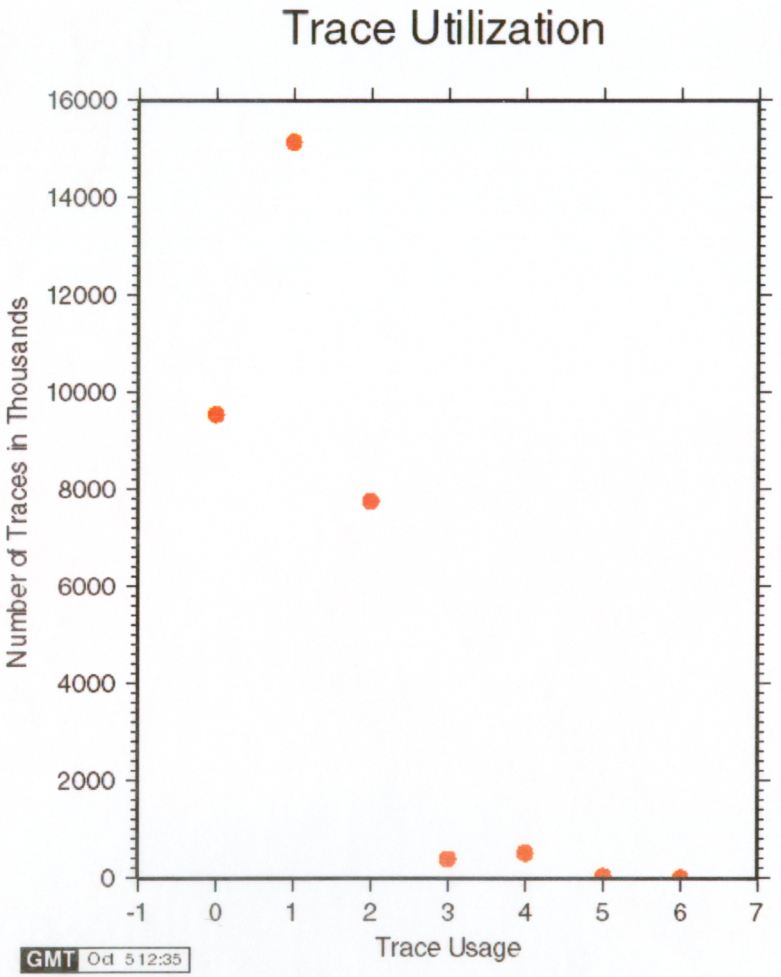


Figure 10. Trace utilization for the binning of 0.7-4-100. The bin size is 25 m by 50 m.

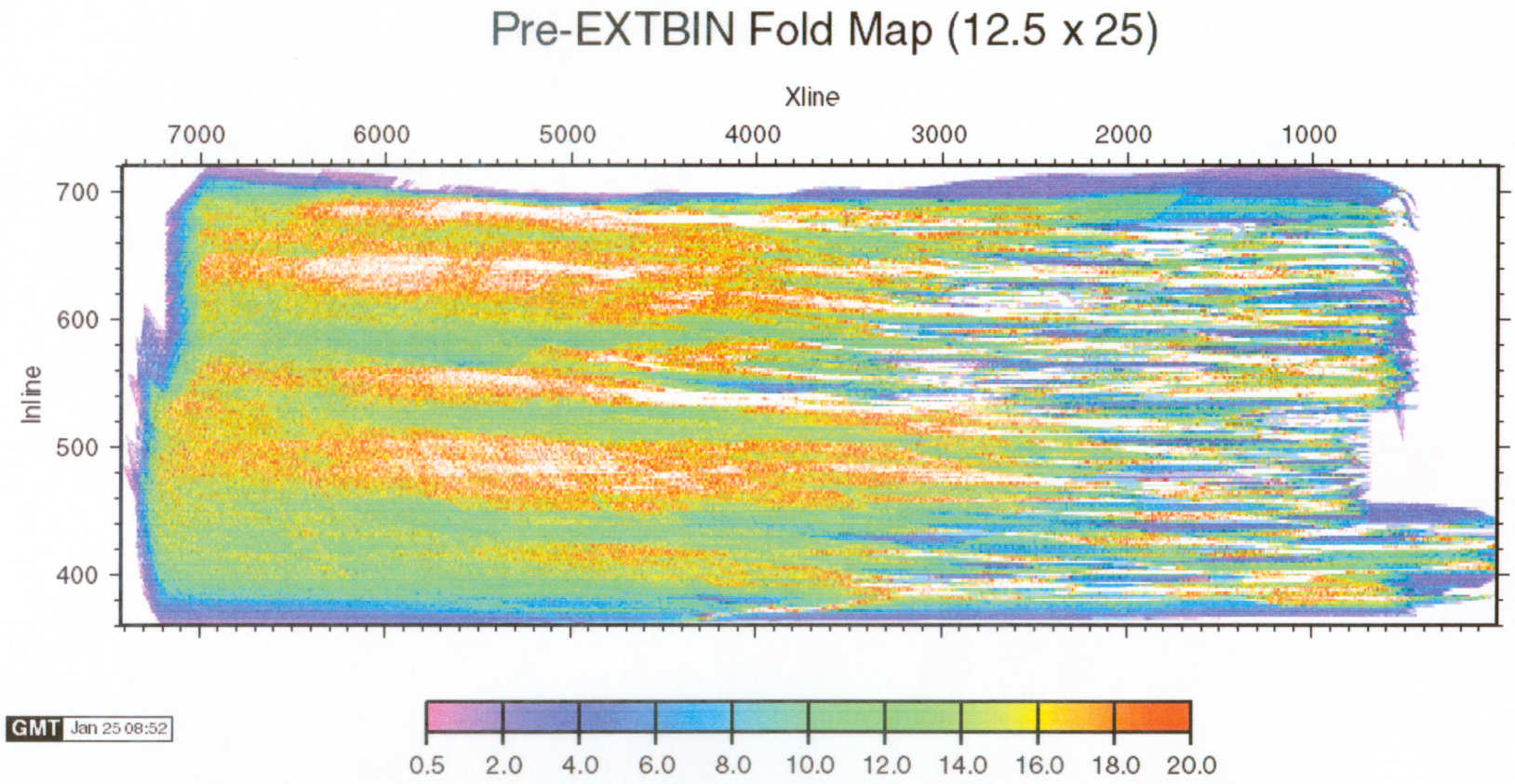


Figure 11. Fold map without bin extension. Bin size is 12.5 m by 25 m

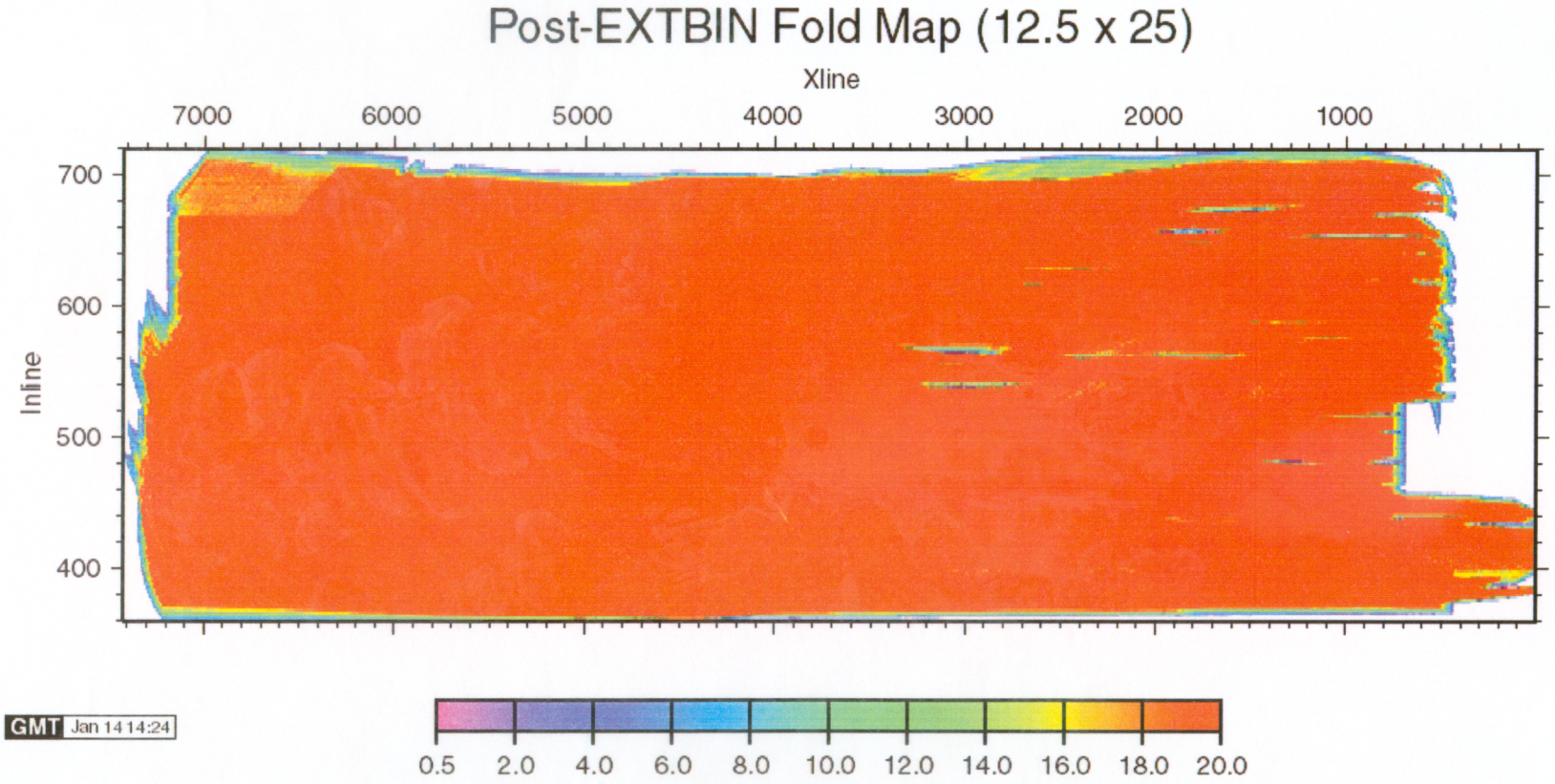


Figure 12. Fold map with binning parameters 2-4-400.
Bin size is 12.5 m by 25 m

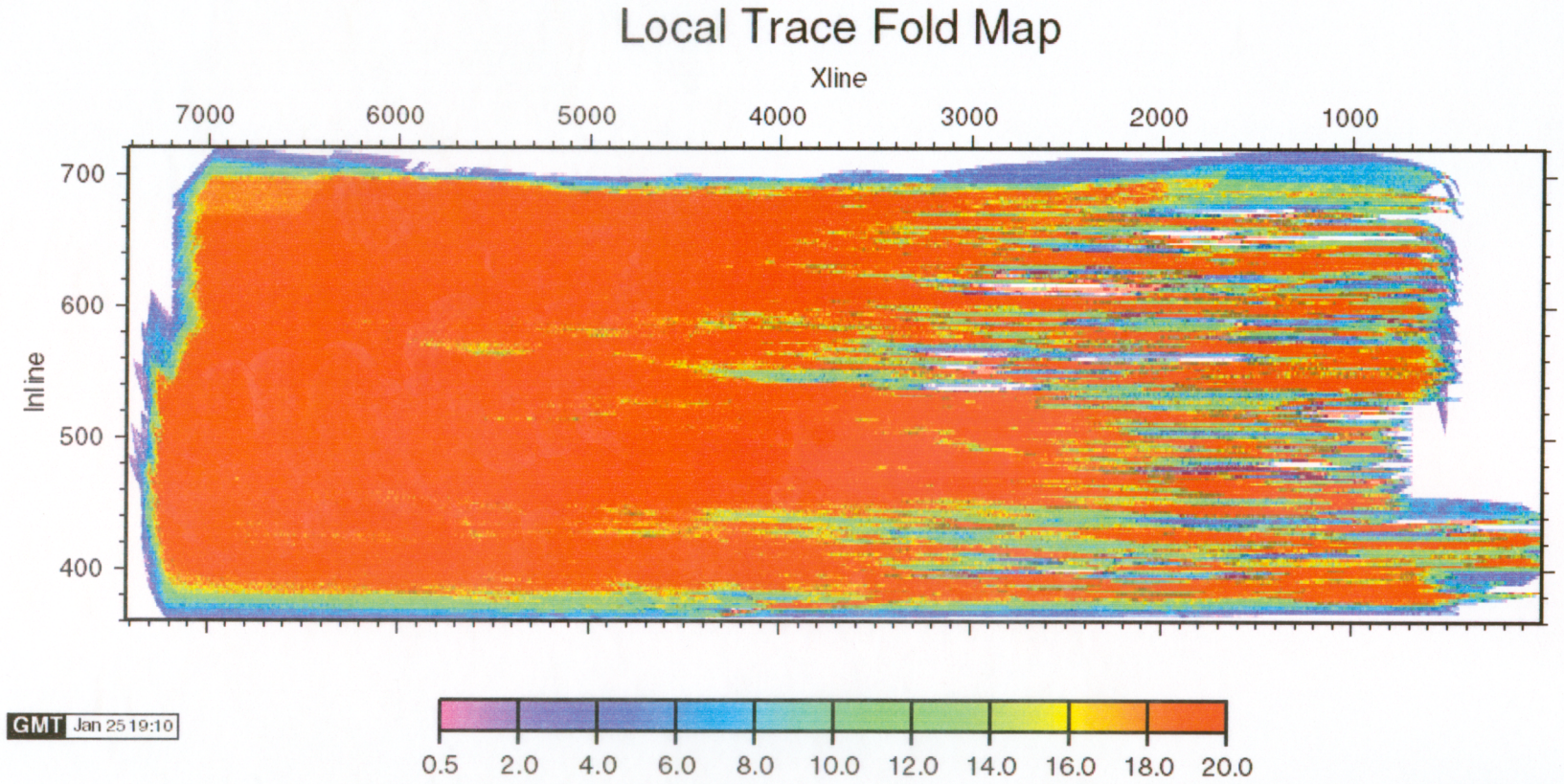


Figure 13. Fold map of traces within 14 m to bin centers. Bin ning parameters are 2-4-400. Bin size is 12.5 m by 25 m

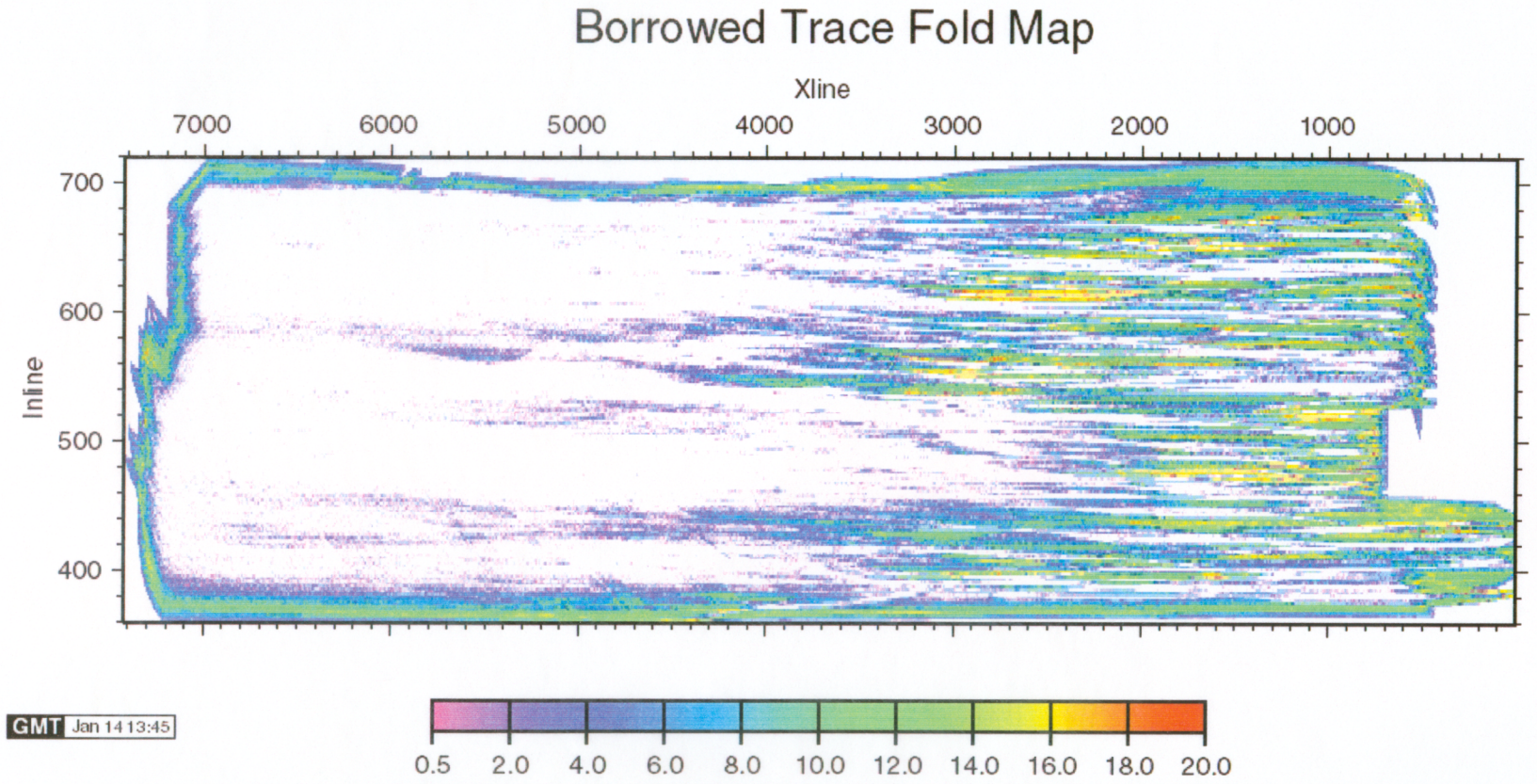


Figure 14. Fold map for traces within a distance of 14 - 62.5 m to bin centers. Binning parameters are 2-4-400 and the bin size is 12.5 m by 25 m.

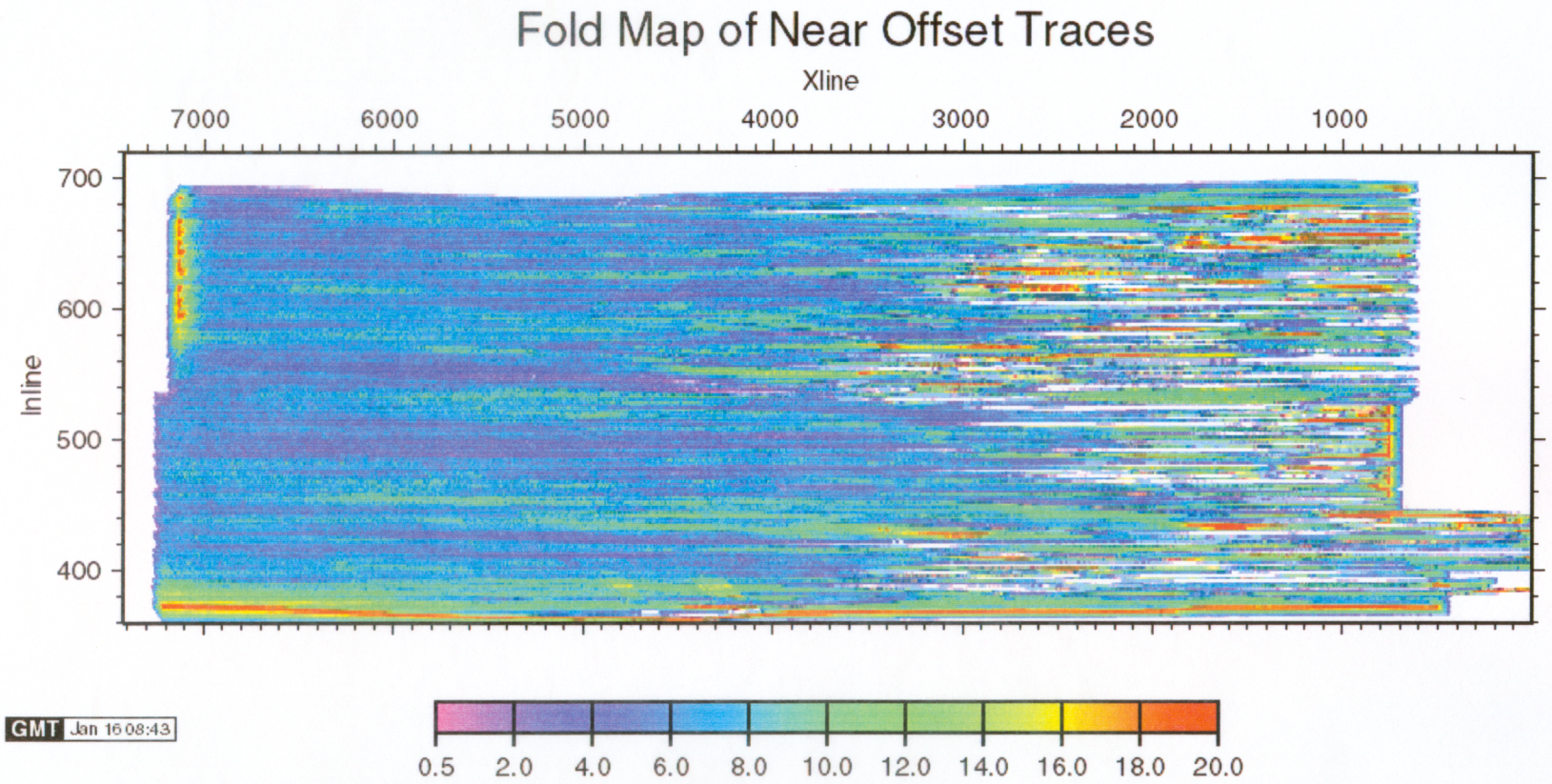


Figure 15. Fold map of traces with offsets 0 - 2000 m. Binning parameters are 2-4-400. The bin size is 12.5 m by 25 m.

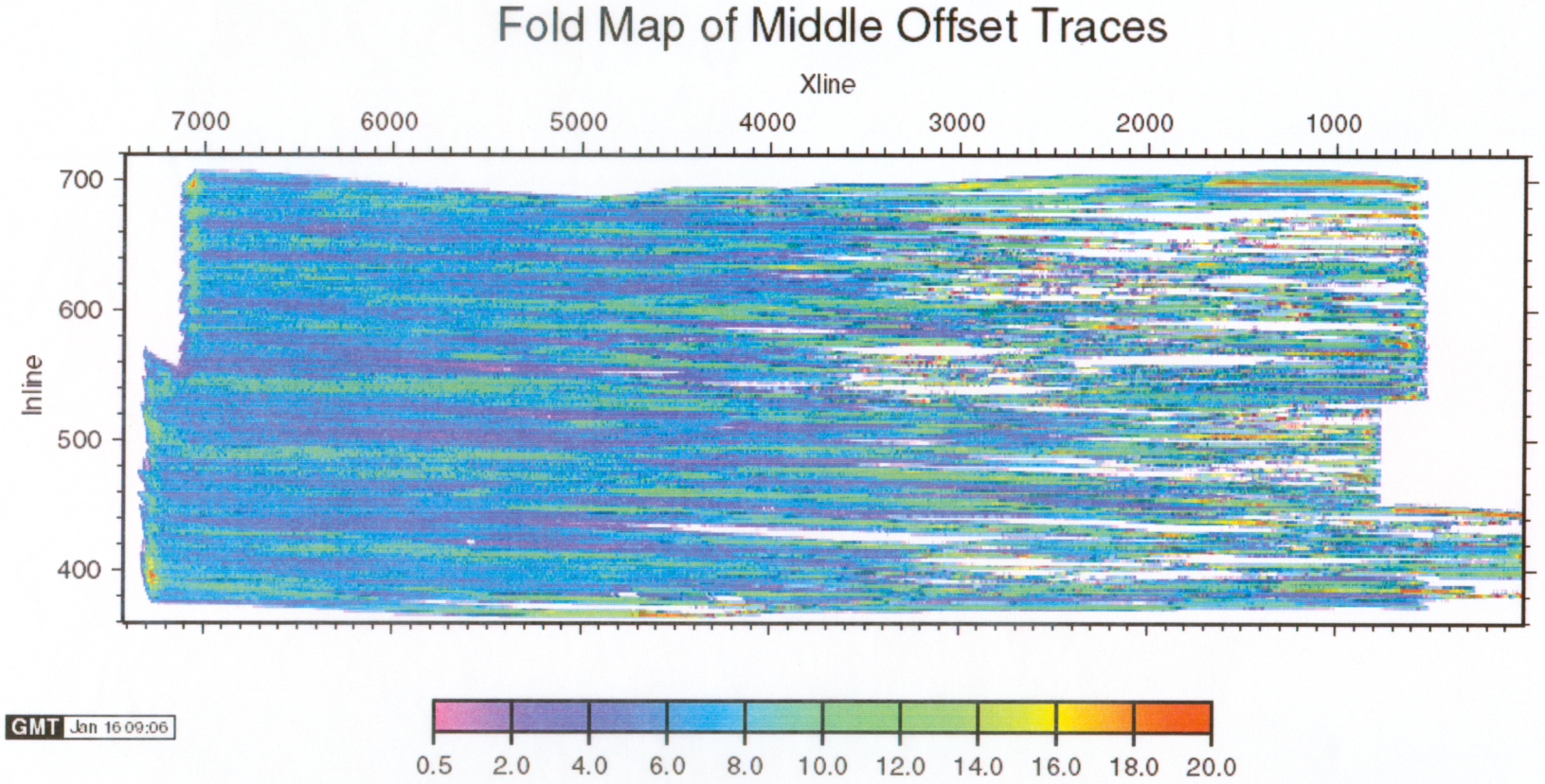


Figure 16. Fold map of traces with offsets 2000 - 4000 m. Binning parameters are 2-4-400. The bin size is 12.5 m by 25 m.

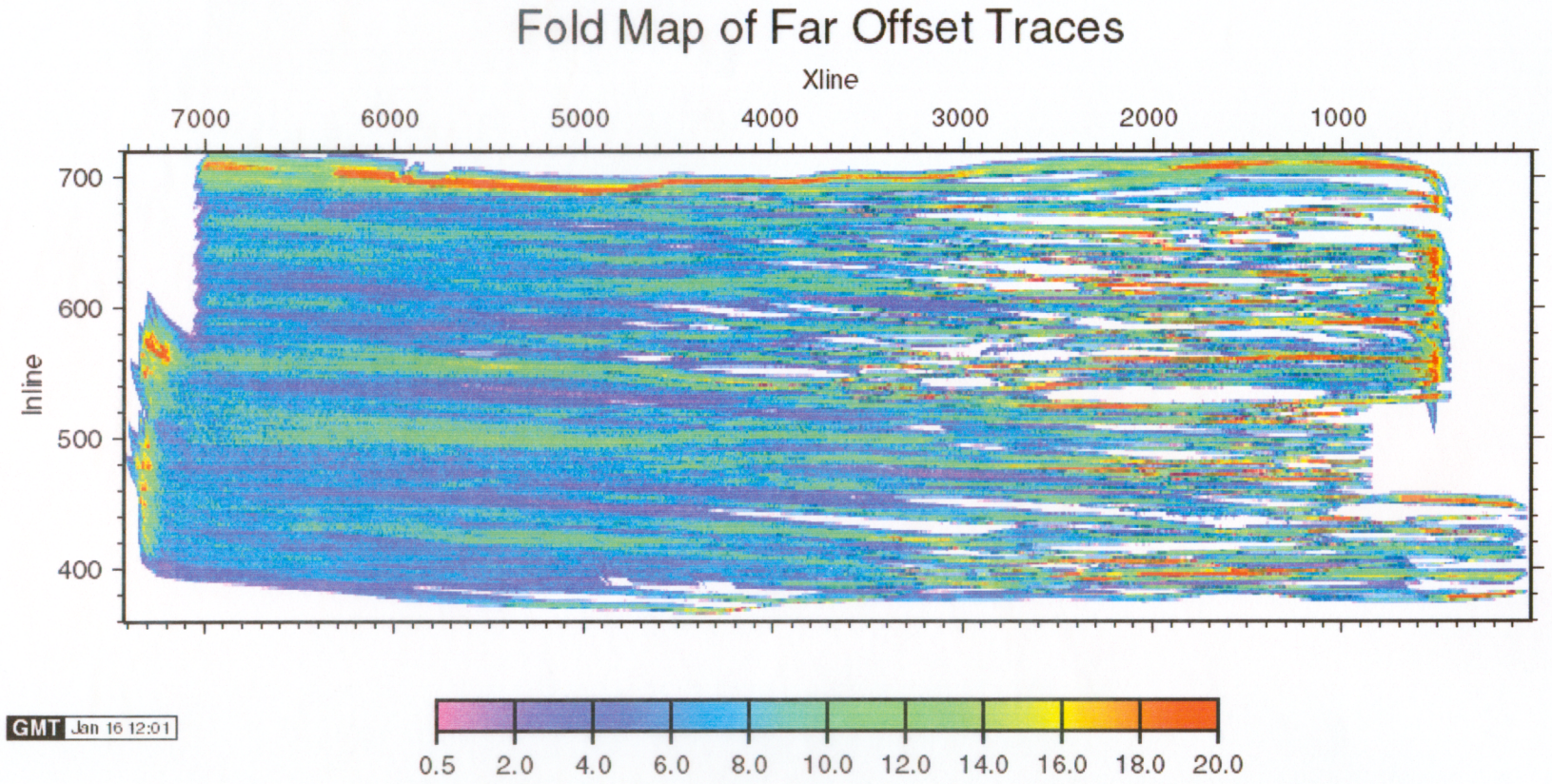


Figure 17. Fold map of traces with offsets 4000 - 6200 m. Binning parameters are 2-4-400. The bin size is 12.5 m by 25 m.

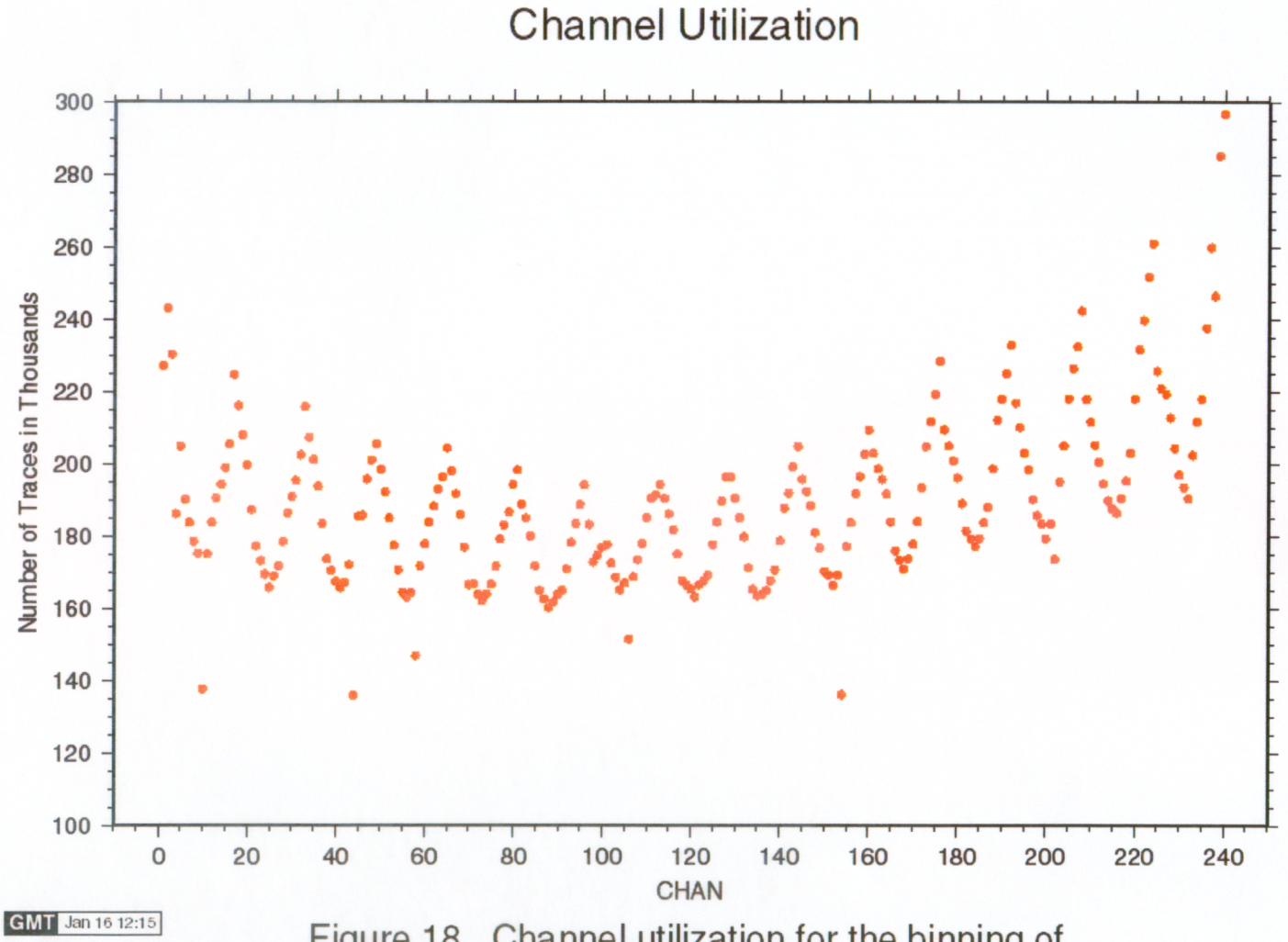


Figure 18. Channel utilization for the binning of 2-4-400. The bin size is 12.5 m by 25 m.

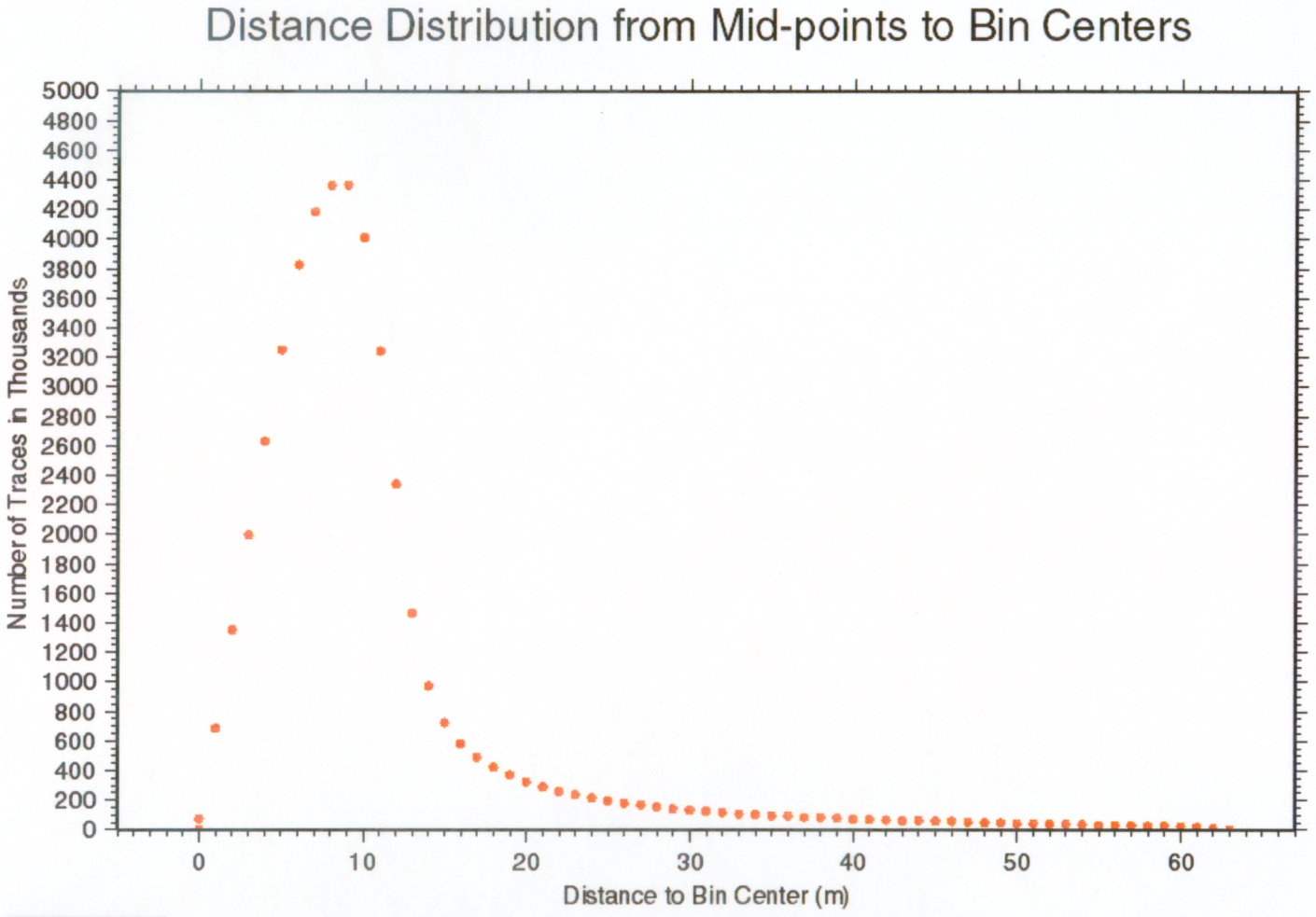


Figure 19. Trace distance distribution from mid-points to bin centers. Binning parameters are 2-4-400. The bin size is 12.5 m by 25 m.

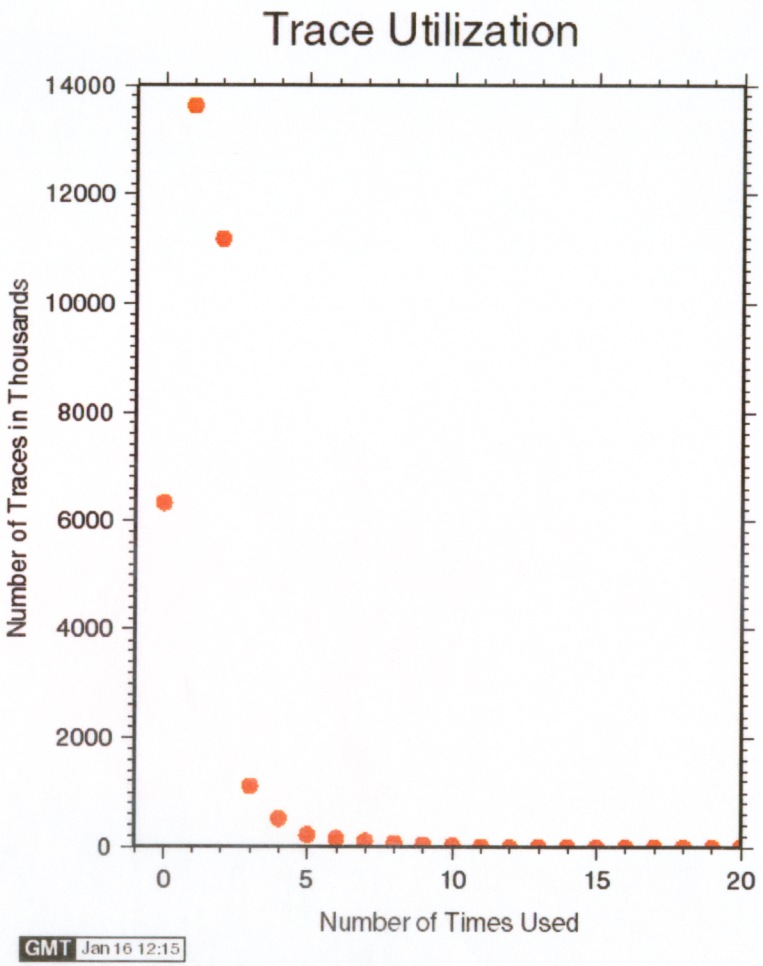


Figure 20. Trace utilization for the binning of 2-4-400. The bin size is 12.5 m by 25 m.

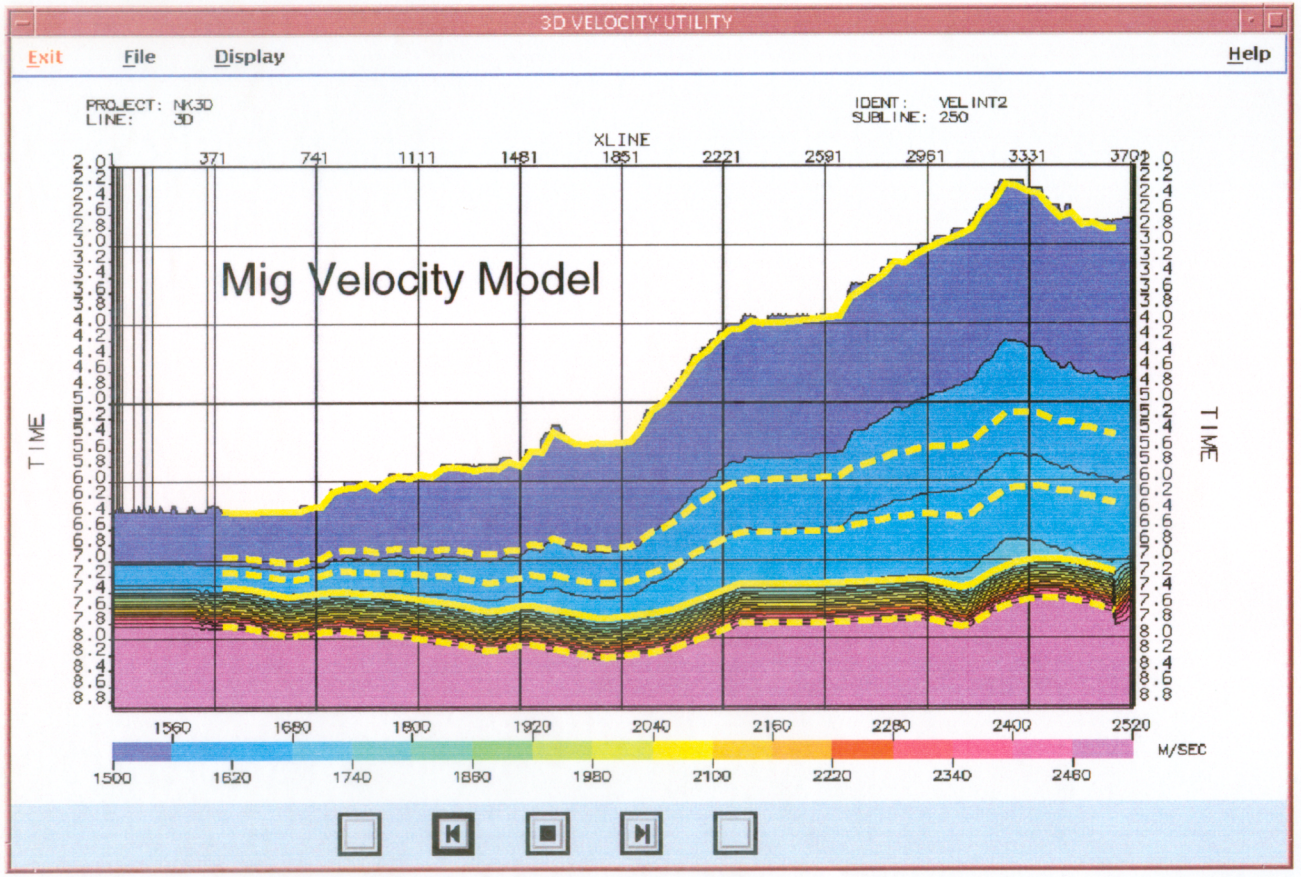


Figure 21. Interval velocity model (VELINT2) for time migration.