# Summary report of *R/V Roger Revelle* Site Survey AMAT03 to the IODP Environmental Protection and Safety Panel (EPSP) in support for proposal IODP626

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http://eprints.soton.ac.uk/45921/

# SITE PEAT-1C (Early Eocene equator)

## 12° 04.089'N, 142°09.698'W

### *SITE OBJECTIVES*

Leg 199 drilled a N-S transect across the equatorial region at about 56 Ma. Sites on this transect had generally drifted below the CCD by 52-53 Ma. Thus we presently lack calcareous sediments from the region of the equatorial circulation system during this time of maximum Cenozoic warmth. . PEAT-1C has been located on crust with an age of about 53 Ma in order to intercept the interval between 53 and 50 Ma in basal carbonate sediments above the shallow early Eocene CCD (3200-3300 m; Lyle et al., 2002; Lyle et al., 2005; Rea and Lyle, 2005). This interval was poorly sampled on the 56 Ma transect of Leg 199.

Average (non-carbonate) accumulation rates at this time were moderate, showing only slight increases in some of the more northern sites on the Leg 199 transect (1215, 1220; Lyle et al., 2002). What is particularly interesting in the records of Leg 199 is that the very shallow CCD of this early Eocene time appears to deepen to the north, perhaps suggesting a northern source for the bottom waters. Sites targeting this time interval would ideally give us sediments with sufficient carbonate material to better constrain the isotopic and biotic characteristics of the near surface equatorial waters.

Following SSEP recommendations we have positioned the site to the south of the estimated paleo-equatorial position at the target age in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

### *GENERAL DESCRIPTION*

PEAT-1C was chosen for survey because the crustal age was in the target range and the satellite map suggested that the topography was slightly elevated above the expected depth for 53 Ma crust. We found a region of abyssal hills bound by a large volcanic rise to the east, and several seamounts to the SW. The abyssal hills are more widely spaced than at previous sites, and trend NW rather than northeast. We noted a change in trend of abyssal hills between PEAT-2C and PEAT-1C perhaps associated with the Pacific plate reorganization that occurred at about 50 Ma (Rea and Dixon, 1983).

## *AMAT-03 SURVEY*

The PEAT-1C site survey was conducted on 7 April 2006 on the R/V Revelle. The site was surveyed using the Simrad EM-120 multibeam system, Knudsen 320B subbottom profiler, and using a seismic reflection acquisition system consisting of dual 150 c.i. GI guns (seismic source) and the Scripps 48-channel Geometrics GeoEel streamer. We surveyed at a nominal 6 knots . PEAT-1C was also piston cored, and an 11.3 m core (RR0603-11JC) was recovered.

The PEAT-1C survey area has relatively gentle abyssal hills, and more uniform sediment cover than some of our other site surveys. About 150-200 msec TWTT of sediment draped all the topography, with slightly more in the valleys and in the deeper SW corner of the site. PEAT-1C was chosen on a seismic line going down the western valley, in an area where basal reflections were weaker but better imaged than at other sites.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-11JC & TC, 11.30m,
12°07.488'N, 142°15.679'W , 5047 m.

RR0603-11JC&TC were taken to the west of the proposed location of PEAT-1C to try to sample below a transparent seismic layer, assumed to be clays. The core is located on a modest rise on the western side of the PEAT-1C survey area where the transparent layer thinned. The core consisted entirely of clay with zeolites, micronodules, and reworked radiolarians. Figure PEAT1C-4 shows the MST records from the core, while Figure PEAT1C-5 shows a summary of the reworked radiolaria from the core. They range in age from early Miocene to early Eocene. -

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-1C):
AMAT-03-PEAT1C line 8, 2006 JD098 05:57:59UTC, SP 42439.
Nearest crossing : PEAT1C line 1 crosses line 8 at
2006 JD097 19:13:47UTC, SP 38579

Crustal age: 53 Ma
Ship location @ SP42439: 12° 04.039'N, 142° 09.692'W
PEAT-1C Location: 12° 04.089'N, 142° 09.698'W
Site water depth: 5132 m (6.842 sec TWTT)
Basement depth: 5319m (7.078 sec TWTT)
Sediment thickness: 0.236 sec TWTT( 187m using Leg 199 composite, Bush et al., 2006)
Proposed Drilling Depth: 187m

*Velocity Table from Bush et al. (2006):*

| **Depth (mbsf)** | **TWTT (ms)** | **Velocity (m/s)** |
|---|---|---|
| 0-50 | 0-65 | 1540 |
| 50-250 | 65-315 | 1600 |
| 250-TD | >315 | 1660 |

PEAT-1C was chosen south of the intersection between line 1 and line 8 because the basal seismic horizons looked weaker but are well-imaged. The lack of nearby hills makes us confident that this change is not the result of out-of-plane geometry. We are looking for less-strong basal seismic horizons to avoid cherts as much as possible (Figures PEAT1C-6 and PEAT1C-7). The sediment section is slightly thicker than average for the PEAT-1 survey region.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-1C Line 1
PEAT-1C Line 2
PEAT-1C Line 3
PEAT-1C Line 4
PEAT-1C Line 5
PEAT-1C Line 6
PEAT-1C Line 7
PEAT-1C Line 8

## *FIGURES*

Fig PEAT1C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-1C is marked.

Fig PEAT1C-2: Swathmap bathymetry for the PEAT-1C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-11JC are marked.

Fig PEAT1C-3a: Map of shotpoints and seismic lines in the PEAT-1C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-11JCare marked.

Fig PEAT1C-3b: Map of survey times and seismic lines in the PEAT-1C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-11JC are marked.

Fig PEAT1C-4: MST physical properties data for RR0603-11JC.

Fig PEAT1C-5: Plot of ages reworked radiolaria found in RR0603-11JC, showing average early Oligocene age, but a range from early Miocene to middle Eocene.

Fig PEAT1C-6: Seismic reflection profile annotated in GMT hours, from PEAT-1 Line 8 of the 48-channel seismic reflection survey. The data are filtered, stacked, and migrated. PEAT-1C Line 8 goes down the western abyssal valley at the site. The site was chosen where basal reflections appeared less strong, to avoid possible cherts.

Fig PEAT1C-7: Seismic reflection profile annotated in shotpoint, from PEAT-1 Line 8 of the 48-channel seismic reflection survey. The data are filtered, stacked, and migrated. PEAT-1C Line 8 goes down the western abyssal valley at the site. The site was chosen where basal reflections appeared less strong, to avoid possible cherts.

Fig PEAT1C-8: Crossline seismic profile PEAT-1C line 1 annotated in GMT hours from the AMAT-03 survey. PEAT-1C was located S of the crossline in an area with better defined older seismic horizons.

Fig PEAT1C-9: Crossline seismic profile PEAT-1C line 1 annotated in CDP from the AMAT-03 survey. PEAT-1C was located S of the crossline in an area with better defined older seismic horizons

Fig PEAT1C-8: Chirp subbottom profile from line 8 across PEAT-1C, from AMAT-03.Proposed drill site is marked.

Fig PEAT1C-9: Chirp subbottom profile along line 1, the crossline to line 8.

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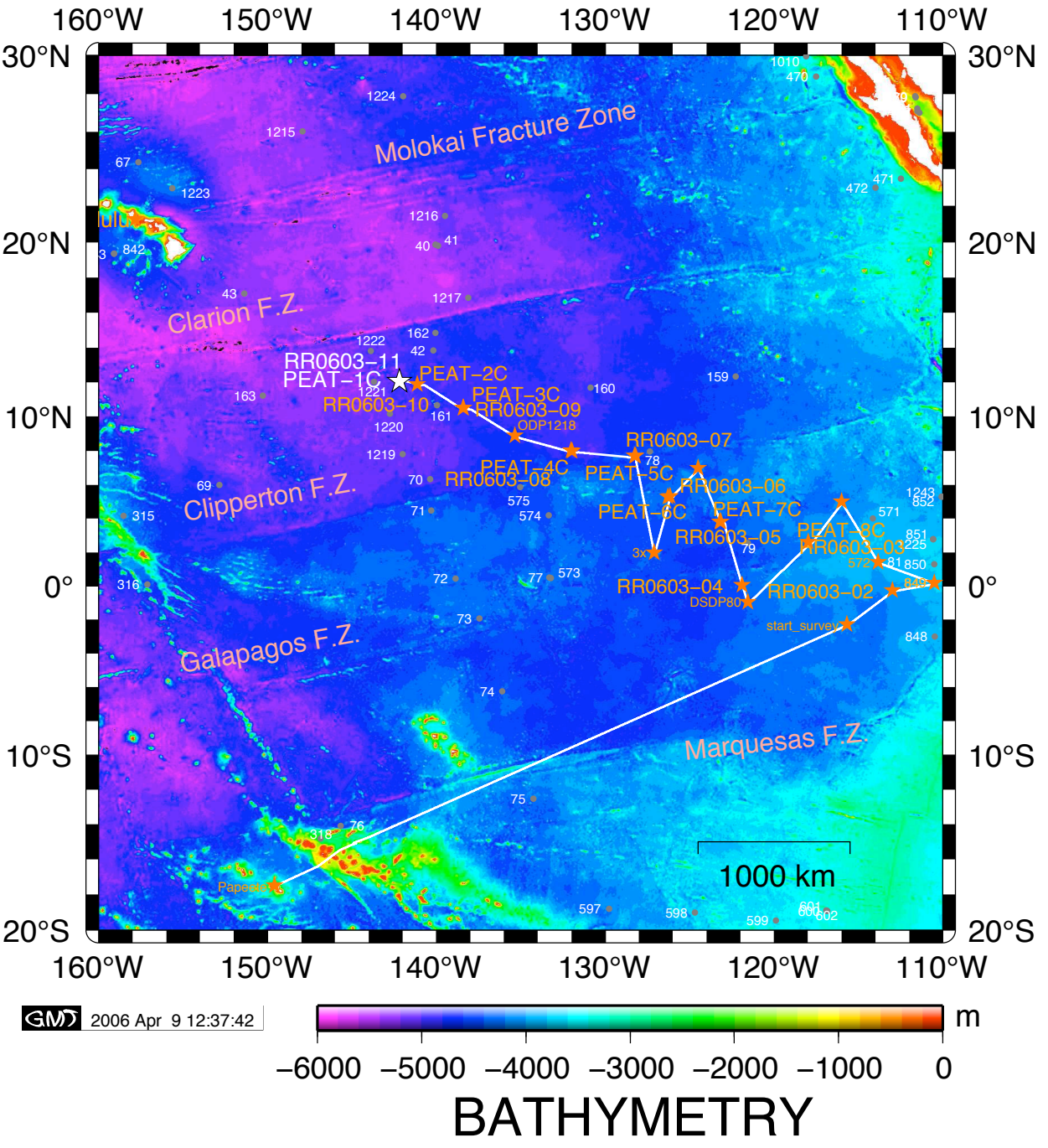
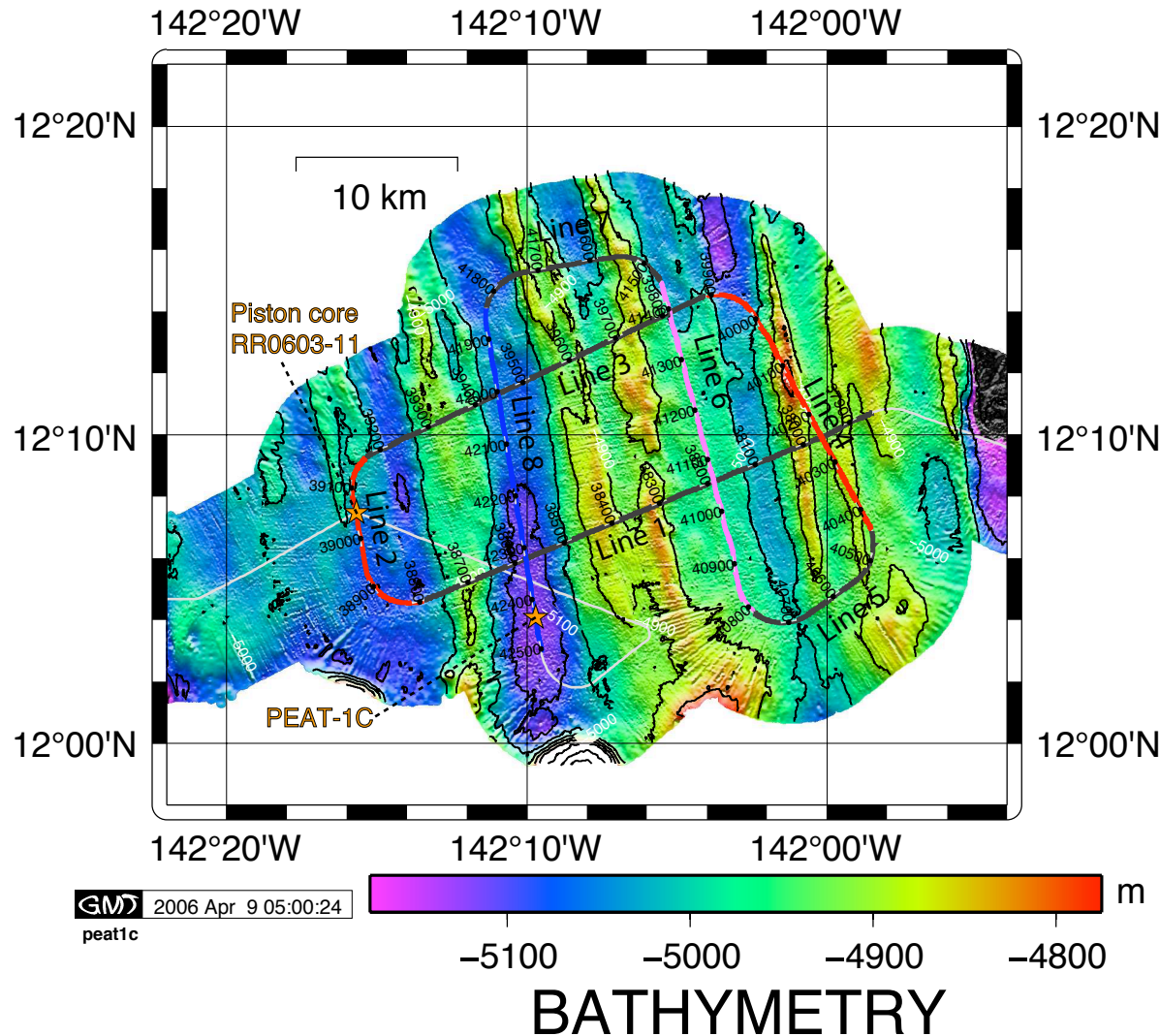
FigPEAT1C-1

# AMAT–03 PEAT–1C OVERVIEW



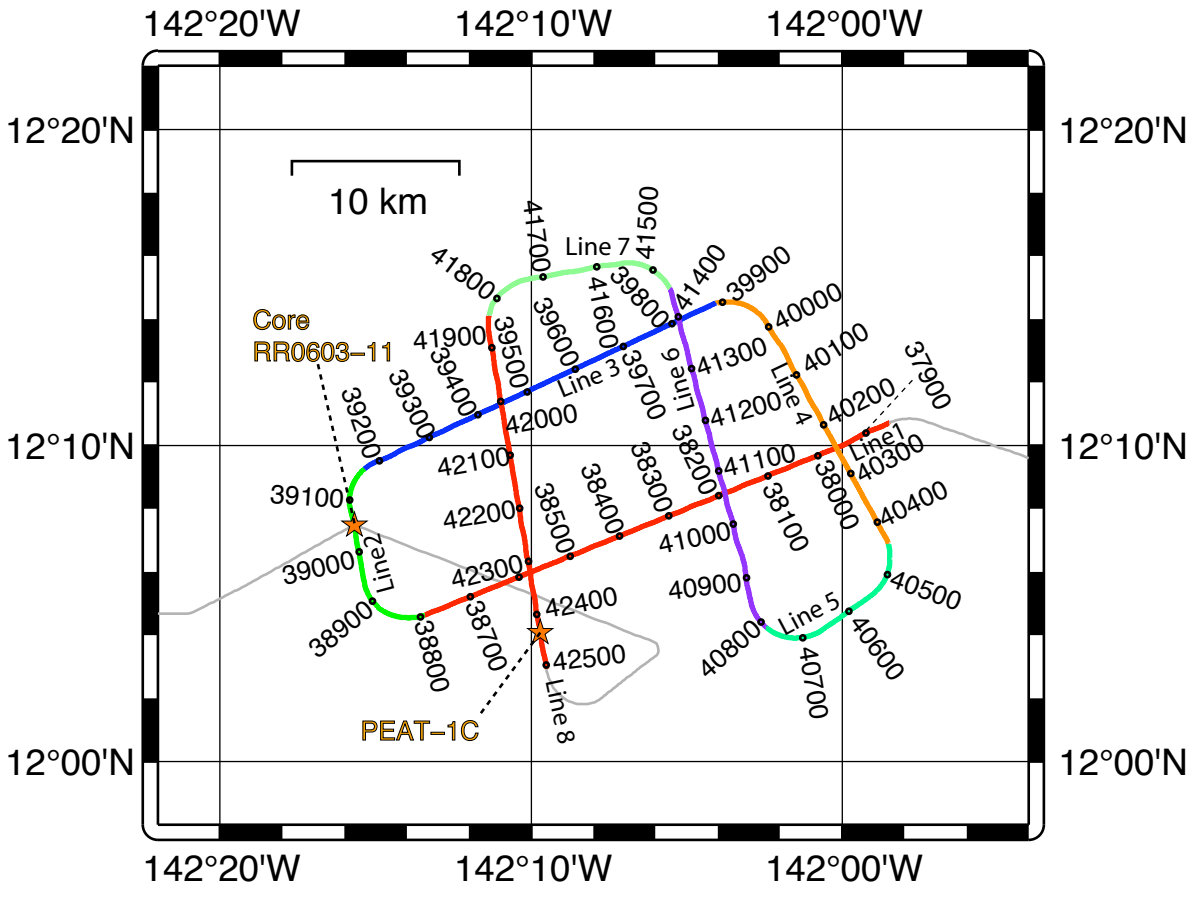
FigPEAT1C-2

# PEAT–1C



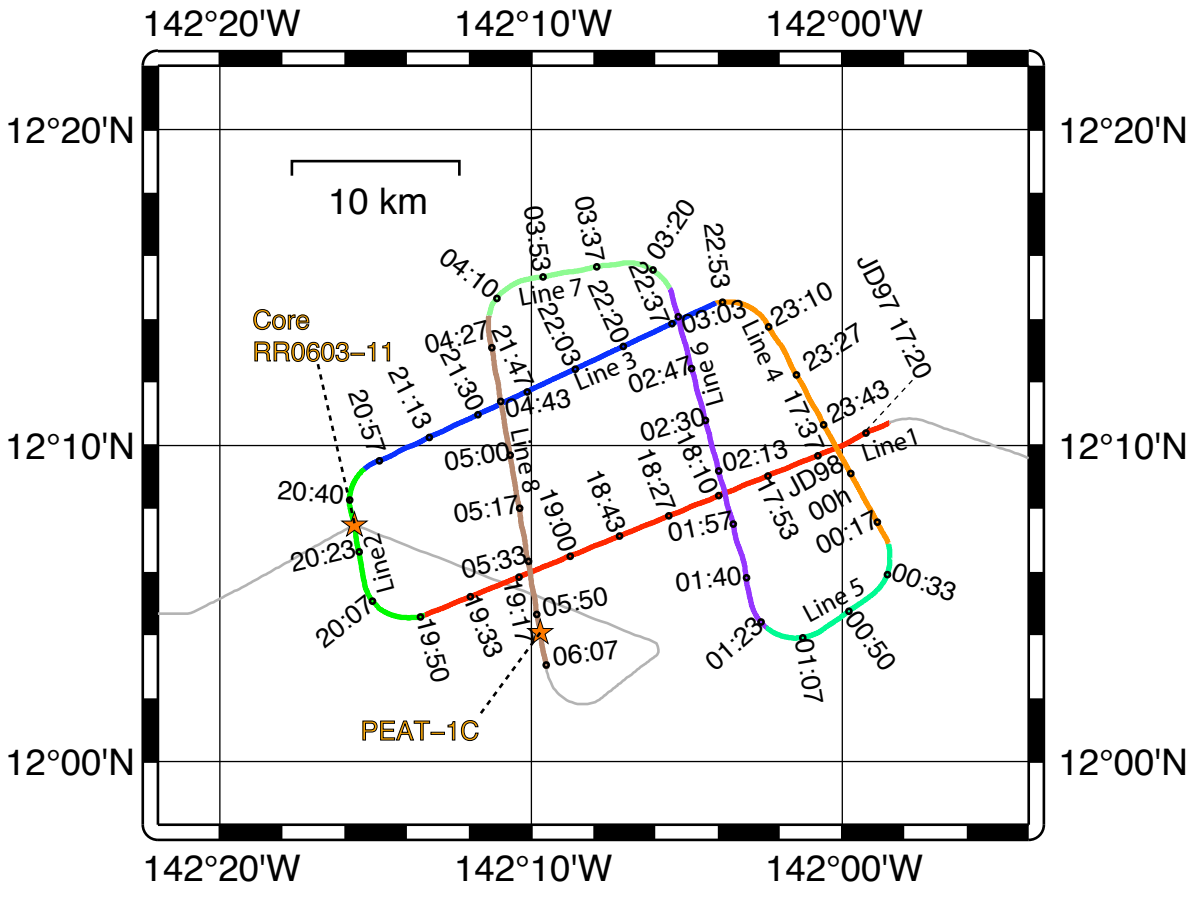
FigPEAT1C-3a

# PEAT–1C

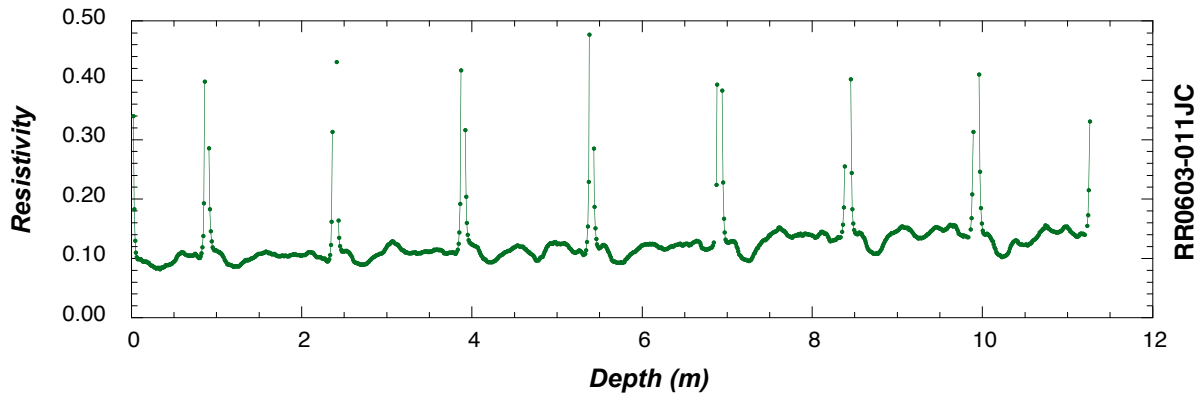


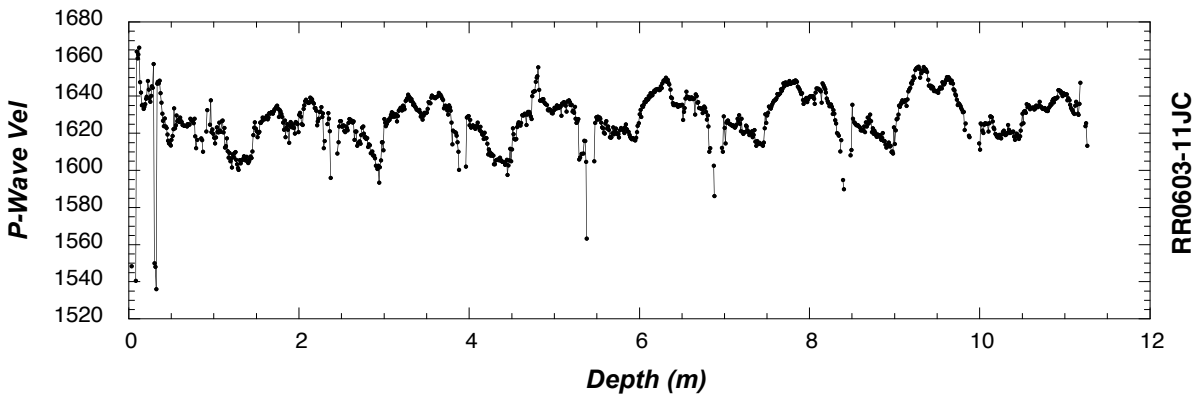
FigPEAT1C-3b

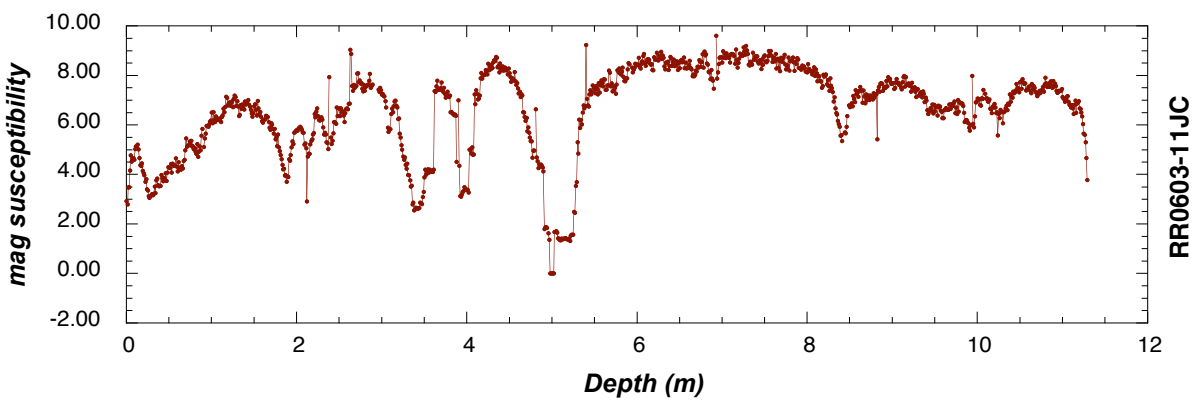
# PEAT–1C

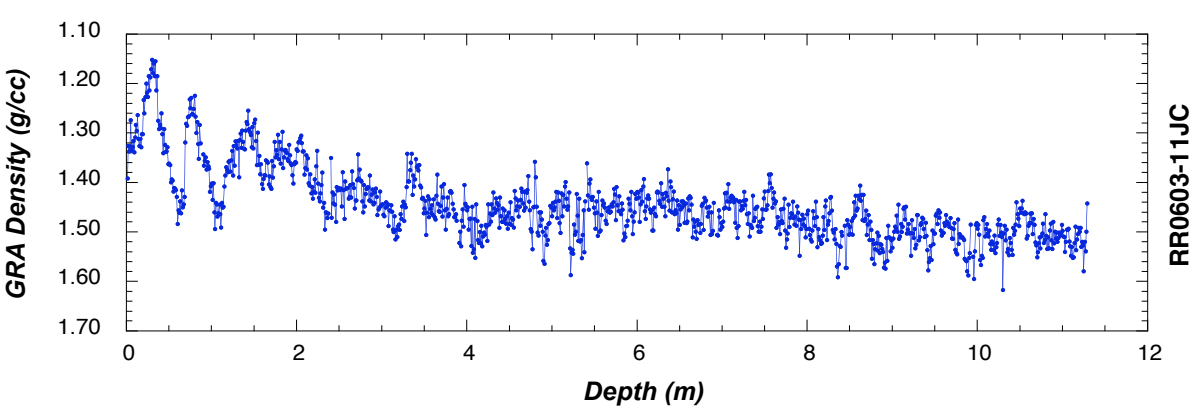


# RR0603-11JC, from PEAT-1C

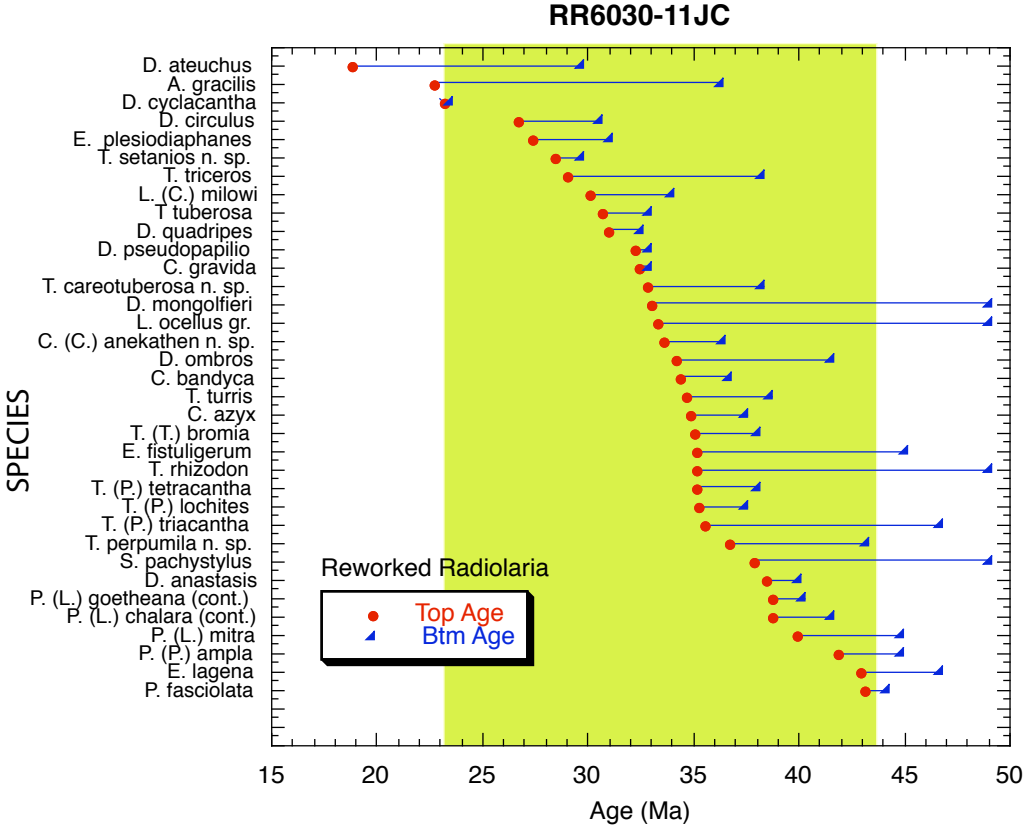


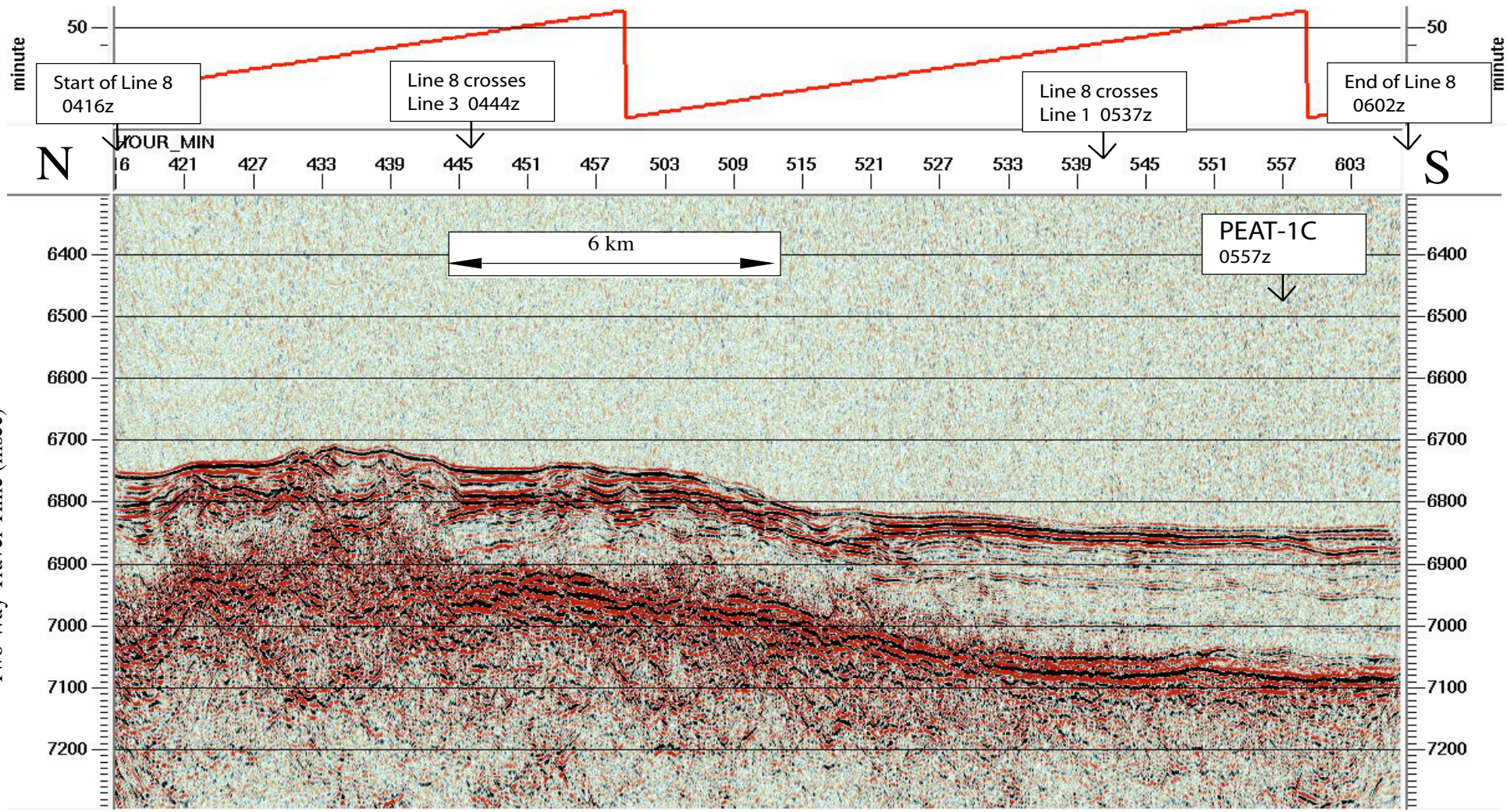



FigPEAT1C-5

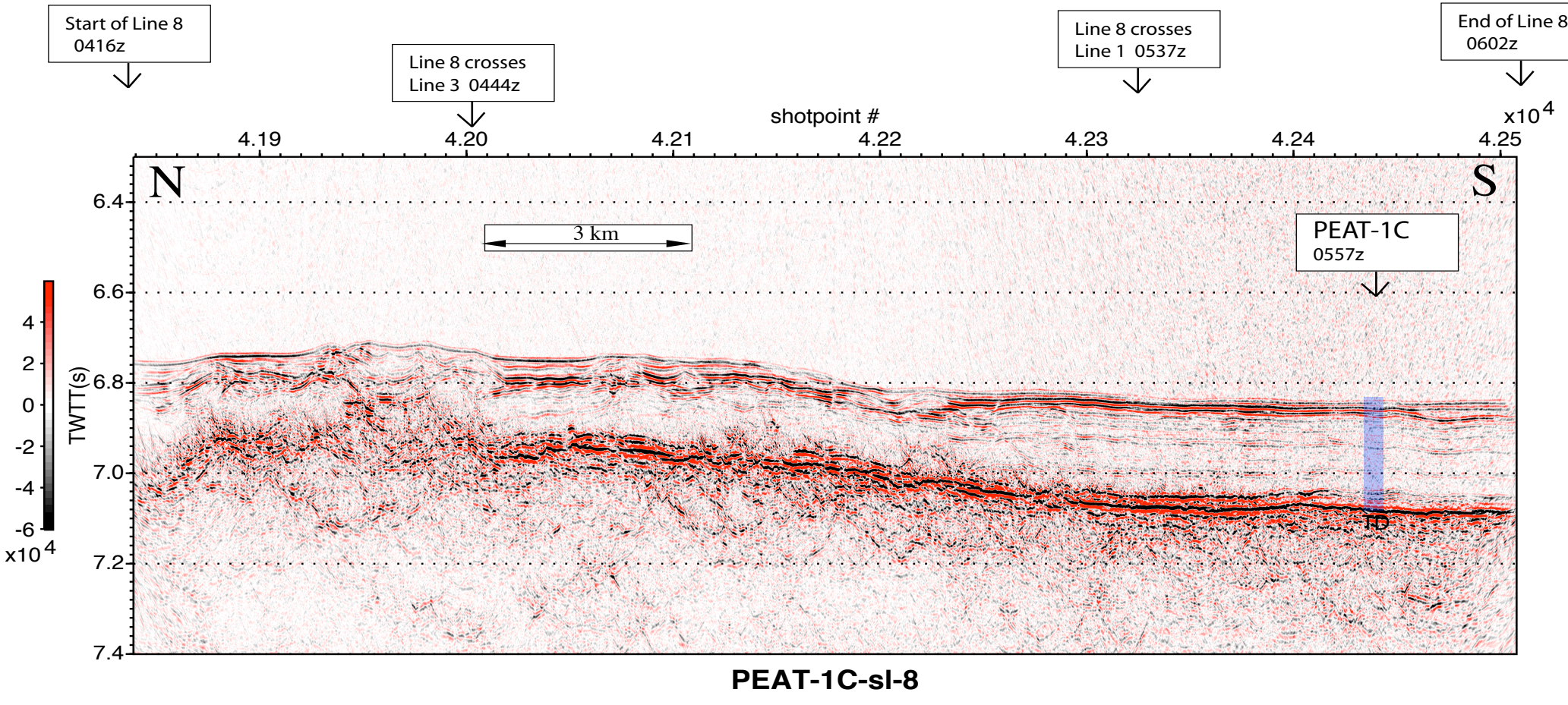

RR6030-11JC
SPECIES
D. ateuchus
A. gracilis
D. cyclacantha
D. circulus
E. plesiodiaphanes
T. setanios n. sp.
T. triceros
L. (C.) milowi
T tuberosa
D. quadripes
D. pseudopapilio
C. gravida
T. careotuberosa n. sp.
D. mongolfieri
L. ocellus gr.
C. (C.) anekathen n. sp.
D. ombros
C. bandyca
T. turris
C. azyx
T. (T.) bromia
E. fistuligerum
T. rhizodon
T. (P.) tetracantha
T. (P.) lochites
T. (P.) triacantha
T. perpumila n. sp.
S. pachystylus
D. anastasis
P. (L.) goetheana (cont.)
P. (L.) chalara (cont.)
P. (L.) mitra
P. (P.) ampla
E. lagena
P. fasciolata
Reworked Radiolaria
Top Age
Btm Age
15
20
25
30
35
40
45
50
Age (Ma)

# Fig PEAT1C-6




AMAT-03RR Chirp
JD 98 PEAT1c Line 8
0416-0602z
Course 170

Fig PEAT1C-7




**PEAT-1C-sl-8**

AMAT-03RR Chirp
JD 98 PEAT1c Line 8
0416-0602z
Course 170

Fig PEAT1C-8

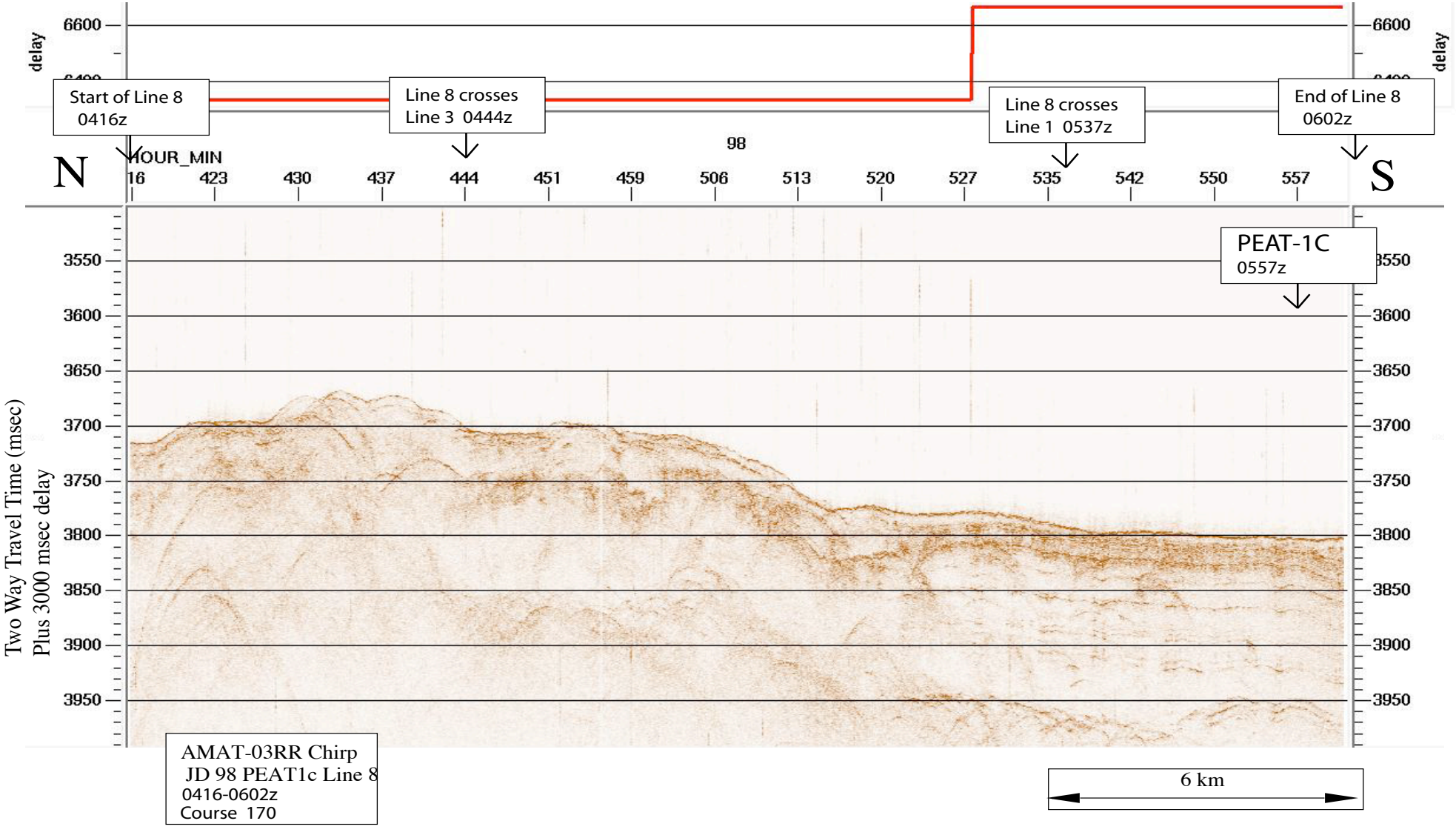
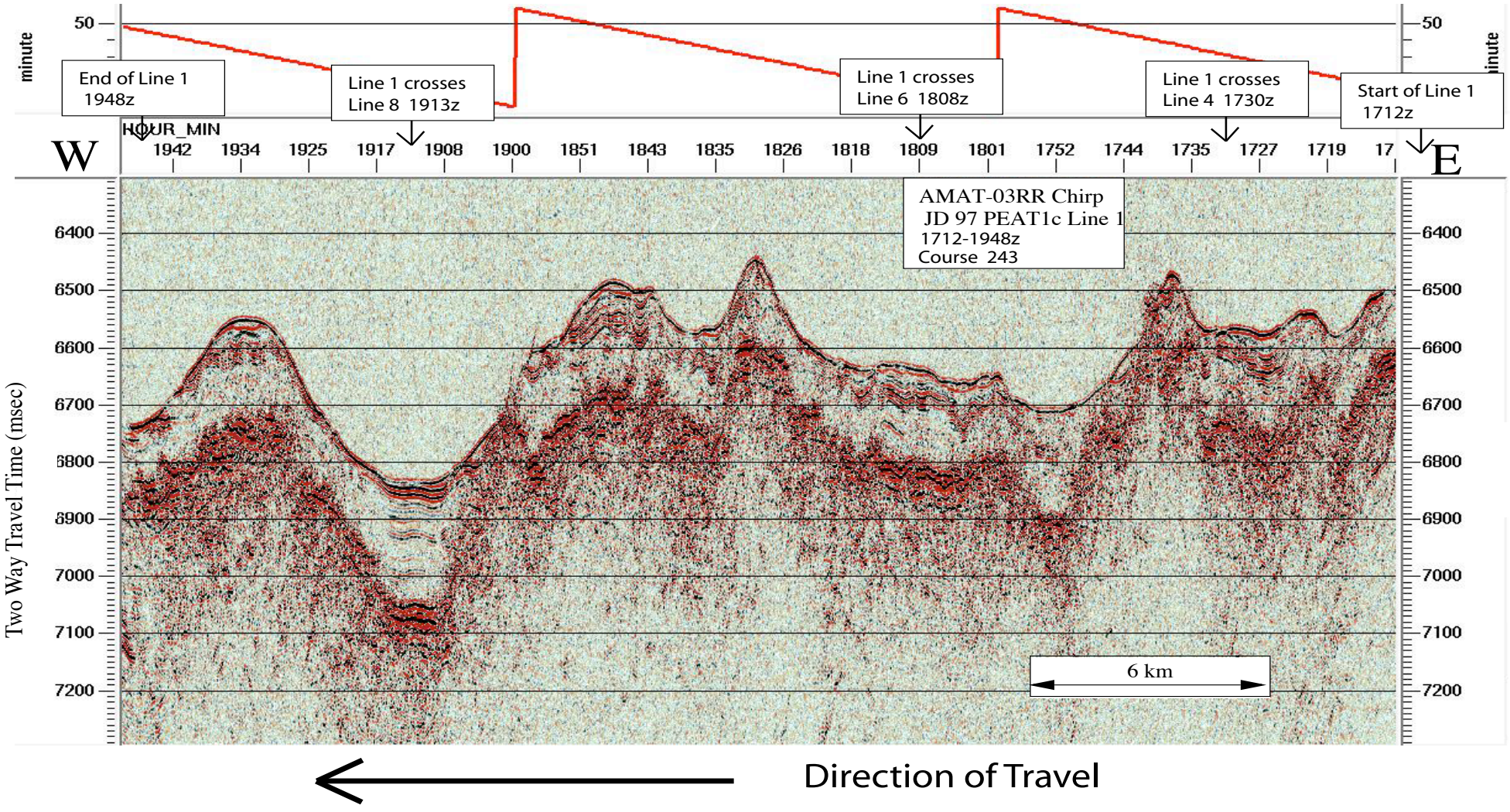

delay
6600
Start of Line 8
0416z
Line 8 crosses
Line 3 0444z
Line 8 crosses
Line 1 0537z
End of Line 8
0602z
98
N
HOUR_MIN
16
423
430
437
444
451
459
506
513
520
527
535
542
550
557
S
PEAT-1C
0557z
3550
3600
3650
3700
3750
3800
3850
3900
3950
Two Way Travel Time (msec)
Plus 3000 msec delay
AMAT-03RR Chirp
JD 98 PEAT1c Line 8
0416-0602z
Course 170
6 km

Fig PEAT1C-9




Direction of Travel

Fig PEAT1C-10

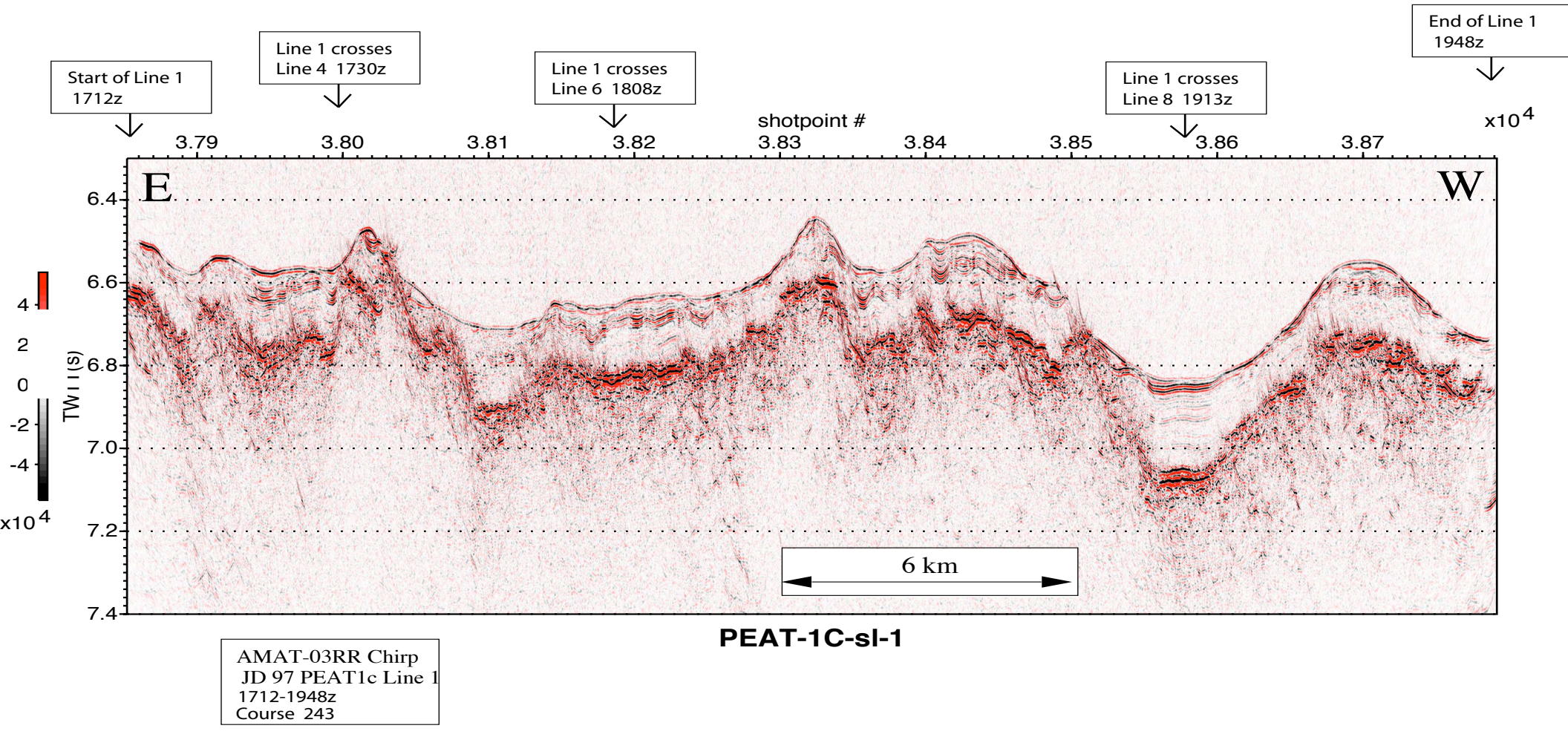
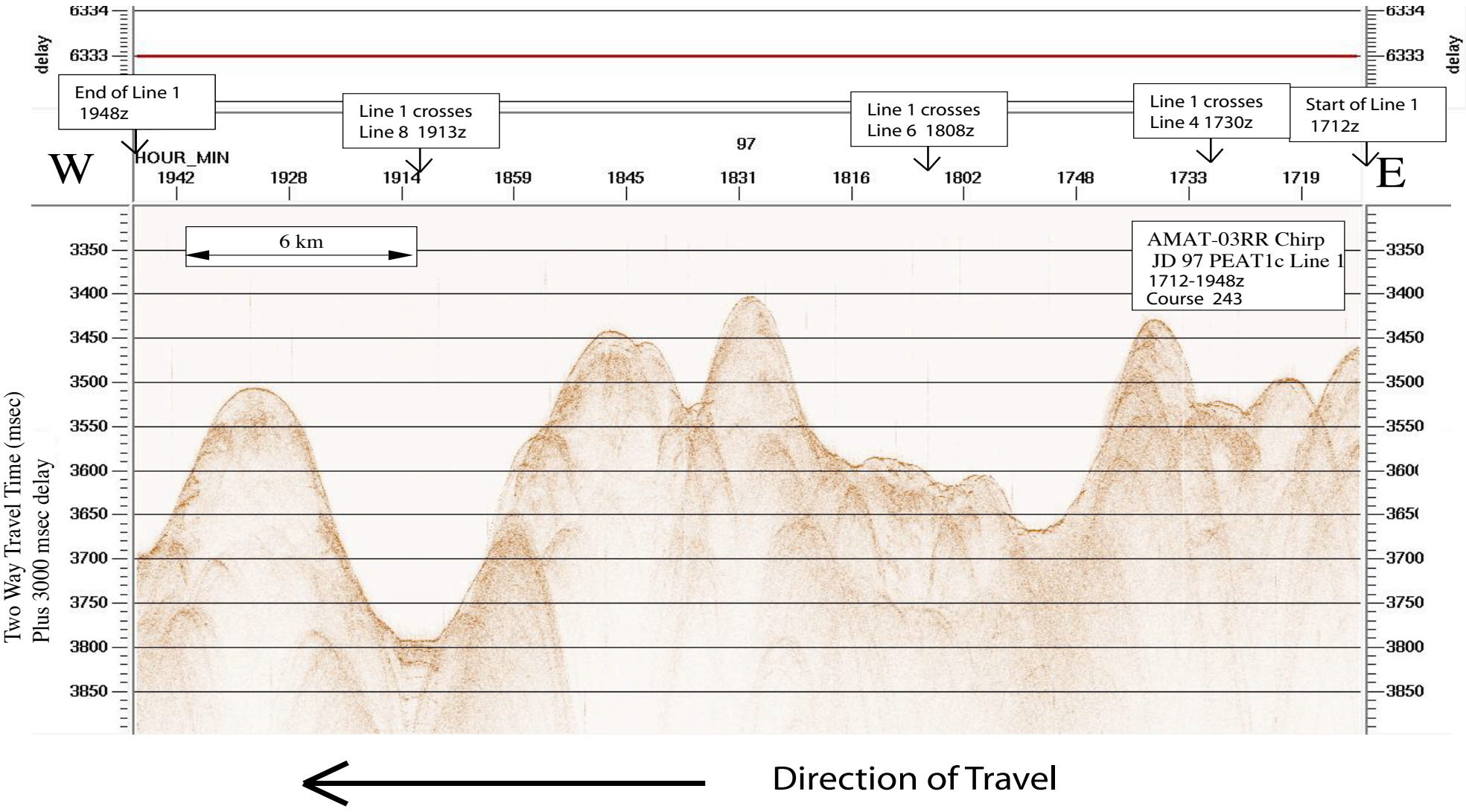


Fig PEAT1C-11




Direction of Travel

# SITE PEAT-2C
# (early Eocene equator/ early Eocene climatic optimum)

# 11° 54.711'N, 141° 02.744'W, 4941 mbsl

## *SITE OBJECTIVES*

During the early Eocene, a very shallow CCD and the initial more rapid Pacific plate subsidence near the shallower ridge-crest conspire to make the time window during which carbonate is preserved in sediment shorter (ca. 2-5 Ma) than during other geological epochs with a deeper CCD. Thus, while ODP Leg 199 Sites recovered good records of pelagic carbonates during and just after the Paleocene-Eocene Thermal Maximum (PETM) (Lyle, M., P. A. Wilson, T. R. Janecek et al., 2002; Nunes & Norris, 2006; Raffi et al., 2005), the time period of the Early Eocene Climatic Optimum (Zachos et al., 2001) is not well sampled, and requires dedicated site planning in order to obtain optimally preserved carbonate records from near the paleoequator. Proposed sites PEAT-1C (52 Ma old crust) and 2C (49-50 Ma old cruse) aim to provide the material to address several important questions that to relate causes and responses of the true Cenozoic "Greenhouse" world: The Eocene was a time of extremely warm climates that reached a maximum in temperatures near 52 Ma (Zachos et al., 2001). From this maximum there was a gradual climatic cooling through to the Eocene-Oligocene Boundary. Good paleomagnetic stratigraphy in Leg 199 Sites allowed calibration of nannofossil and radiolarian biostratigraphic datum levels to paleomagnetic reversals for the middle and late Eocene. Leg 199 drilled a N-S transect across the equatorial region at about 56 Ma. Sites on this transect had generally drifted below the CCD by 52-53 Ma. Thus we presently lack calcareous sediments from the region of the equatorial circulation system during this time of maximum Cenozoic warmth. Average (non-carbonate) accumulation rates at this time were moderate, showing only slight increases in some of the more northern sites on the Leg 199 transect (1215, 1216, 1220). What is particularly interesting in the records of Leg 199 is that the very shallow CCD of this early Eocene time appears to deepen to the north, perhaps suggesting a northern source for the bottom waters (Lyle, M., P. A. Wilson, T. R. Janecek et al., 2002; Rea and Lyle, 2005). Sites targeting this time interval would ideally give us sediments with sufficient carbonate material to better constrain the isotopic and biotic characteristics of the near surface equatorial waters.

Following SSEP recommendations we have positioned the site to the south of the estimated paleo-equatorial position at the target age in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole

data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

## *GENERAL DESCRIPTION*

PEAT-2C is located in abyssal hill topography north of the Clipperton Fracture Zone and just south of the "Mahi-Mahi Fracture Zone" that was discovered during the Site Survey Cruise EW9709 in preparation of ODP Leg 199 (Figure PEAT2C-2) on 49–50 Ma crust. There is a general slope in topography to the north, with the southern side of the site being more elevated. N-S trending small ridges and troughs (ca. 5 km width) make up the typical topography. Bathymetric relief across the abyssal hills is 50 –200 meters, and sediment cover is around 200 msec TWTT. The closest previous drilling locations north of the Clipperton and south of the Mahi-Mahi Fracture (Figure PEAT2C-1) comprise ODP Sites 1220 and 1221 approximately 100nm to the west (basement ages just before the Paleocene/Eocene boundary at 56.0 Ma). North of the Mahi-Mahi fracture zone and to the east of the proposed Site PEAT-2C are DSDP Sites 42 (basment age ca. 45 Ma, J. Backman) and 162 (basement age estimated at ca. 49 Ma), and to the west ODP Site 1222 (on 56 Ma crust).

## *AMAT-03 Survey*

PEAT-2C was surveyed on 6th April 2006 with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. We used the 48-channel streamer for the site survey and a nominal survey speed of 6 knots. The site was also piston cored, and an 11.31m core (RR0603-10JC) was recovered.

The PEAT-2 survey area was located to be above 49 to 50 Ma basement on abyssal hill topography. The 48-channel stacked and migrated data reveal a regions at the flanks of tilted ridges where older horizons are exposed nearer the surface (images in cross-strike lines 1 and 6). The coring suggests that the surface sediments were formed about 20 Ma (see below), The biostratigrapic analysis of surface sediments indicates an age no older than 19–23 Ma, but due to barren and reworked samples in the sediment core it is not possible to obtain any further information about the possible sedimentation rates in the basal section, other than that the minimum sedimentation rate across the entire section is of the order of 6 m/Myr.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-10JC & TC, 11.31m,
11°53.000'N 141° 02.751'W , 4935 m.

RR0603-10JC&TC were taken to the south of the proposed drillsite, near the cross between lines 1 and line 6. The core site is located on a modest rise, with about 200 msec TWTT beneath the core site

The piston core recovered 11.31 meters of siliceous and zeolitic yellowish-brown and grey mottled clays, and no carbonate (Figure PEAT2C-4). The GRA density data from Core RR0603-JC does show quasi-regular cycles, but these cannot be interpreted

with the lacking available age-control The core catcher sample and samples at the section 7/8 break were barren of all but fish teeth and debris. Above that the samples contained a highly reworked assemblage of radiolarians (Figure PEAT2C-5), containing the more robust species the ages represented. It is thus hard to say what the age of the sediments themselves are, but the youngest components of the preserved assemblage would indicate an age no older than 19 Ma to 23 Ma.

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-2C):
AMAT-03-PEAT2C line 6, 2006 JD096 17:52:29UTC, SP 32971.
Nearest crossing: crossing of PEAT2C line 6 with line 1 at
2006 JD096 17:55:22UTC, SP 32987 (line 6) and
2006 JD096 09:39:41UTC, SP 30013 (line 1)

Crustal age: 49–50 Ma
Ship location @ SP32971: 11°54.760'N 141° 02.748'W
PEAT-2C Location: 11°54.711'N, 141°02.744'W
Site water depth: 4941 m (6.588 sec TWTT)
Basement depth: 5103 m (6.793 sec TWTT)
Sediment thickness: 0.205 sec TWTT
(162m using ODP199 velocity profile (Busch et al., 2006))
Proposed Drilling Depth: to tag basement (167m is best estimate).

*Velocity Table from Bush et al. (2006):*

| **Depth (mbsf)** | **TWTT (ms)** | **Velocity (m/s)** |
|---|---|---|
| 0-50 | 0-65 | 1540 |
| 50-250 | 65-315 | 1600 |
| 250-TD | >315 | 1660 |

PEAT-2C was chosen very close to the intersection between lines 1 and line 6, to maximize the thickness of the deeper section (Figures PEAT2C-6 and –7) and minimizing a set of high-amplitude, flat reflectors to the south of the crossing lines (possible chert, "peg-leg" type reflector between shotpoints 32713–32932). The cross and proposed drill site are within the deep sediment fill between to north-south running minor basement hills.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-2C Line 1
PEAT-2C Line 2
PEAT-2C Line 3
PEAT-2C Line 4
PEAT-2C Line 5
PEAT-2C Line 6
PEAT-2C Line 7
PEAT-2C Line 8

## *FIGURES*

Fig PEAT2C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-2C is marked. Also shown are navigation data from site survey cruise EW9709 in support for ODP Leg 199.

Fig PEAT2C-2: Swathmap bathymetry for the PEAT-2C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-10JC are marked.

Fig PEAT2C-3a: Map of shotpoints and seismic lines in the PEAT-2C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-10JCare marked.

Fig PEAT2C-3b: Map of survey times and seismic lines in the PEAT-2C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-10JC are marked.

Fig PEAT2C-4: MST physical properties data for RR0603-10JC.

Fig PEAT2C-5: Re-worked radiolarian occurrences of core RR0603-10JC based on shipboard biostratigraphy.

Fig PEAT2C-6: Seismic profile PEAT-2C line 6 annotated in UTC, with position and penetration depth of proposed site PEAT-2C marked. The data are filtered, stacked, and migrated.Also shown are position of crossing lines.

Fig PEAT2C-7: Seismic profile PEAT-2C line 6 annotated in shotpoint, with position and penetration depth of proposed site PEAT-2C marked. The data are filtered, stacked, and migrated.Also shown are position of crossing lines.

Fig PEAT2C-8: Crossline seismic profile PEAT-2C line 1 from AMAT-03 annotated in UTC.

Fig PEAT2C-9: Crossline seismic profile PEAT-2C line 1 from AMAT-03 annotated in shotpoint.

Fig PEAT3C-10: Chirp subbottom profile from line 1 the crossline just north PEAT-2C, from AMAT-03. Proposed drill site is just south of the cross with line 6.

Fig PEAT2C-11: Chirp subbottom profile from line 6 across PEAT-2C from AMAT-03. Proposed drill site is marked.

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<http://wwwodp.tamu.edu/publications/199_SR/VOLUME/CHAPTERS/226.PDF>.

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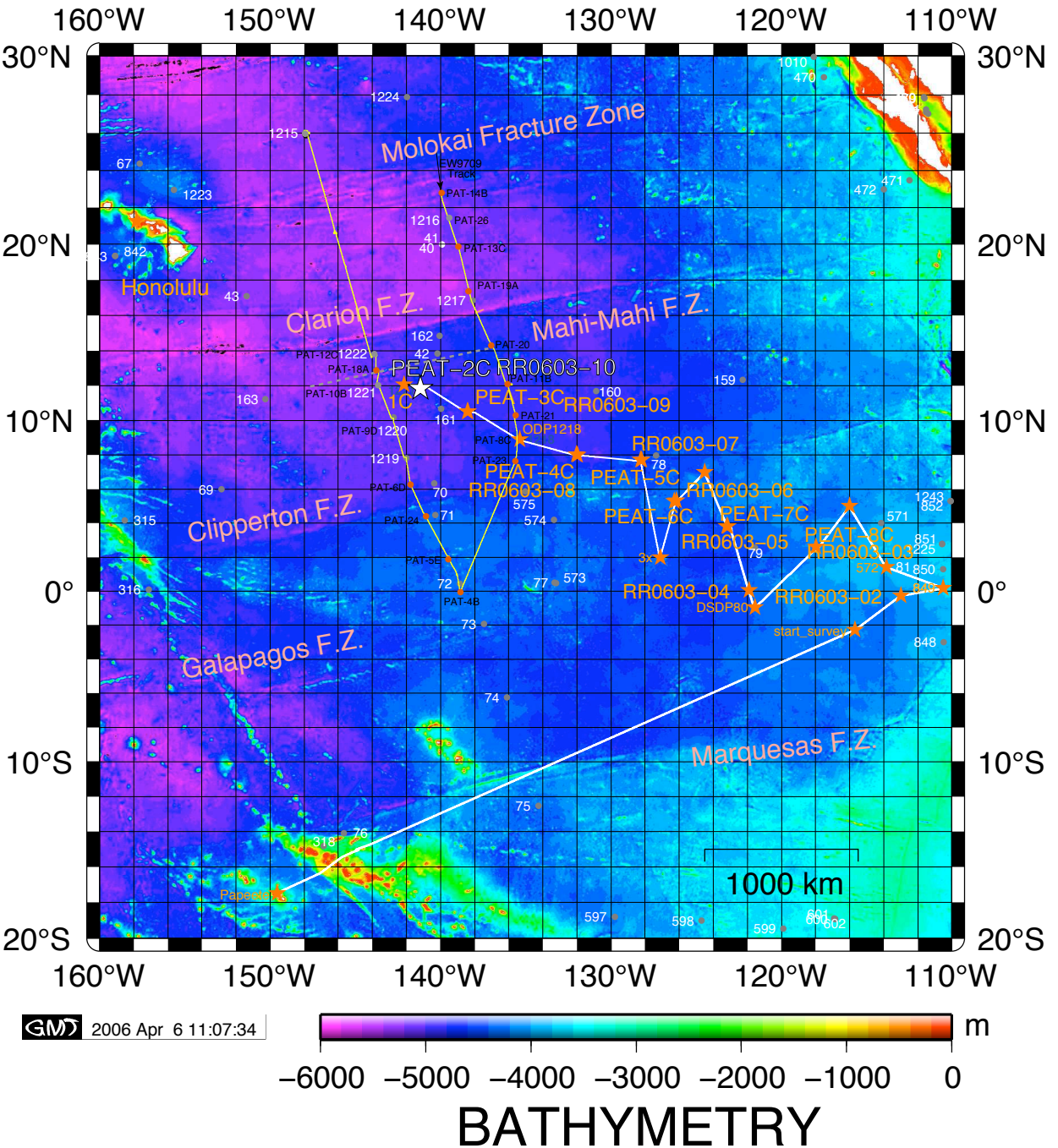
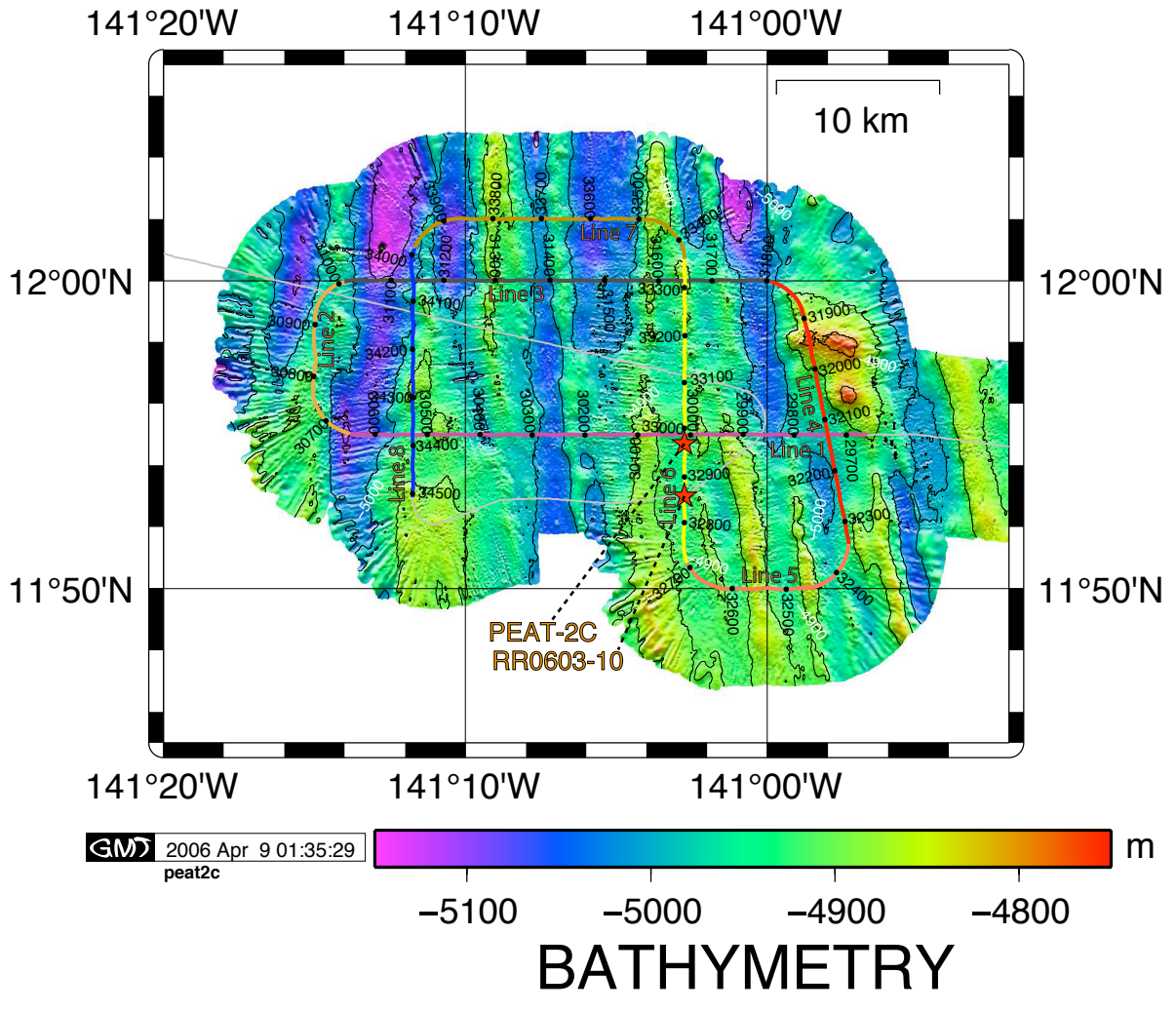
FigPEAT2C-1

# AMAT–03 PEAT–2C OVERVIEW



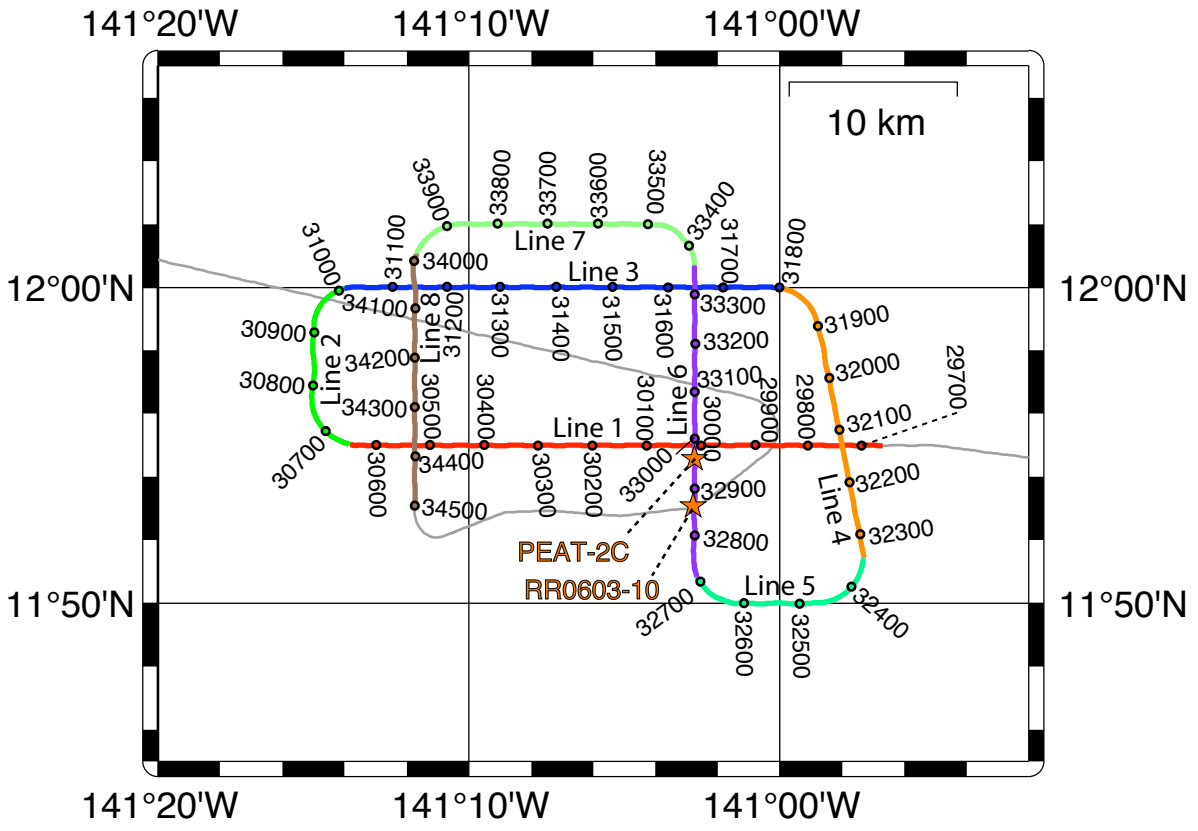
FigPEAT2C-2

# PEAT–2C



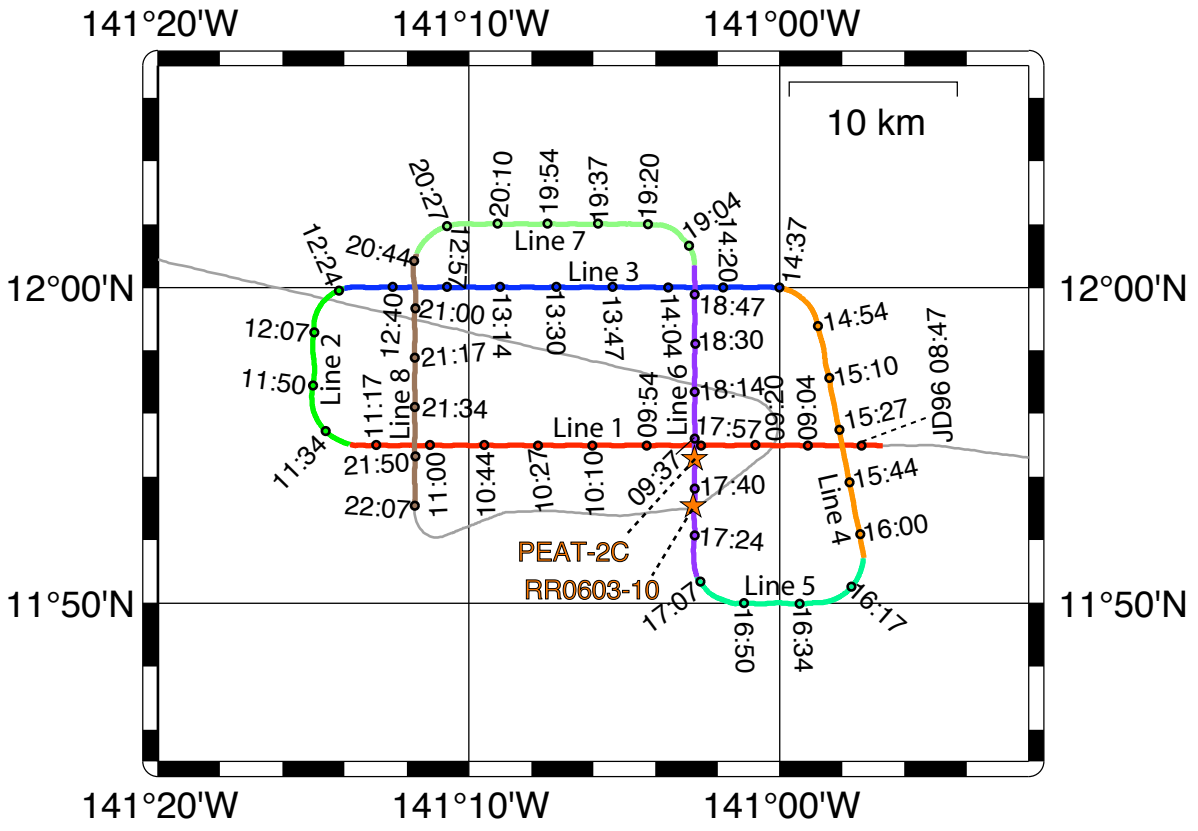
FigPEAT2C-3a

# PEAT–2C

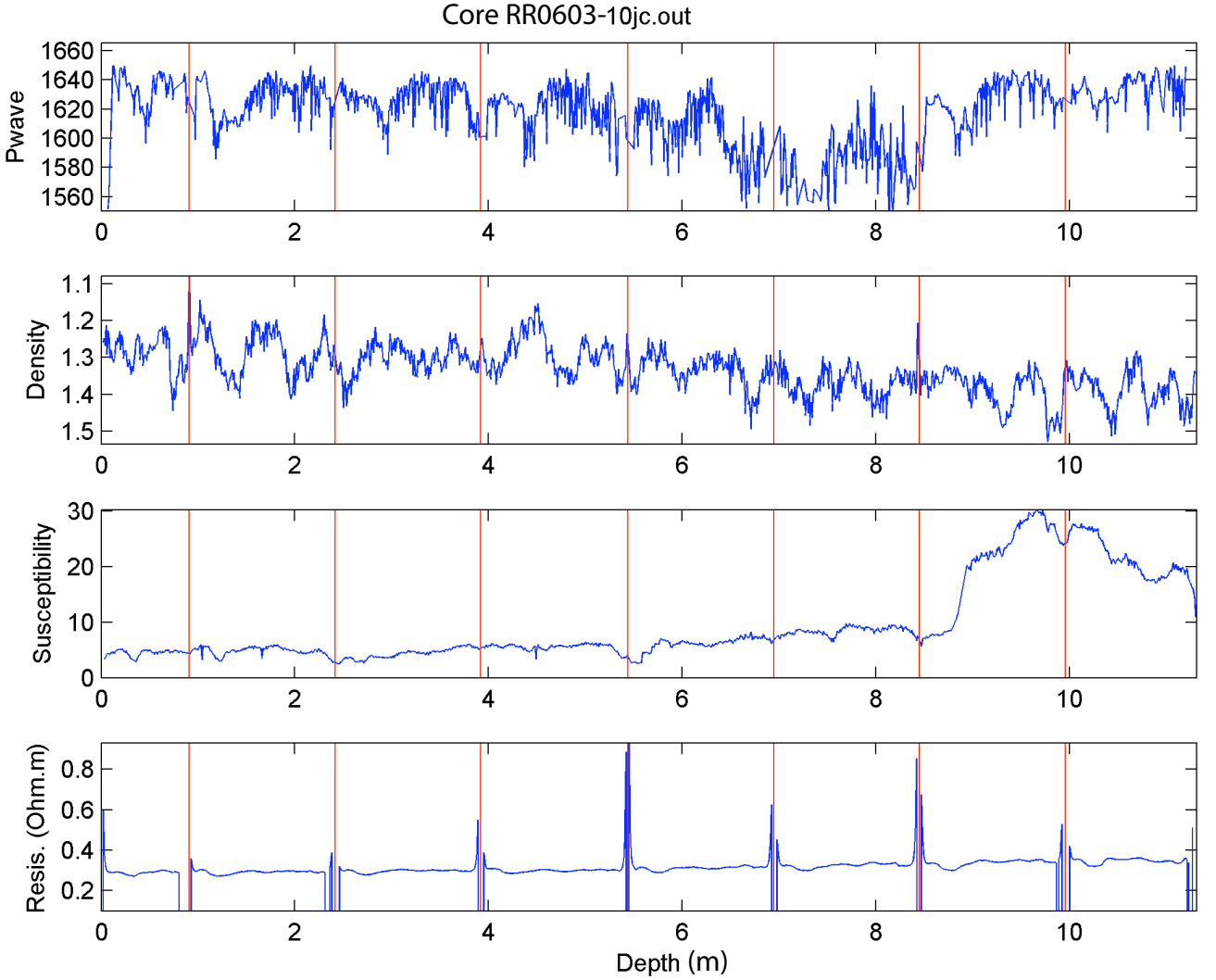


FigPEAT2C-3b

# PEAT–2C



FigPEAT2C-4


Core RR0603-10jc.out
Pwave
1660
1640
1620
1600
1580
1560
0
2
4
6
8
10
Density
1.1
1.2
1.3
1.4
1.5
Susceptibility
30
20
10
0
Resis. (Ohm.m)
0.8
0.6
0.4
0.2
Depth (m)

FigPEAT2C-5

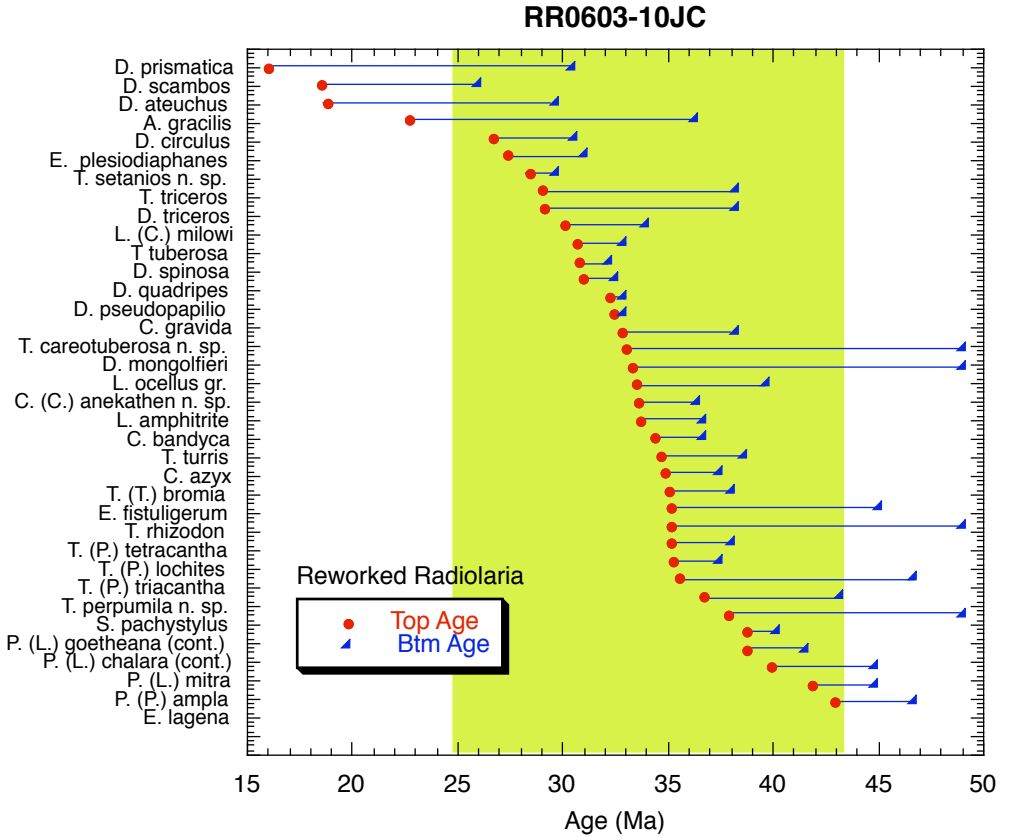

RR0603-10JC
SPECIES
D. prismatica
D. scambos
D. ateuchus
A. gracilis
D. circulus
E. plesiodiaphanes
T. setanios n. sp.
T. triceros
D. triceros
L. (C.) milowi
T tuberosa
D. spinosa
D. quadripes
D. pseudopapilio
C. gravida
T. careotuberosa n. sp.
D. mongolfieri
L. ocellus gr.
C. (C.) anekathen n. sp.
L. amphitrite
C. bandyca
T. turris
C. azyx
T. (T.) bromia
E. fistuligerum
T. rhizodon
T. (P.) tetracantha
T. (P.) lochites
T. (P.) triacantha
T. perpumila n. sp.
S. pachystylus
P. (L.) goetheana (cont.)
P. (L.) chalara (cont.)
P. (L.) mitra
P. (P.) ampla
E. lagena
Reworked Radiolaria
Top Age
Btm Age
15
20
25
30
35
40
45
50
Age (Ma)

Fig PEAT2C-6

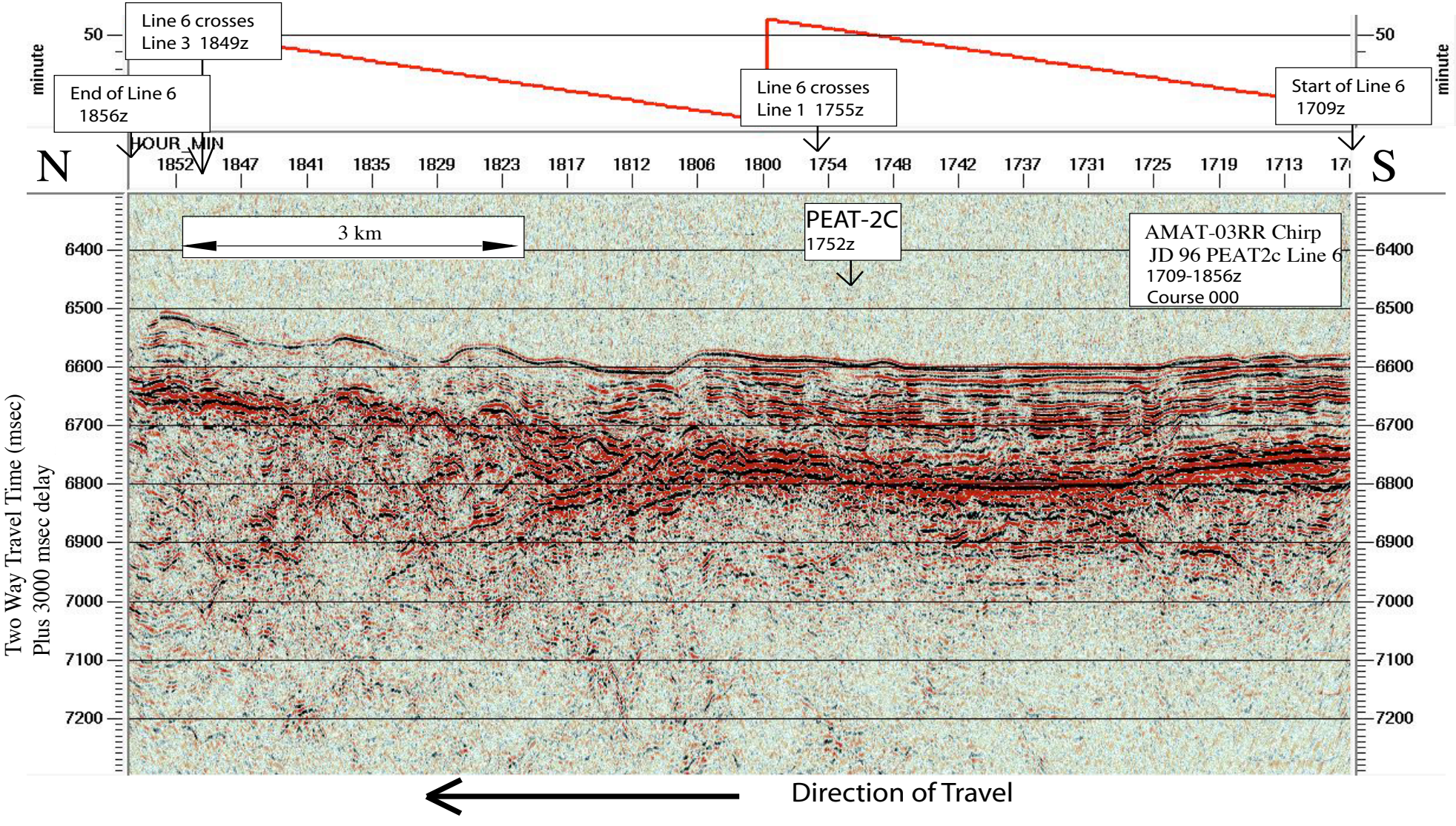
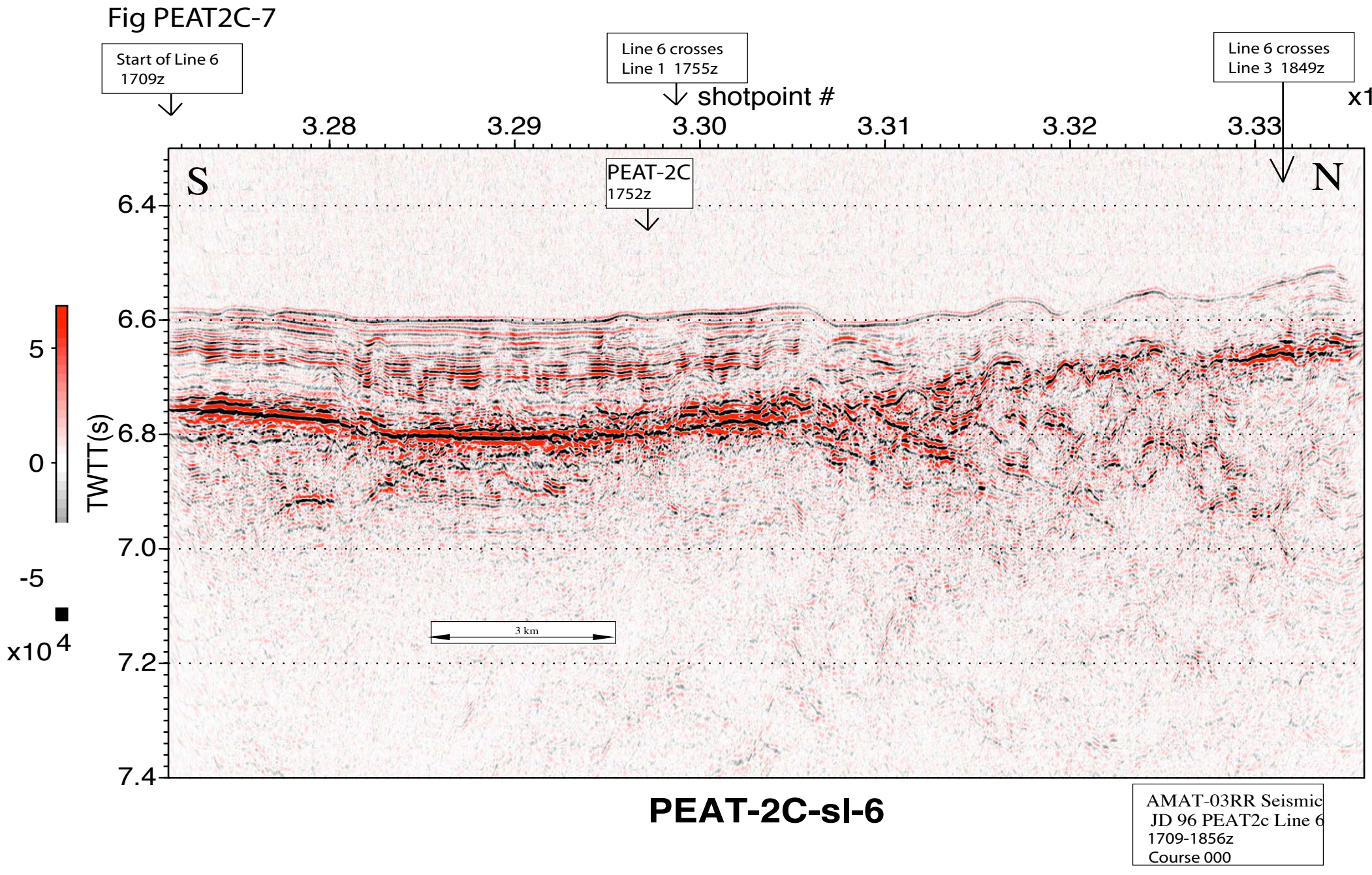

Line 6 crosses
Line 3 1849z
End of Line 6
1856z
Line 6 crosses
Line 1 1755z
Start of Line 6
1709z
minute
50
N
S
HOUR_MIN
1852
1847
1841
1835
1829
1823
1817
1812
1806
1800
1754
1748
1742
1737
1731
1725
1719
1713
3 km
PEAT-2C
1752z
AMAT-03RR Chirp
JD 96 PEAT2c Line 6
1709-1856z
Course 000
6400
6500
6600
6700
6800
6900
7000
7100
7200
Two Way Travel Time (msec)
Plus 3000 msec delay
Direction of Travel

Fig PEAT2C-7


Start of Line 6
1709z
Line 6 crosses
Line 1 1755z
Line 6 crosses
Line 3 1849z
shotpoint #
3.28
3.29
3.30
3.31
3.32
3.33
x1
S
N
PEAT-2C
1752z
6.4
6.6
6.8
7.0
7.2
7.4
TWTT(s)
5
0
-5
x10 4
3 km
PEAT-2C-sl-6
AMAT-03RR Seismic
JD 96 PEAT2c Line 6
1709-1856z
Course 000

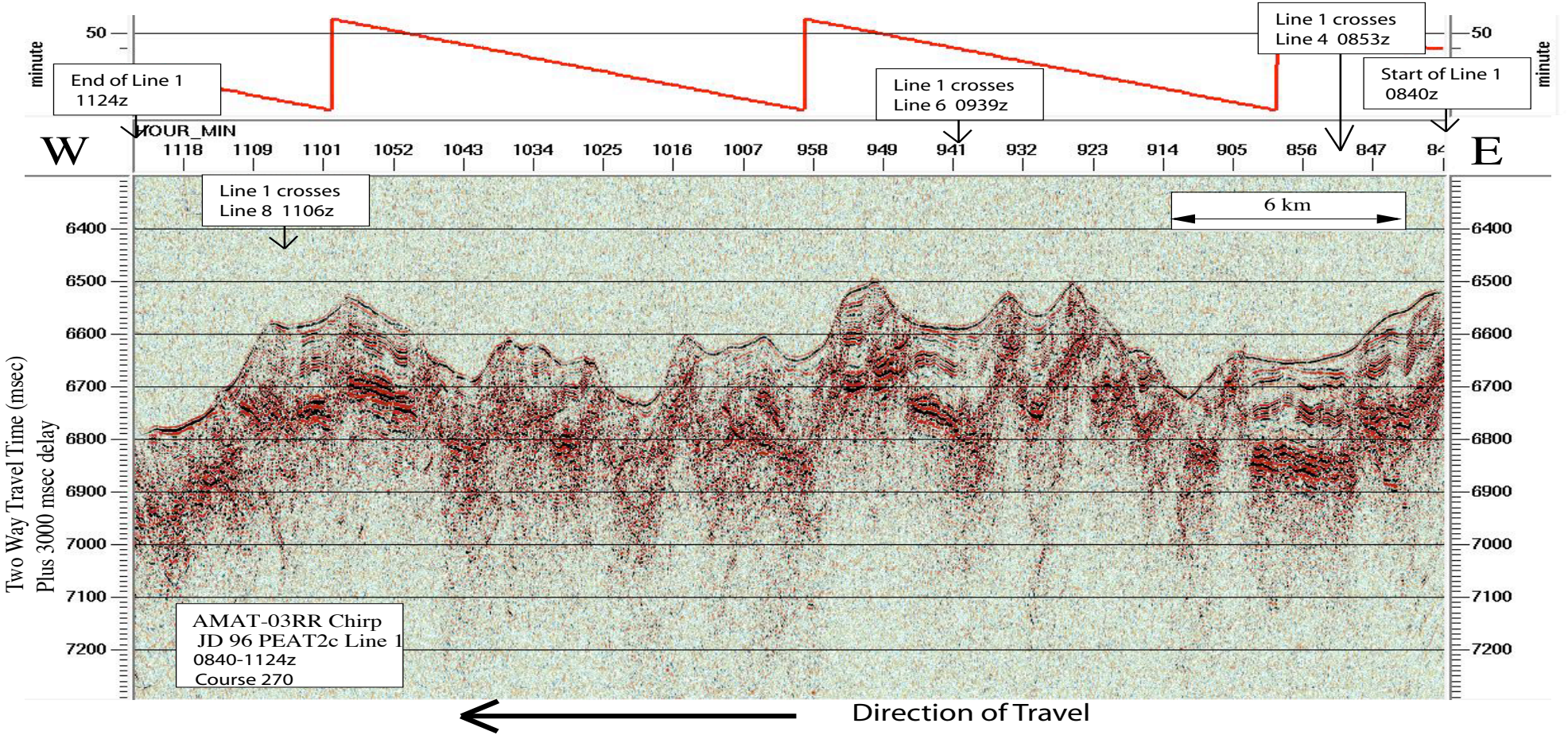

50
minute
End of Line 1
1124z
Line 1 crosses
Line 4 0853z
Line 1 crosses
Line 6 0939z
Start of Line 1
0840z
50
minute
W
HOUR_MIN
1118 1109 1101 1052 1043 1034 1025 1016 1007 958 949 941 932 923 914 905 856 847 84
E
Line 1 crosses
Line 8 1106z
6 km
6400
6500
6600
6700
6800
6900
7000
7100
7200
Two Way Travel Time (msec)
Plus 3000 msec delay
AMAT-03RR Chirp
JD 96 PEAT2c Line 1
0840-1124z
Course 270
Direction of Travel

Fig PEAT2C-9

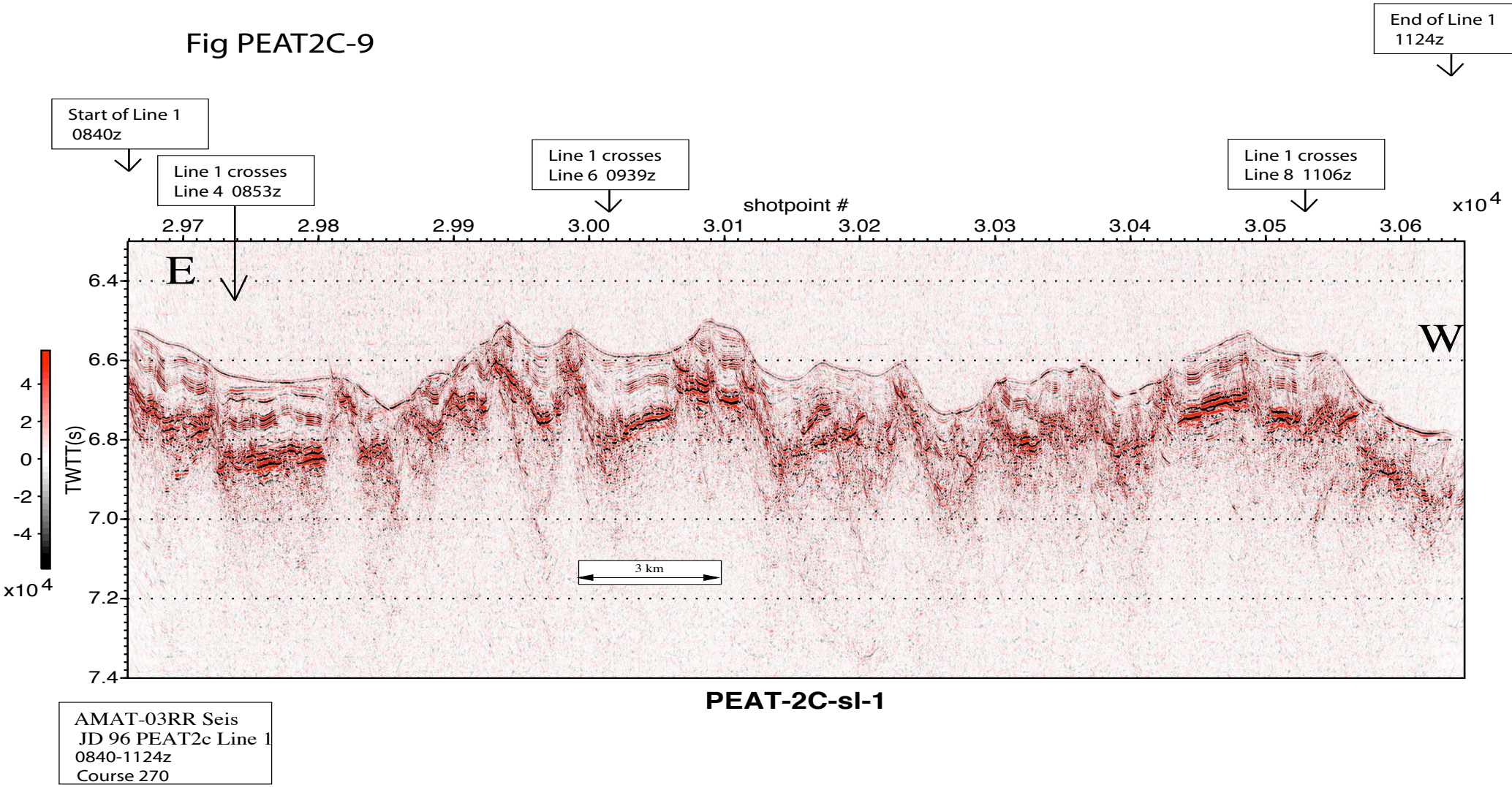

End of Line 1
1124z
Start of Line 1
0840z
Line 1 crosses
Line 4 0853z
Line 1 crosses
Line 6 0939z
Line 1 crosses
Line 8 1106z
shotpoint #
x10 4
2.97
2.98
2.99
3.00
3.01
3.02
3.03
3.04
3.05
3.06
E
W
6.4
6.6
6.8
7.0
7.2
7.4
TWTT(s)
4
2
0
-2
-4
x10 4
3 km
PEAT-2C-sl-1
AMAT-03RR Seis
JD 96 PEAT2c Line 1
0840-1124z
Course 270

Fig PEAT2C-10

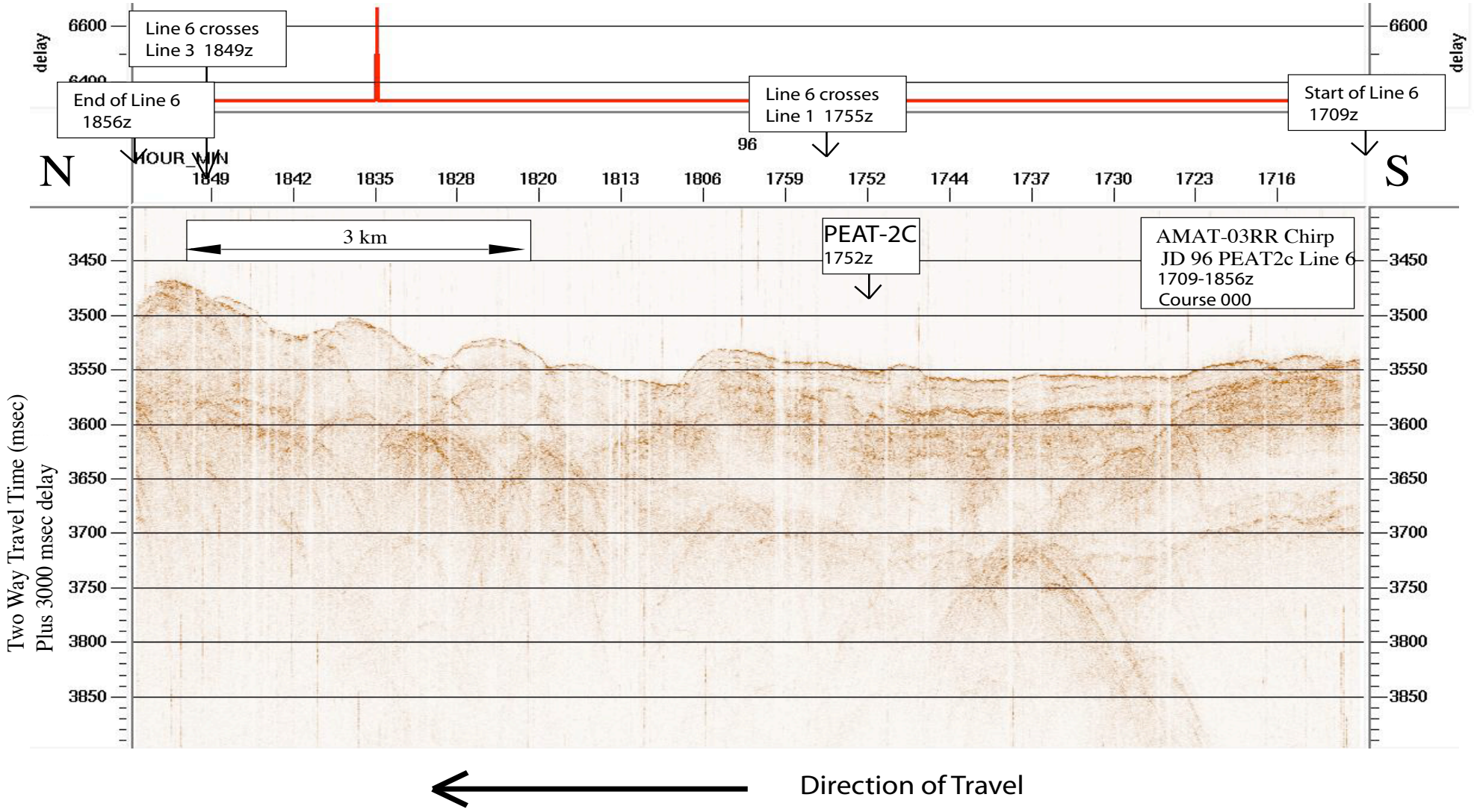
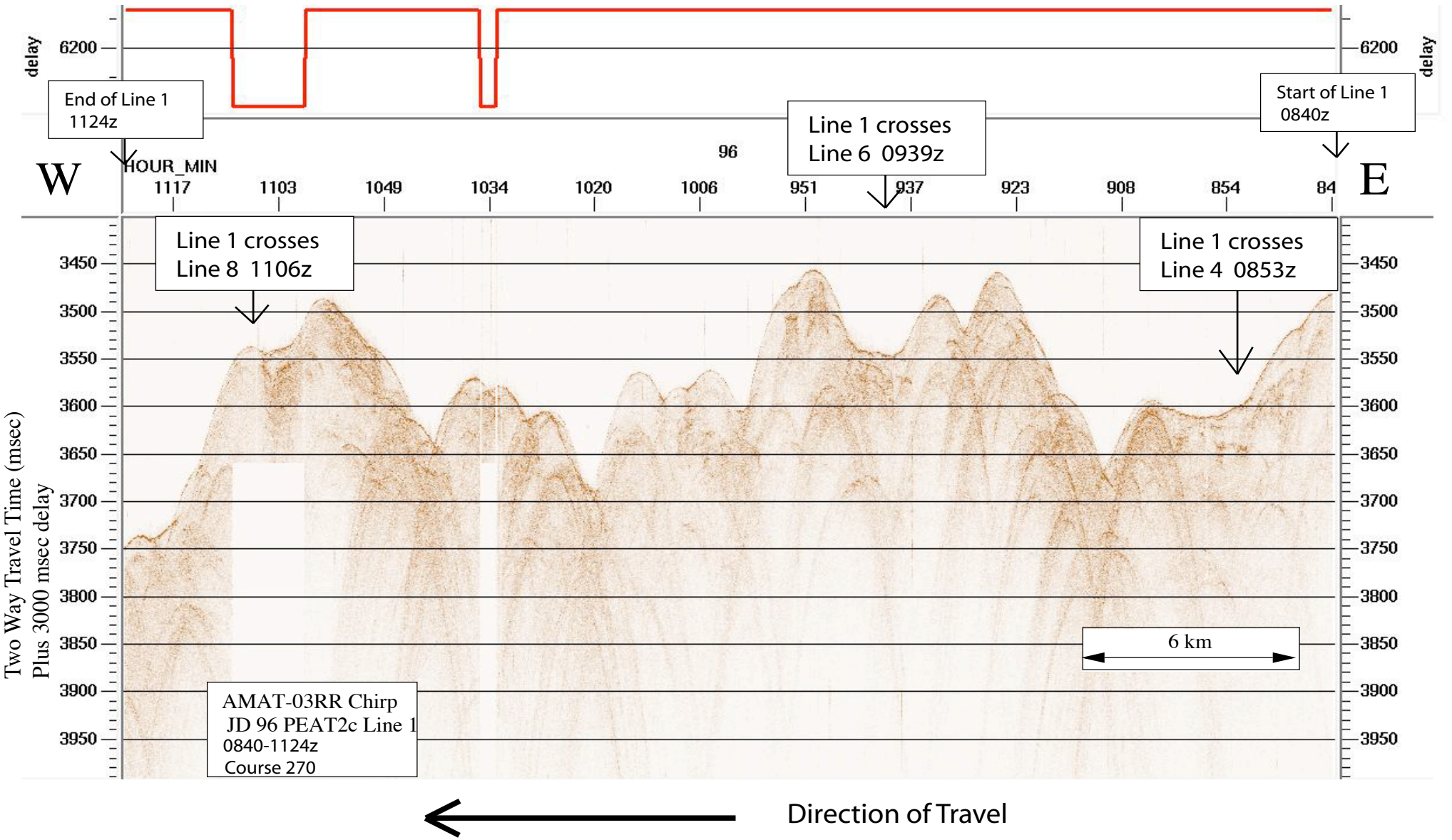


Fig PEAT2C-11

# PEAT2C Chirp, line 1



# SITE PEAT-3C (middle Eocene equator)

# 10° 30.997'N, 138° 25.175'W

## *SITE OBJECTIVES*

Good paleomagnetic stratigraphy in Leg199 Sites allowed a much improved calibration of nannofossil and radiolarian biostratigraphic datums. Together, these stratigraphies allowed the development of a more detailed picture of temporal variations in sediment accumulation through the mid and upper Eocene of the tropical Pacific. These data show a factor of up to 2-3x increase in accumulation rates of siliceous ooze within the middle Eocene (41 to 45 Ma). There are also several notable periods of highly fluctuating CCD, associated with intervals in which carbonate is preserved to 4000 m, or about 700 m deeper than the average Eocene CCD (Lyle, Wilson, Janecek, and the Leg 199 shipboard scientific party. 2002; Lyle et al., 2005; Rea and Lyle, 2005). Such fluctuations in the CCD are similar in magnitude to the Eocene-Oligocene boundary.

High siliceous diatom sedimentation occurs at a time of an apparent short reversal in the mid Eocene cooling trend. It is difficult to interpret the cause of such a substantial change in silica flux during a very warm climatic regime. At the very least we need good carbonate recovery during this interval in order to apply the substantial array of carbonate-based proxies to this interval in order to evaluate the temperature and structure of the near-surface ocean.

Following SSEP recommendations we have positioned the site to the south of the estimated paleo-equatorial position at the target age in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

## *GENERAL DESCRIPTION*

PEAT-3C is located in abyssal hill topography north of the Clipperton Fracture Zone (Figure PEAT3C-2) on 46 Ma crust. There is a general slope in topography to the north, with the southern side of the site being more elevated. Bathymetric relief across the abyssal hills is 75 –150 meters and sediment cover is around 200 msec TWTT.

## *AMAT-03 Survey*

PEAT-3C was surveyed on 4-5 April 2006 (julian days 94 and 95) with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and

150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. We used the 48-channel GeoEel streamer for the site survey and a nominal survey speed of 6 knots. The site was also piston cored, and an 11.3 m core (RR0603-9JC) was recovered.

The PEAT-3 survey area was located above 46 Ma crust on abyssal hill topography. The 48-channel stacked and migrated data reveal a region where the sediment column that had been deposited is eroding away. Outcropping older horizons are common along line 1 and at the northern ends of the cross lines. The coring suggests that the surface sediments were formed about 20 Ma (see below), and give an average sedimentation rate of 7 m/MY for the entire sediment section.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-09JC & TC, 11.27m,
10°31.00'N 138° 23.399'W , 4878 m.

RR0603-9JC&TC were taken to the east of the proposed drillsite on the cross between lines 3 and line 8. The core site is located on a modest rise, with about 200 msec TWTT beneath the core site

The piston core recovered about 4 meters of zeolitic clay, then 2 meters of radiolarian clay overlying early Miocene carbonates. The change in lithology is clearly shown by the increase in density and resistivity at about 6 m downcore (Figure PEAT3C-4). The carbonate section consists of alternating nannofossil ooze and radiolarian nannofossil ooze in meter-scale cycles. The base of the piston core dates to about 21 Ma based upon the combined radiolarian and nannofossil stratigraphy. The sedimentation rates are modest in the carbonate section, beginning at about 11 m/ M.Y. in the early Miocene, but slowing upcore to 3 m/M.Y. above 800 cm (Fig PEAT3C-5). The zeolitic clay accumulated very slowly—only 4 m in about 19 million years.

## *SEISMIC INTERPRETATION*

**Primary Site (PEAT-3C):**
AMAT-03-PEAT3C line 3, 2006 JD094 20:27:35UTC, SP 21183.
Nearest crossing : of PEAT3C: line 8 at
2006 JD095 03:47:46UTC, SP 23824

Crustal age: 46 Ma
Ship location @ SP21183: 10°30.999'N 138° 25.123'W
PEAT-3C Location: 10° 30.997'N, 138°25.175'W
Site water depth: 4874 m (6.498 sec TWTT)
Basement depth: 5048 m (6.719 sec TWTT)
Sediment thickness: 0.221 sec TWTT(174m using Site 574 velocity profile)
Proposed Drilling Depth: 174m, to just tag basement

**Alternate Site (PEAT-3D):**
AMAT-03-PEAT3C line 6, 2006 JD095 00:43:29UTC, SP 22721.
Nearest crossing : PEAT3C line 3 crosses line 6 at 2006 JD094 21:18:15UTC, SP 21487

Crustal age: 46 Ma
Ship location @ SP22721: 10° 32.772'N 138°20.188'W
PEAT-3D Location: 10° 32.720'N 138° 20.183'W
Site water depth: 4889 m (6.519 sec TWTT)
Basement depth: 4696 m (6.748 sec TWTT)
Sediment thickness: 0.229 sec TWTT (181 m using Site 574 velocity profile)
Proposed Drilling Depth: 181m

*Velocity Table from Site 574, Mayer et al., 1985:*

| **Depth (mbsf)** | **TWTT (ms)** | **Velocity (m/s)** |
|---|---|---|
| 0-76 | 0-100 | 1520 |
| 76-151 | 100-193 | 1613 |
| 151-330 | 193-410 | 1650 |
| >330 | >410 | 1970 |

PEAT-3C was chosen slightly west of the intersection between line 3 and line 8, to maximize the thickness of the deeper section (Figures PEAT3C-6 to –8). The cross with line 8, unfortunately, was just south of a minor basement hill. The low amplitudes of the seismic horizons suggest that the sediment is not lithified, fitting in with the shallow depth to basement. PEAT-3C is a relatively small target, about 720 m across.

A second site, PEAT-3D was chosen as an alternate. It is located about 2 km north of the cross between lines 6 and 3 along line 6 (Figures PEAT3C-9 and –10). The alternate site has a thinner basal sediment section although the total sediment column is slightly thicker. Chirp subbottom profiling occasional reveals indistinct horizons to about 60 m subsurface. However, over most of the area few or no subsurface horizons can be distinguished using chirp.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-3C Line 1
PEAT-3C Line 2
PEAT-3C Line 3
PEAT-3C Line 4
PEAT-3C Line 5
PEAT-3C Line 6
PEAT-3C Line 7
PEAT-3C Line 8

## FIGURES

Fig PEAT3C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-3C is marked.

Fig PEAT3C-2: Swathmap bathymetry for the PEAT-3C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-09JC are marked.

Fig PEAT3C-3a: Map of shotpoints and seismic lines in the PEAT-3C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-09JCare marked.

Fig PEAT3C-3b: Map of survey times and seismic lines in the PEAT-3C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-09JC are marked.

Fig PEAT3C-4: MST physical properties data for RR0603-09JC.

Fig PEAT3C-5: Sedimentation rates for RR0603-09JC based on shipboard radiolarian and nannofossil biostratigraphy. Shallow carbonates are early Miocene in age, overlain by nonfossiliferous red clay.

Fig PEAT3C-6: a) western half of Seismic profile PEAT-3C line 3 across PEAT-3C from AMAT-03. b) the eastern half of PEAT-3C line 3 profile forms the nearest crossline with line 6 near PEAT-3D. Both halves are annotated in UTC. All profiles are filtered, stacked, and migrated.

Fig PEAT3C-7: PEAT3-C line 3, annotated in shotpoints. All profiles are filtered, stacked, and migrated.

Fig PEAT3C-8: Crossline seismic profile PEAT-3C line 8 from AMAT-03, annotated in UTC. Site was moved w of the crossline along line 3 to an area with clear older seismic horizons. All profiles are filtered, stacked, and migrated.

Fig PEAT3C-9: Alternate Site PEAT-3D shown on PEAT3C line 6, annotated in UTC. The site was moved north of the cross with line 3 to an area with a better-defined sediment column.

Fig PEAT3C-10: Alternate Site PEAT-3D shown on PEAT3C line 6, annotated in shotpoints. The site was moved north of the cross with line 3 to an area with a better-defined sediment column.

Fig PEAT3C-11: Chirp subbottom profile from line 3 across PEAT-3C, from AMAT-03.Proposed drill site is marked.

Fig PEAT3C-12: Chirp subbottom profile from line 6 across PEAT-3D, the alternate drillsite, from AMAT-03.Proposed drill site is marked.

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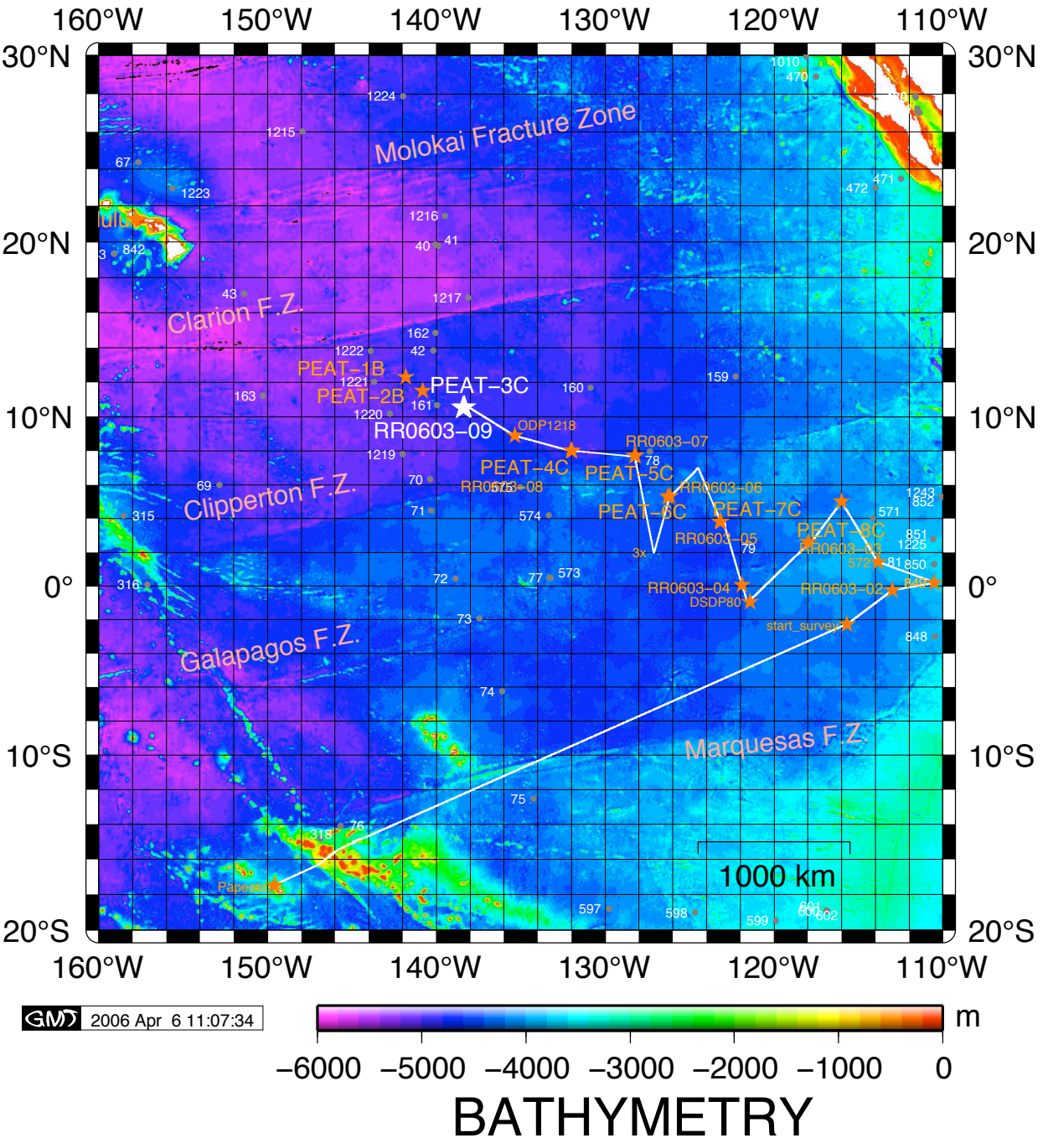
Sager, W.W., and M.S. Pringle, Mid-Cretaceous to Early Tertiary apparent polar wander path of the Pacific plate, J. Geophys. Res., 93, 11753-11771, 1988.

FigPEAT3C-1

# AMAT–03 PEAT–3C OVERVIEW



FigPEAT3C-2

# PEAT–3C

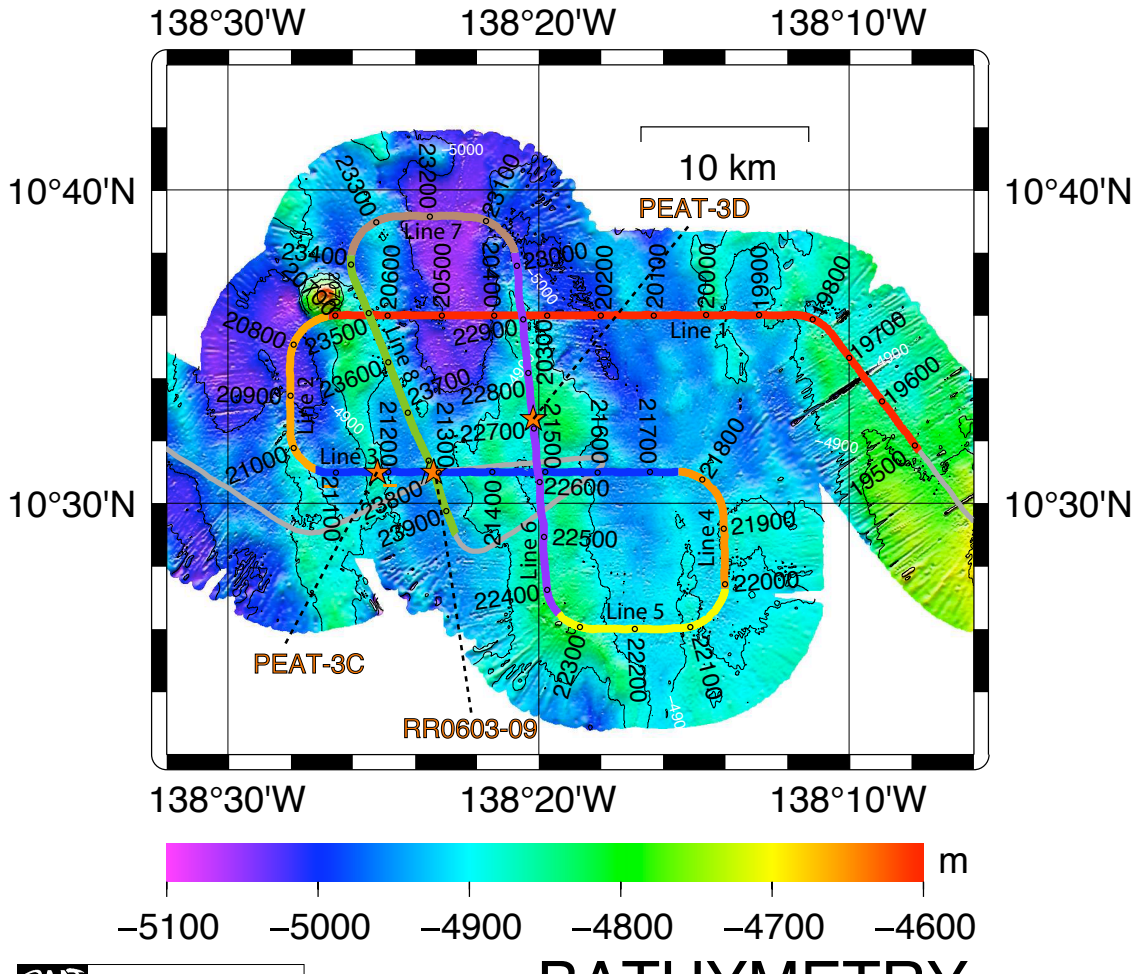


Fig PEAT3C-3a

# PEAT–3C

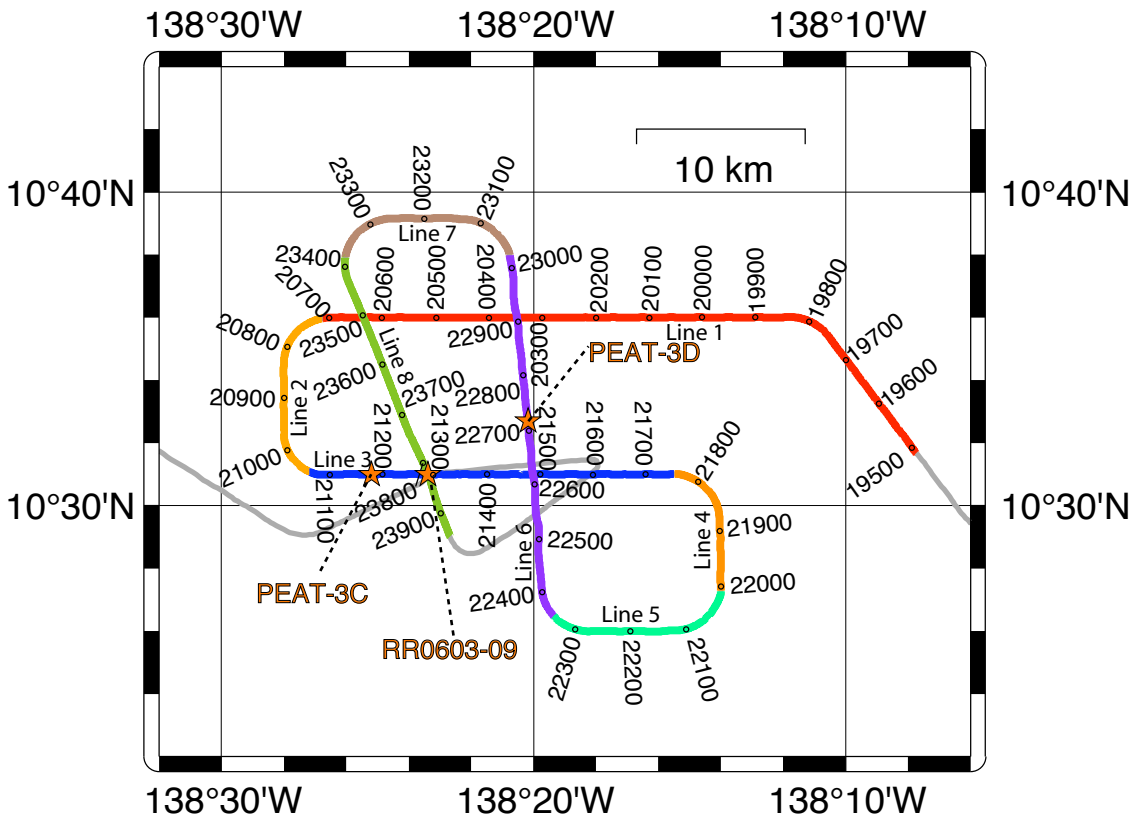
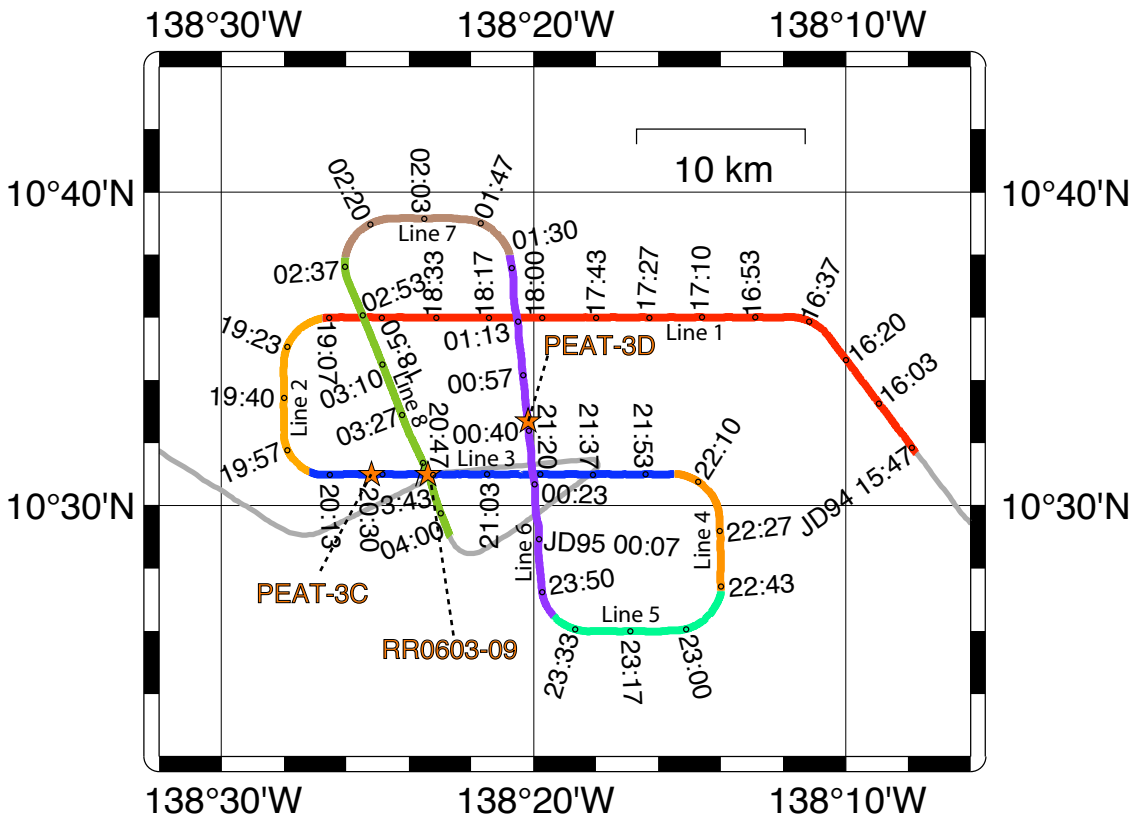
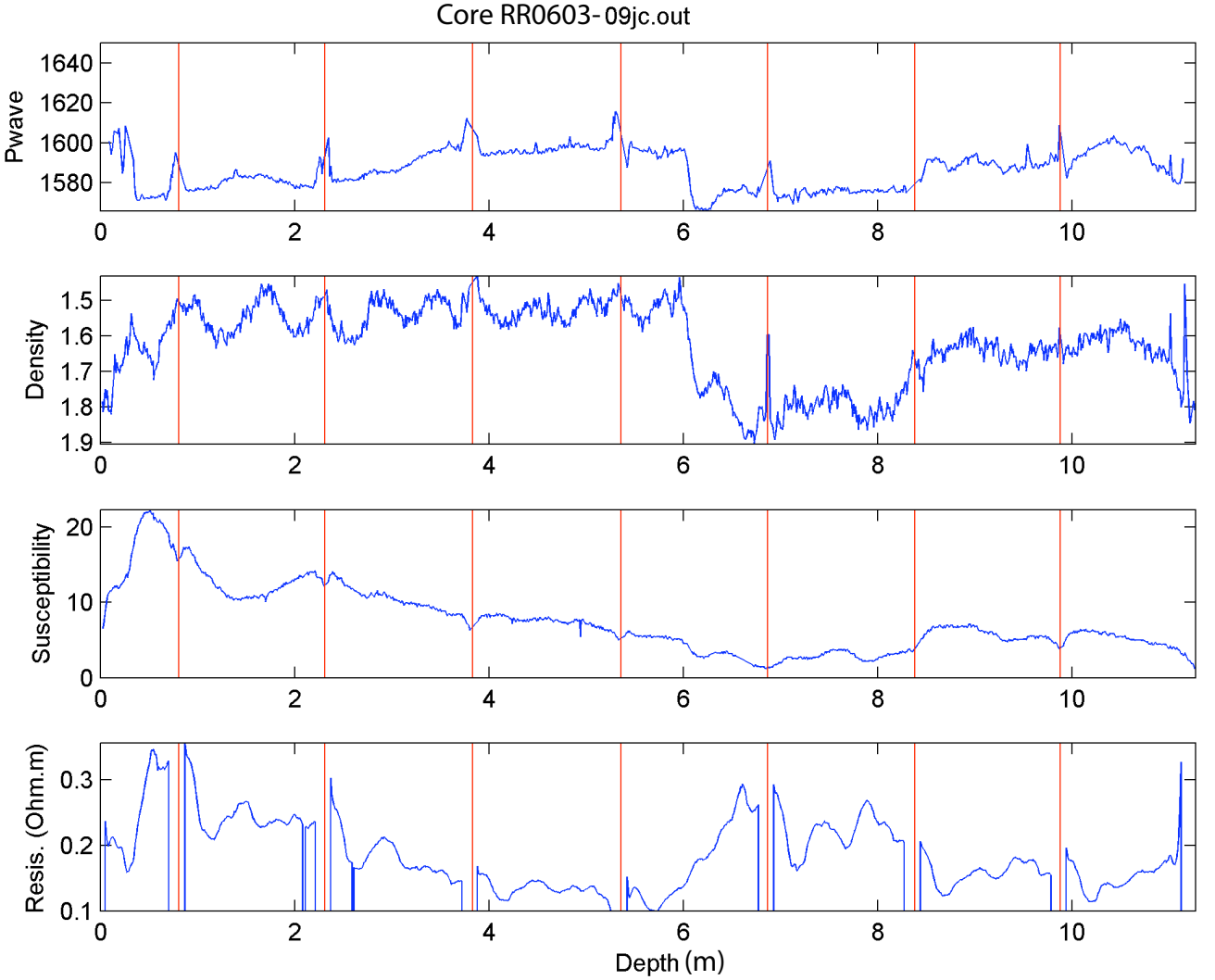


Fig PEAT3C-3b

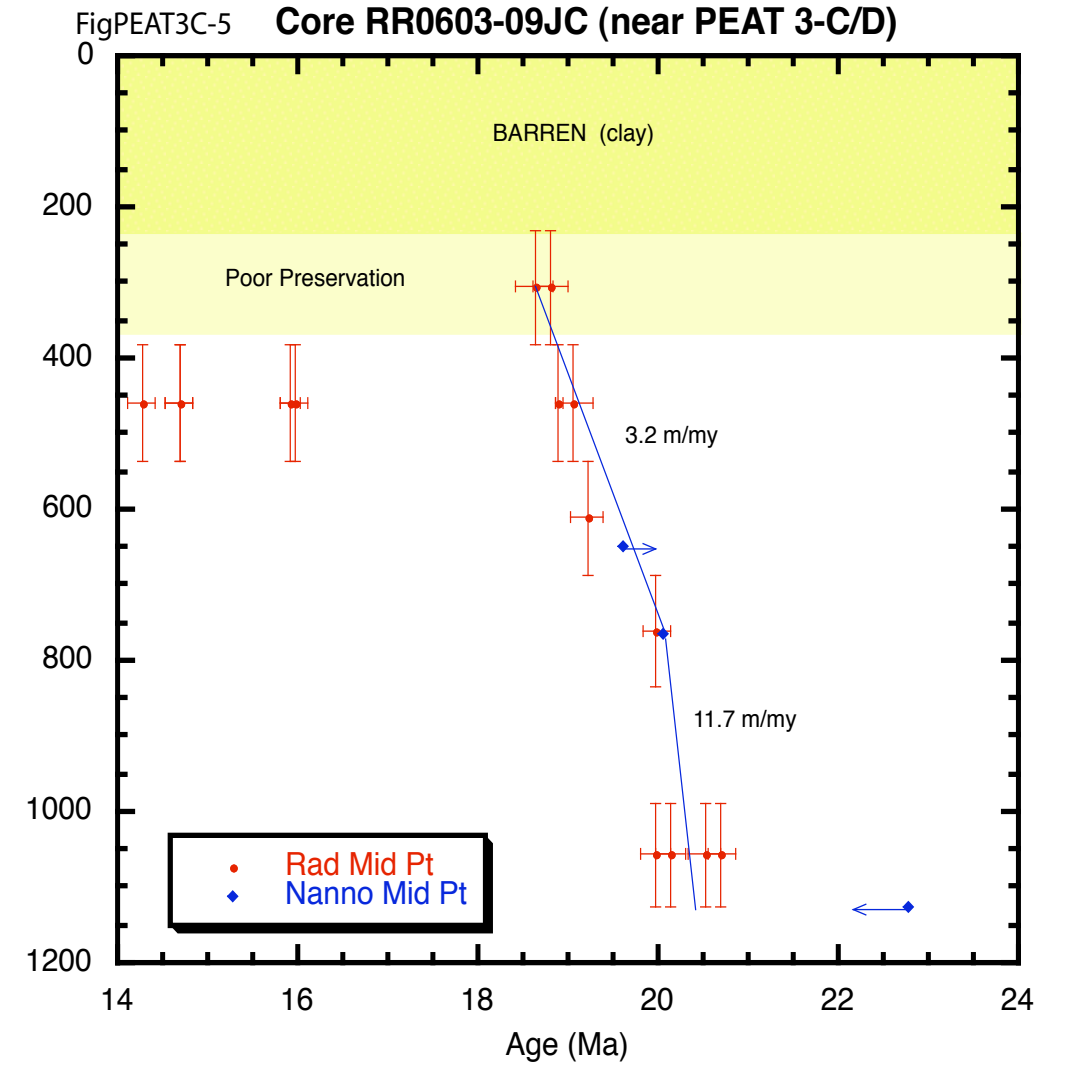
# PEAT–3C



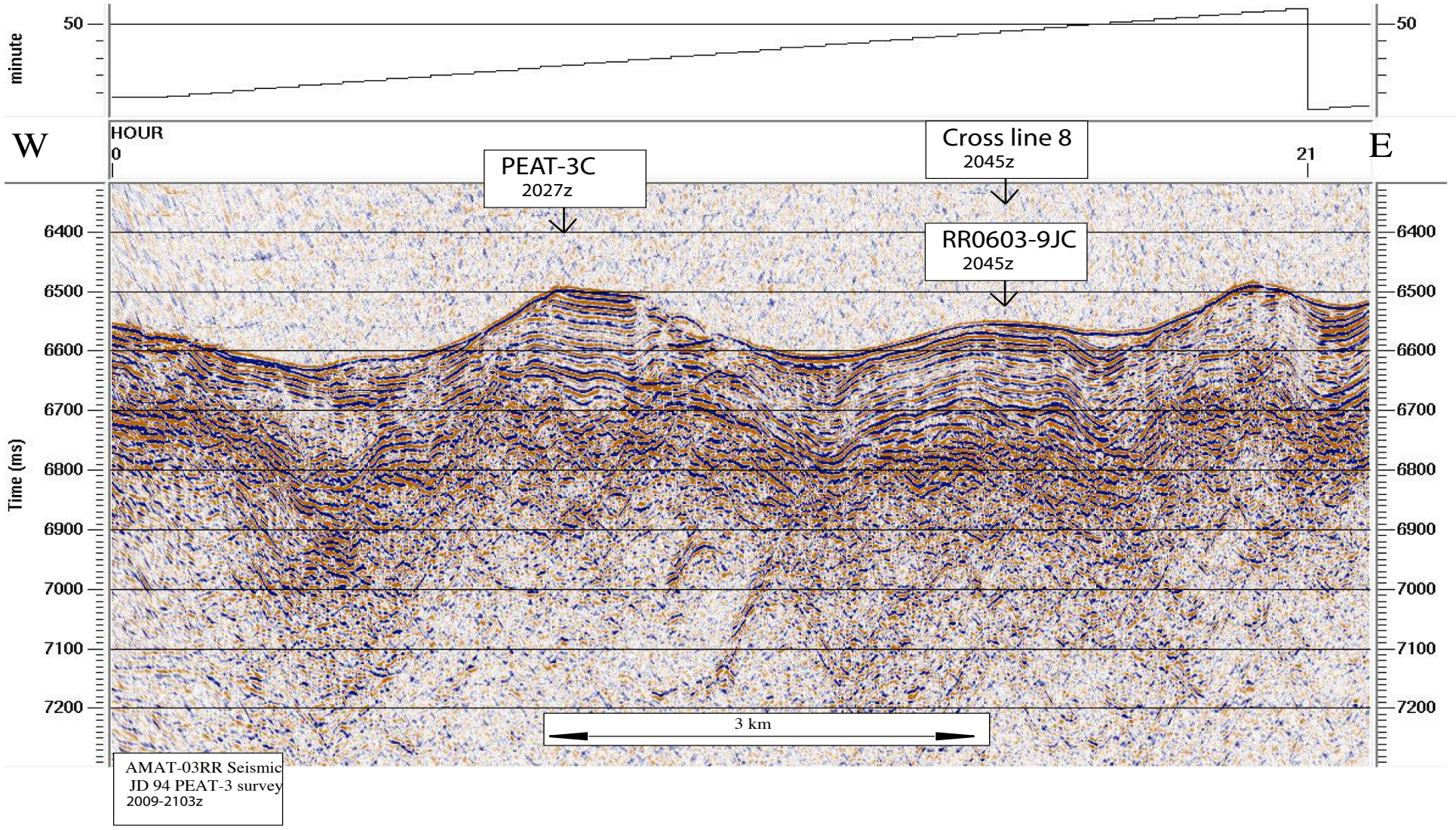
FigPEAT4C-4


Core RR0603-09jc.out
Pwave
1640
1620
1600
1580
0
2
4
6
8
10
Density
1.5
1.6
1.7
1.8
1.9
Susceptibility
20
10
0
Resis. (Ohm.m)
0.3
0.2
0.1
Depth (m)

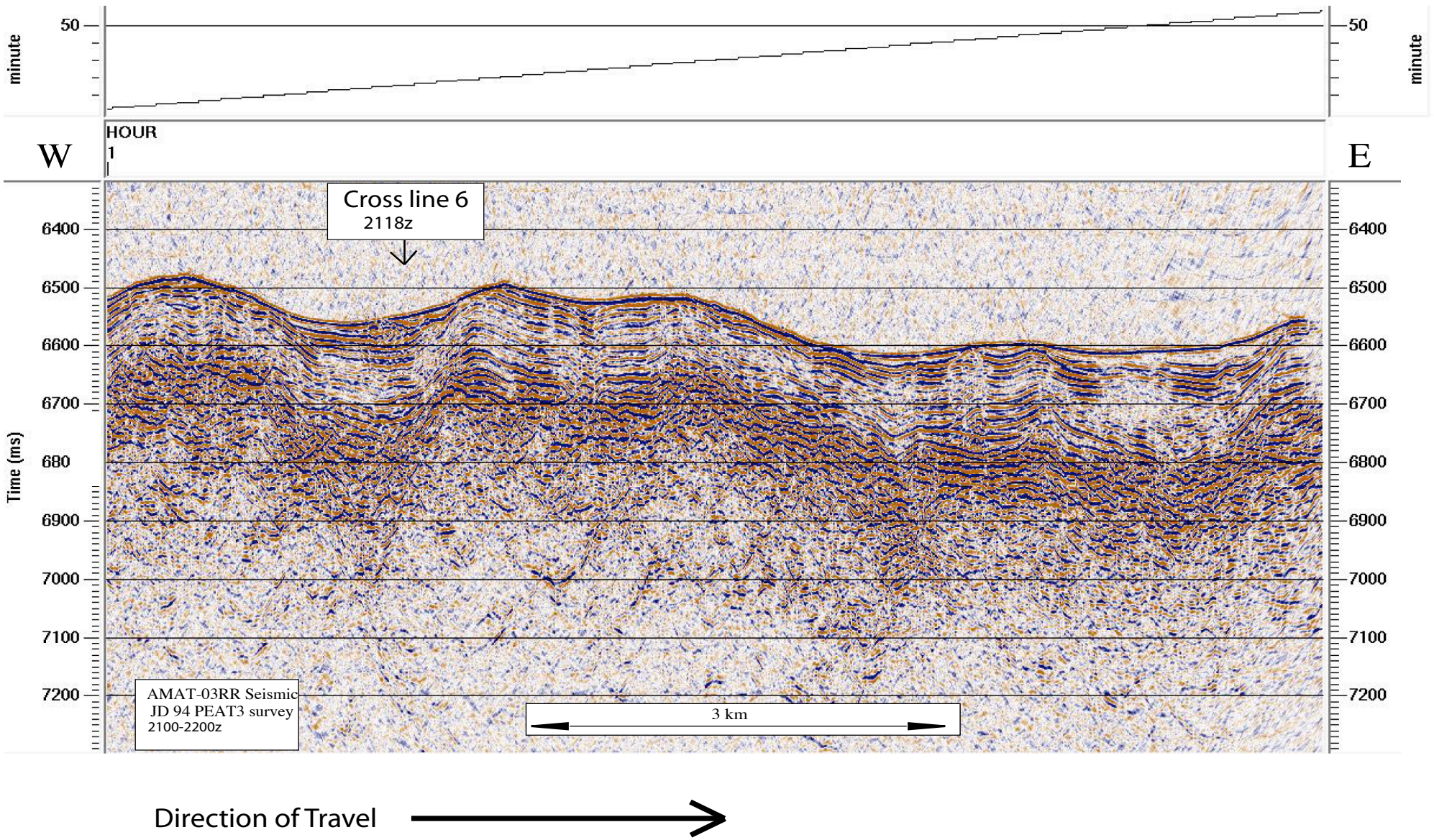
FigPEAT3C-5


Core RR0603-09JC (near PEAT 3-C/D)
BARREN (clay)
Poor Preservation
3.2 m/my
11.7 m/my
Rad Mid Pt
Nanno Mid Pt
0
200
400
600
800
1000
1200
14
16
18
20
22
24
Age (Ma)

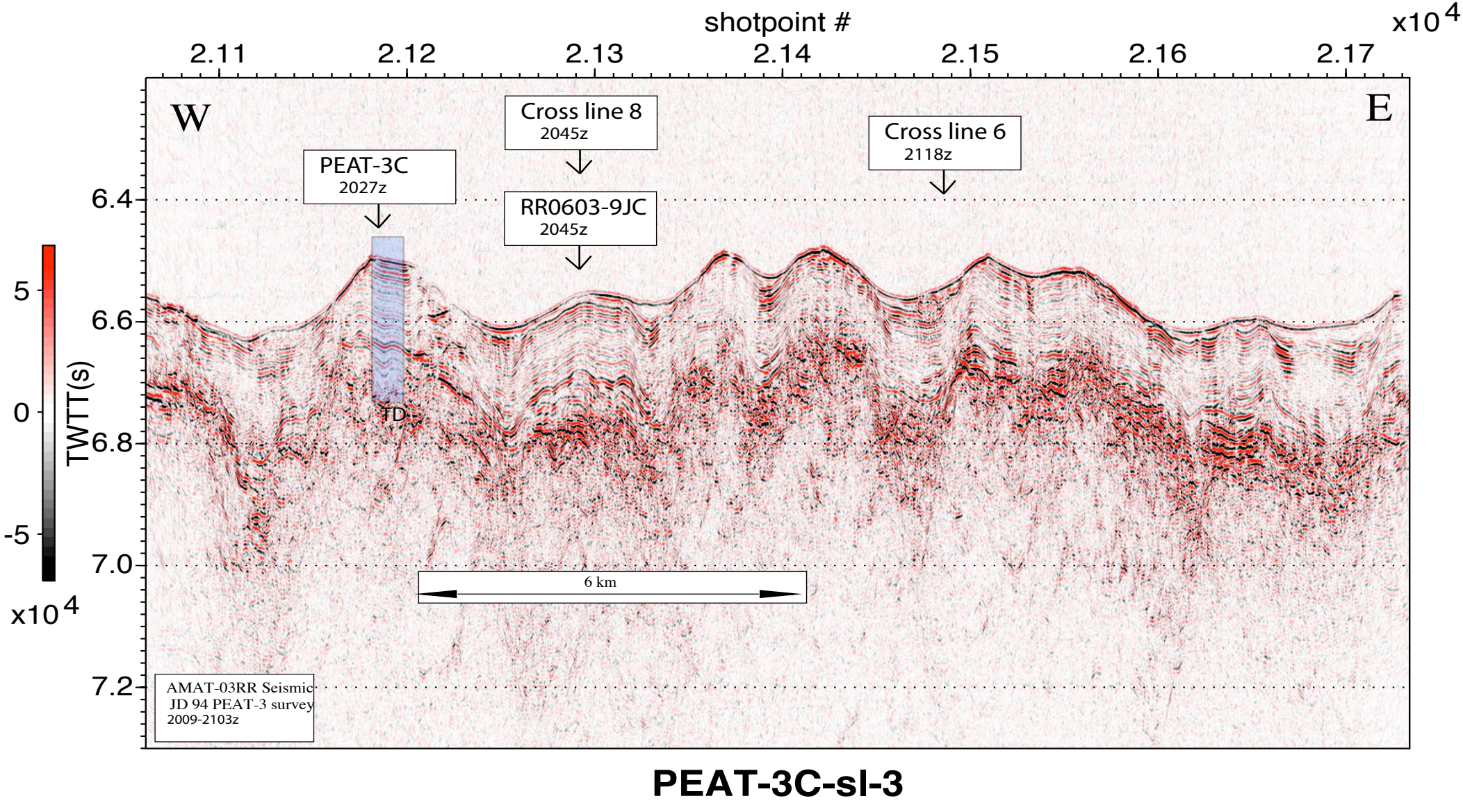
# FigPEAT3C-6a: PEAT-3C Line 3, west



# FigPEAT3C-6b: PEAT-3C Line 3, east

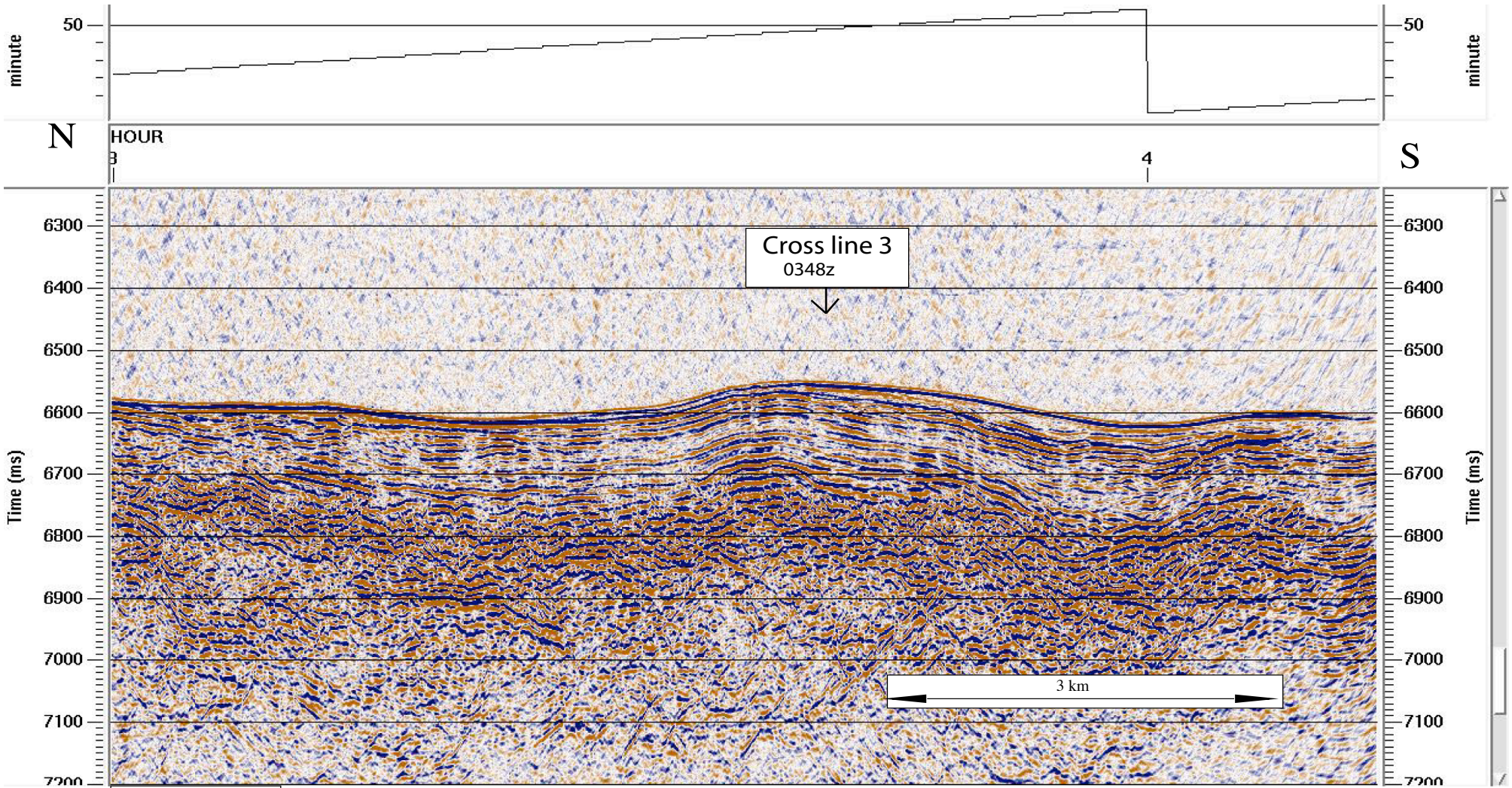


# FigPEAT3C-7: PEAT-3C Line 3

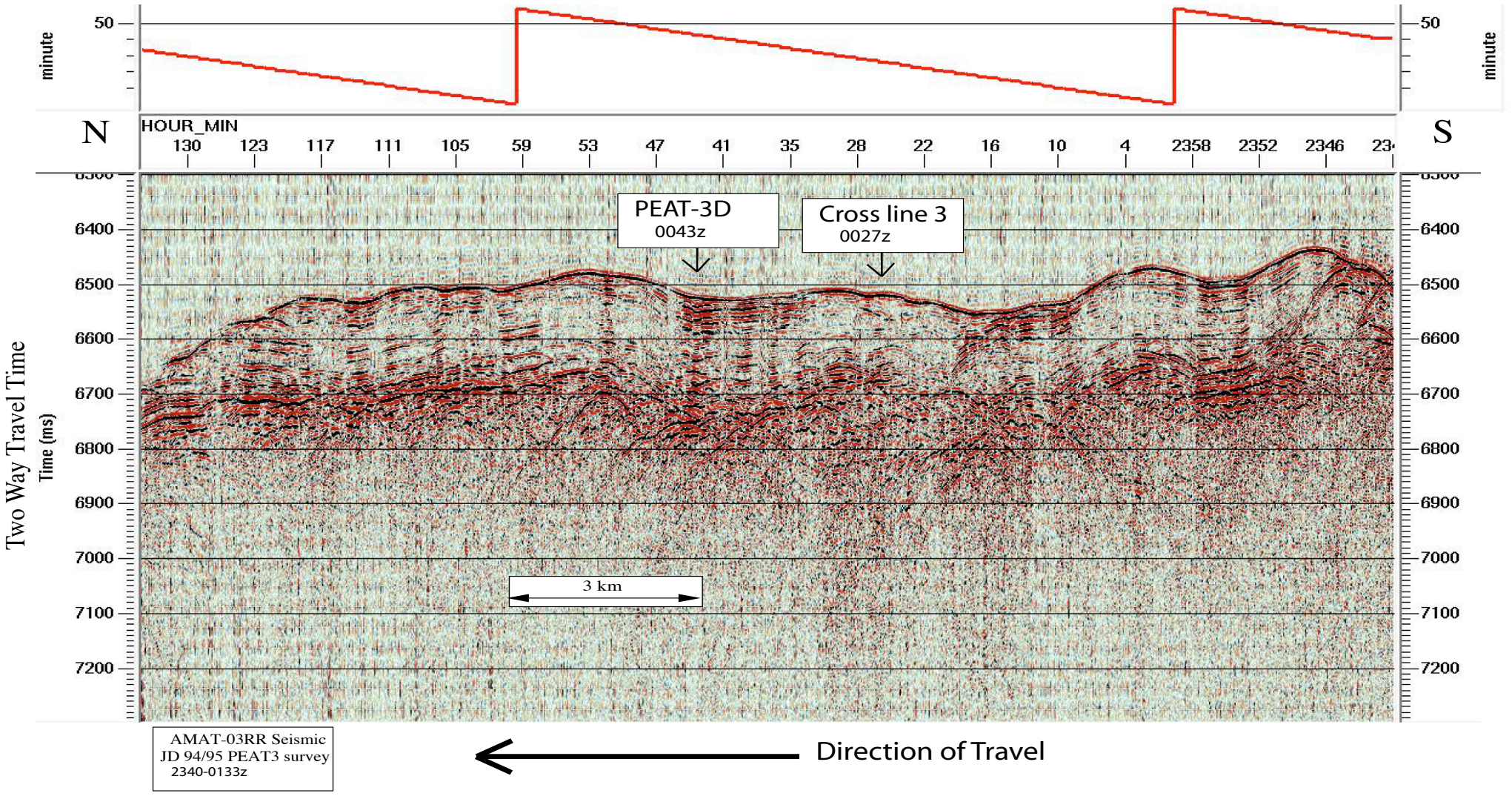



**PEAT-3C-sl-3**

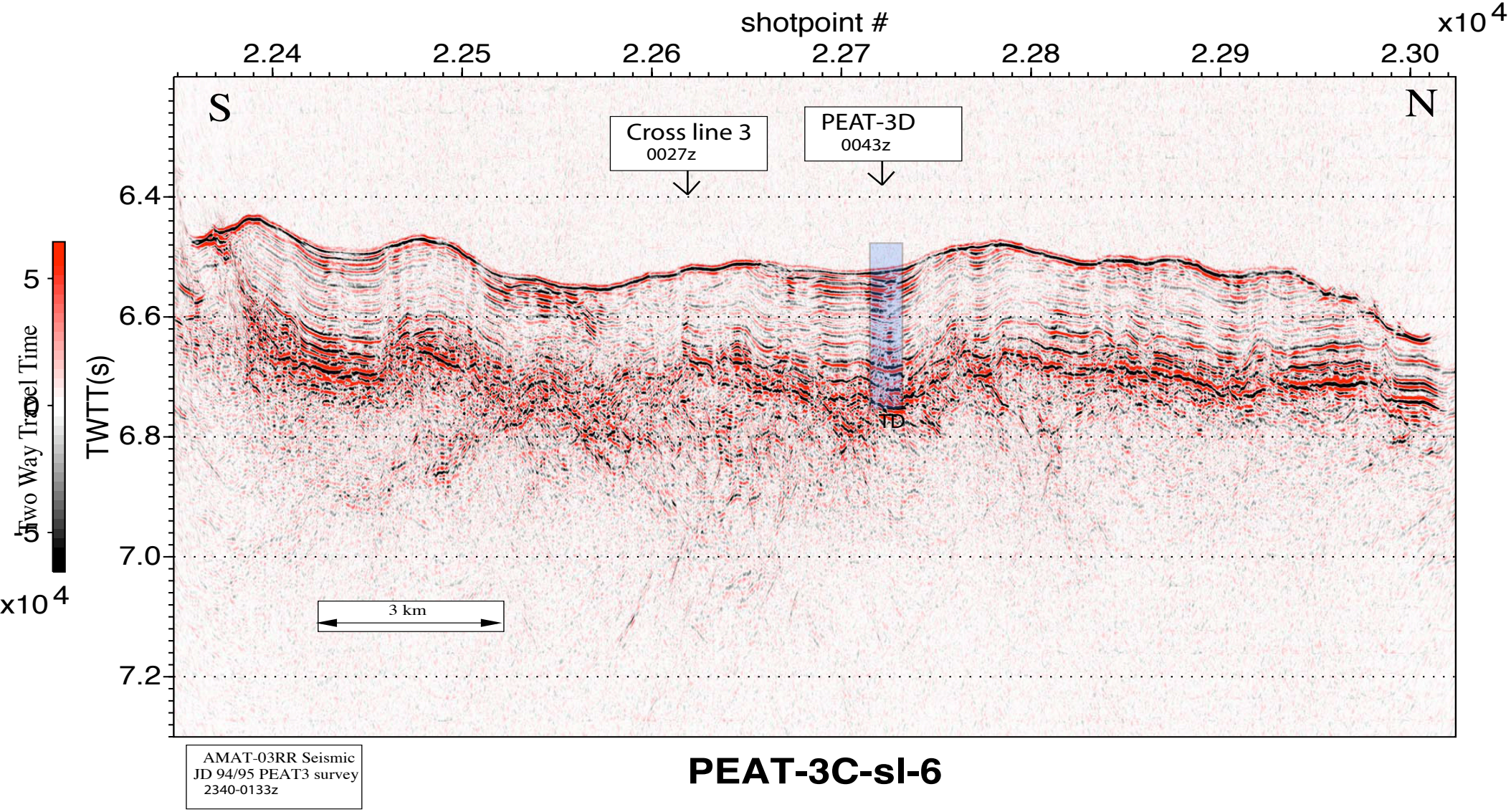
# FigPEAT3C-8: PEAT-3C Line 8, south



# FigPEAT3C-9: PEAT-3C Line 6



# FigPEAT3C-10: PEAT-3C Line 6



# Fig PEAT3C-11
# PEAT-3C Line 3, Chirp

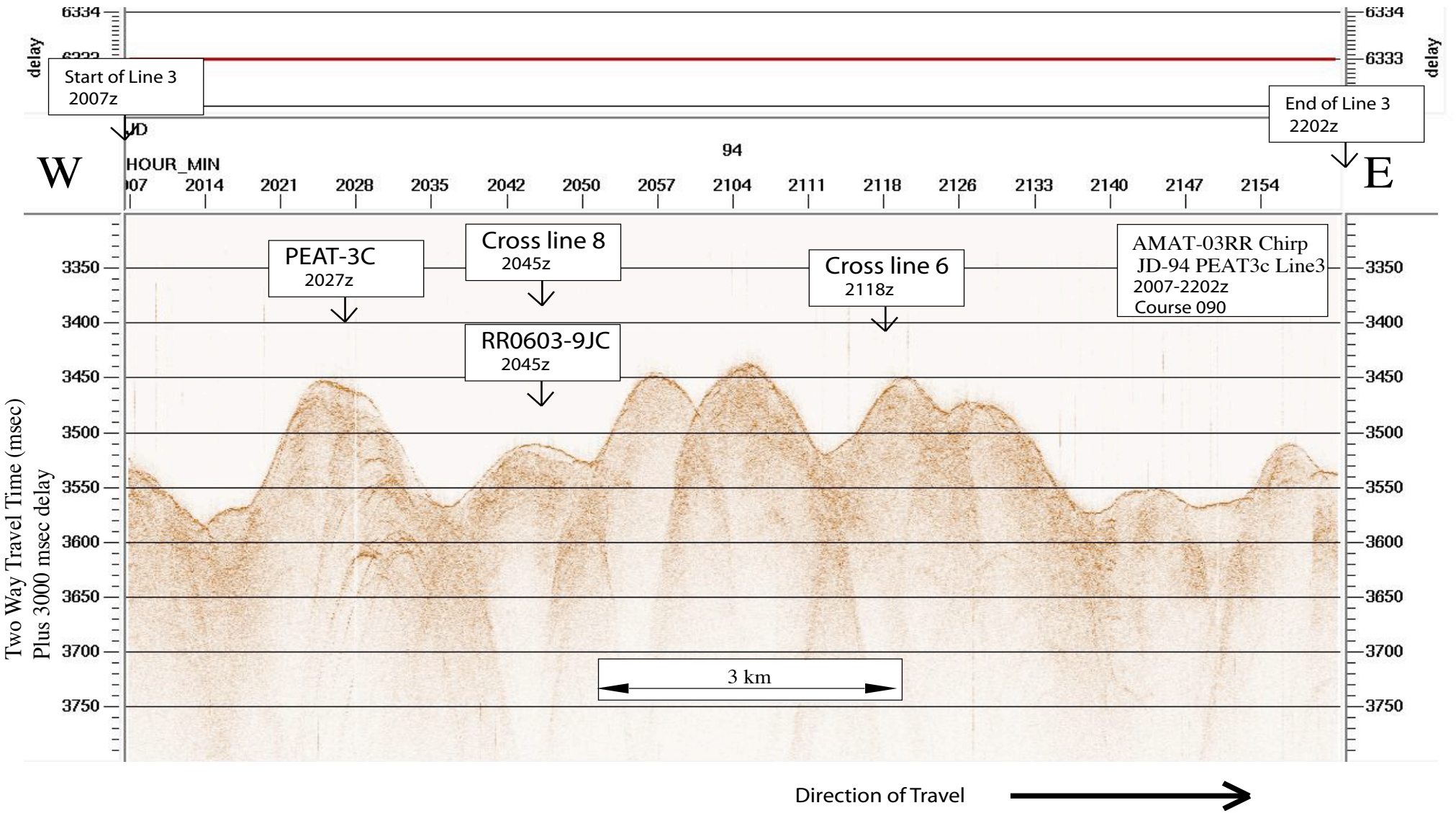
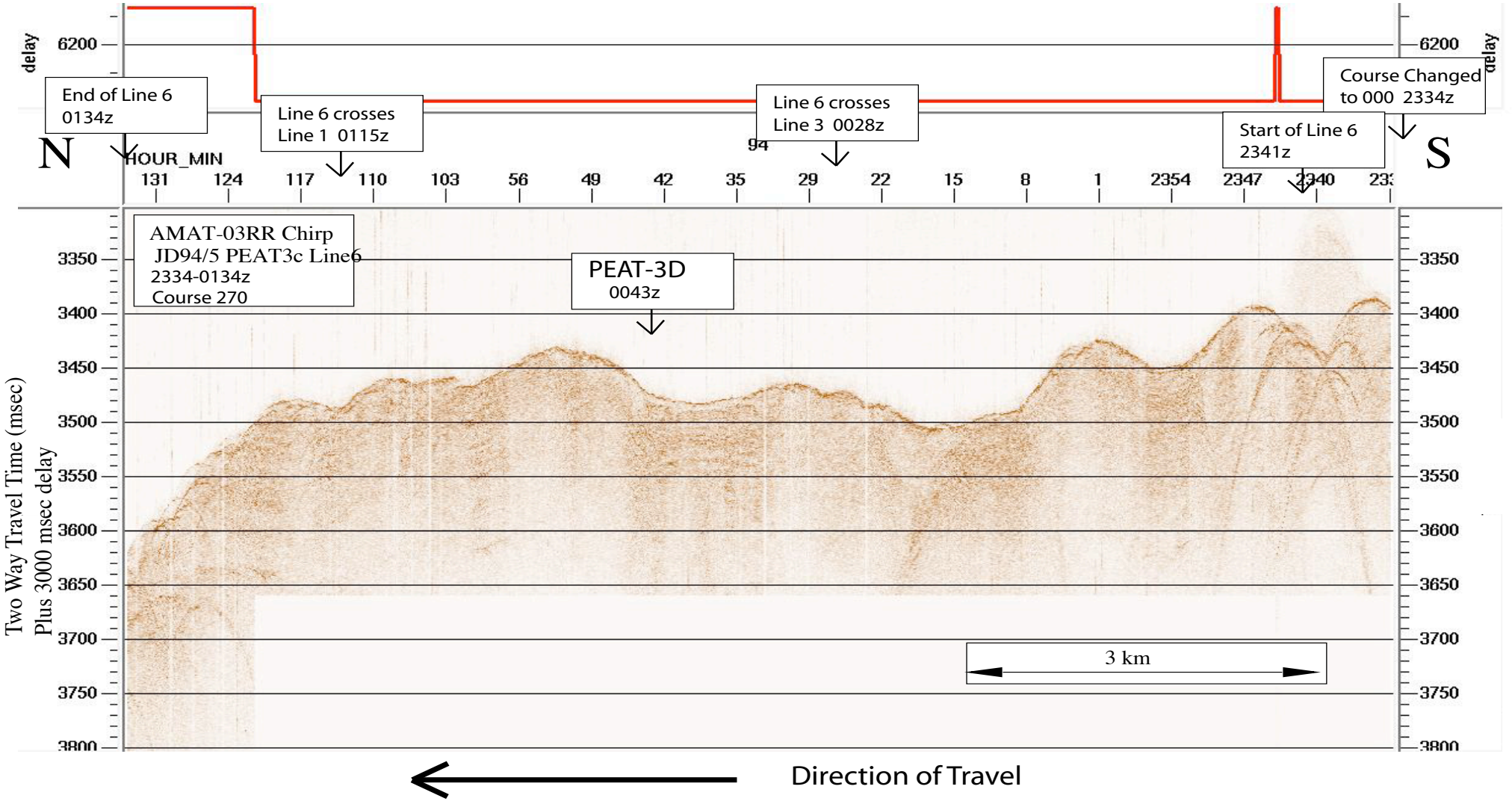


Fig PEAT3C-12



# SITE PEAT-4C (late Eocene & Eoc/Oligocene boundary)

# 07° 59.999'N, 131° 58.396'W, 4809 mbsl

## *SITE OBJECTIVES*

Site PEAT-4C targets the events bracketing the Eocene/Oligocene transition, with the specific aim to recover carbonate bearing sediments of latest Eocene age prior to a large deepening of the CCD that occurred during this greenhouse-to-icehouse transition (Kennett & Shackleton, 1976; Miller et al., 1991; Zachos et al., 1996). Site PEAT-4C is located on late middle Eocene crust with an estimated age of ca. 38 Ma. The Eocene/Oligocene transition experienced the most dramatic deepening of the Pacific CCD during the Paleogene (van Andel, 1975), which has now been shown by Coxall et al. (2005) to co-incide with a rapid step-wise increase in benthic oxygen stable isotope ratios, interpreted to reflect the growth of the Antarctic ice-sheet.

So far the most complete Eocene-Oligocene boundary section recovered from the equatorial Pacific has been ODP Site 1218 on 42 Ma old crust; however, it is far from pristine. Carbonate percentages drop markedly below the boundary and go to zero near 34 Ma. This prevented the recovery of information about paleoceanographic conditions prior to the E/O transition, and also has implications for the interpretation of paleotemperature proxies such as Mg/Ca ratios in foraminiferal shells that were bathed in waters with very low carbonate ion concentrations (Lear, pers. comm 2006). Data from ODP Site 1218 allowed the astronomical time calibration of the entire Oligocene (Coxall et al., 2005; Wade and Pälike, 2004, Pälike et al., in prep.), but the lack of carbonate in the uppermost Eocene at this site made the detailed time control now available for the Oligocene much less certain for the late Eocene. The proposed Site PEAT-4C is located on crustal basement age of ca. 38Ma, and crossed the paleo-equator shortly thereafter. It was located to provide the missing information about the crucial chain of events prior and during the Eocene/Oligocene transition.

Following SSEP recommendations we have positioned the site to the south of the estimated paleo-equatorial position at their target ages in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring. The nearest older drill locations in this plate segment bounded by the Clipperton F.Z. to the south and the Clarion F.Z to the north are DSDP 160 (with a crustal age of ca. 35Ma) to the east, and

ODP 1218 (with a crustal age of 42Ma) to the west, lending support to our back rotation modeling.

## *GENERAL DESCRIPTION*

PEAT-4C is located north of the Clipperton Fracture Zone on abyssal hill topography draped with approximately 270m sediment (Fig PEAT4C-2). The fabric of the abyssal hills within the sites is oriented either due north or slightly east of due north.

Water depth in the vicinity of PEAT-4C ranges between 5 to 5.1 km for the depressions between the abyssal hills. The abyssal hills range between 4.7 and 4.85 km waterdepth, and generally show a thicker and more consistent sediment cover than the basins. In fact, a significant amount of the bathymetric difference between hills and depressions is controlled by the amount of sediment cover. The comparison of sediment thickness and clarity of seismic sections led us to chose a location on the middle elevation of one of the abyssal hills.

## *AMAT-03 Survey*

PEAT-4C was surveyed on 02 April 2006 with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. We used the 48-channel digital streamer for this site survey. The site was also piston cored, and an 11.25 m core (RR0603-08JC) was recovered.

The site is thickly covered with sediments (350 msec TWTT; Figure PEAT4C-5). The site has a thin layer of recent to middle Miocene (12 Ma) sediments and most of the surface sediments are devoid of calcium carbonate due to dissolution, leaving the remaining part below the piston core with approximate sedimentation rates of at least 10m/Myr.

Based upon correlation to the Neogene central equatorial Pacific seismic stratigraphy of Mayer et al. (1985) and the Paleogene equatorial Pacific stratigraphy of Lyle et al. (2002), there are about xxx m of Eocene/Oligocene sediment (below orange horizon; Fig PEAT4C-6), for an average Eocene/Oligocene sedimentation rate of xx m/m.y. assuming a crustal age of 38 Ma. The total sediment thickness, using the velocity-depth conversion for Site 574 (Mayer et al., 1985) is 268 m.

Figures PEAT4C-5 and PEAT4C-7 show the primary seismic line (line 1) and the crossline (line 6), while Figures PEAT4C-8 and –9 show the corresponding subbottom profiler records.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-08JC & TC, 11.25m,
08°01.044'N 132°01.357'W, in 4810 m water depth.

RR0603-8JC&TC were taken to the west of the proposed drillsite, and just north of the cross between lines 1 and line 8. The core site is located in a modest abyssal valley where the seismic reflection profile indicated that there was about 260 msec TWTT of sediment.

The combined trigger/piston core lithology consists of a surface layer of siliceous clay over upper Miocene to upper middle Miocene radiolarian oozes, devoid of carbonate. (Figure PEAT4C-10). The age at the base of the core is about 12.4 Ma based on radiolarian assemblages. The overall sedimentation rate in the piston core is about 1 m/Myr, and shows badly preserved and reworked radiolaria in the upper 700cm of the core.

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-4C):
AMAT-03-PEAT4C line 1, 2006 JD092 02:19:49 UTC, SP 01639.
Nearest crossing :crossing of PEAT4C line 1 with line 6 at
Line 1: 2006 JD092 (2. Apr. 2006) 02:19:49UTC, SP 01639
Line 6: 2006 JD092 10:23:29UTC, SP 04541

Crustal age: 37 to 39 Ma
Ship location @ SP01639: 7°59.9968'N 131°58.4428'W
PEAT-4C Location: 7°59.999'N, 131°58.3957'W
Site water depth: 4809 m (6.412 sec TWTT)
Basement depth: 5077 m (6.757 sec TWTT)
Sediment thickness: 0.345 sec ( 268m using Site 574 velocity profile)
Proposed Drilling Depth: 273m, to tag basement

*Velocity Table from Site 574, Mayer et al., 1985:*

| **Depth (mbsf)** | **TWTT (ms)** | **Velocity (m/s)** |
|---|---|---|
| 0-76 | 0-100 | 1520 |
| 76-151 | 100-193 | 1613 |
| 151-330 | 193-410 | 1650 |
| >330 | >410 | 1970 |

PEAT-4C was chosen at the intersection of lines 1 and 6 from the AMAT-03 survey (Figure PEAT4C-4 through –7). PEAT-4C was chosen at the crossing position because the sediment and basement are well imaged. Any additional thickness away from the cross of lines 1 and line 6 was primarily caused by additional Miocene sediment on top, and not by the section of primary interest below. Sediment thickness was estimated using interval velocities published for Site 574 by Mayer et al. (1985). The subbottom profiler sections (Figures PEAT4C-8, -9) image about 20m of transparent surface sediment, and about 100m of layered sediments in the upper sediment column.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-4C Line 1

PEAT-4C Line 2
PEAT-4C Line 3
PEAT-4C Line 4
PEAT-4C Line 5
PEAT-4C Line 6
PEAT-4C Line 7
PEAT-4C Line 8

## *FIGURES*

Fig PEAT4C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-4C is marked.

Fig PEAT4C-2: Swathmap bathymetry for the PEAT-4C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-08JC are marked.

Fig PEAT4C-3a: Map of shotpoints and seismic lines in the PEAT-5C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-07JCare marked.

Fig PEAT4C-3b: Map of survey times and seismic lines in the PEAT-5C AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-07JC are marked.

Fig PEAT4C-4: Seismic profile PEAT-4C line 1 across PEAT-4C, annotated in UTC, from AMAT-03. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of line1 and line6.

Fig PEAT4C-5: Seismic profile PEAT-4C line 1 across PEAT-4C, annotated in shotpoints, from AMAT-03. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of line1 and line6..

Fig PEAT4C-6: Crossline seismic profile PEAT-4C line 6 from AMAT-03. annotated in UTC, from AMAT-03. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of line 6 and line 1.

Fig PEAT4C-7: Crossline seismic profile PEAT-4C line 6 from AMAT-03. annotated in shotpoints, from AMAT-03. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of line 6 and line 1

Fig PEAT4C-8: Chirp subbottom profile from line 1 across PEAT-4C, from AMAT-03. Proposed drill site is marked.

Fig PEAT4C-9: Chirp subbottom profile from line 6 across PEAT-4C, from AMAT-03. Proposed drill site is marked.

Fig PEAT5C-10: MST physical properties data for RR0603-08JC.

Fig PEAT5C-11: Piston-core RR0603-08JC shipboard radiolarian biostratigraphy.

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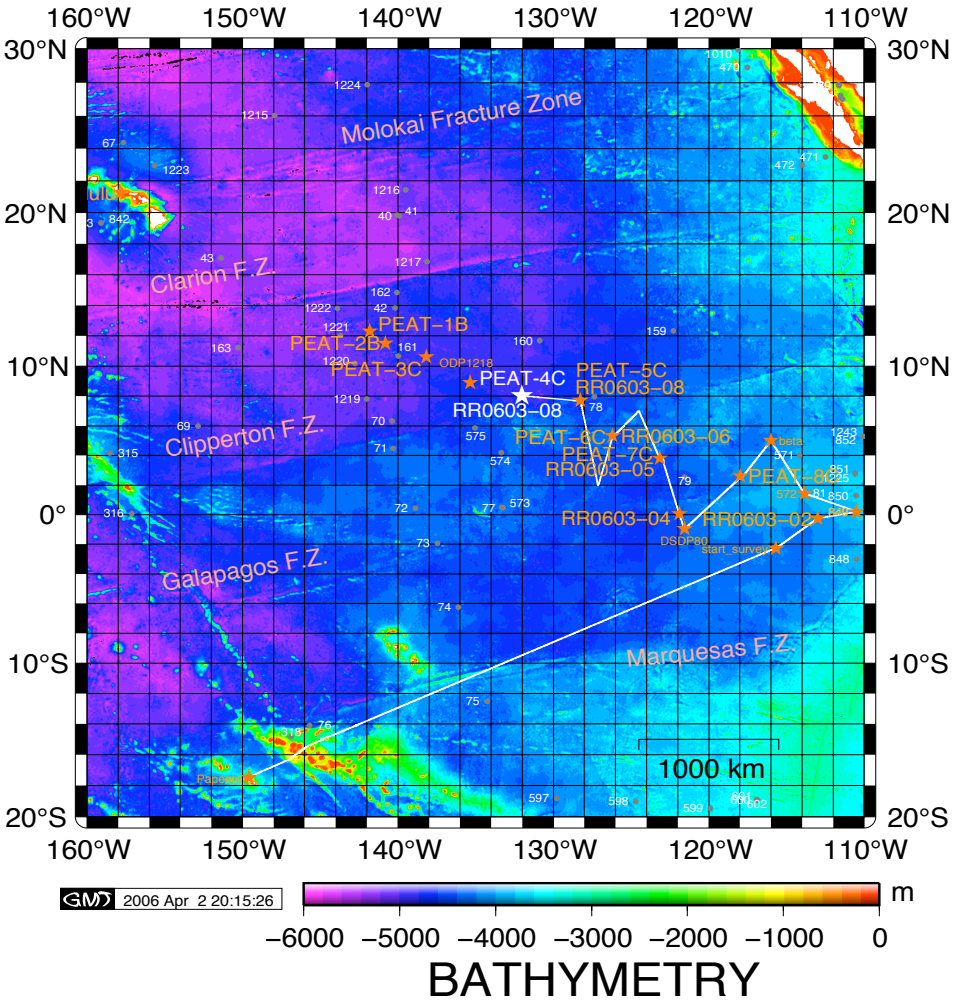
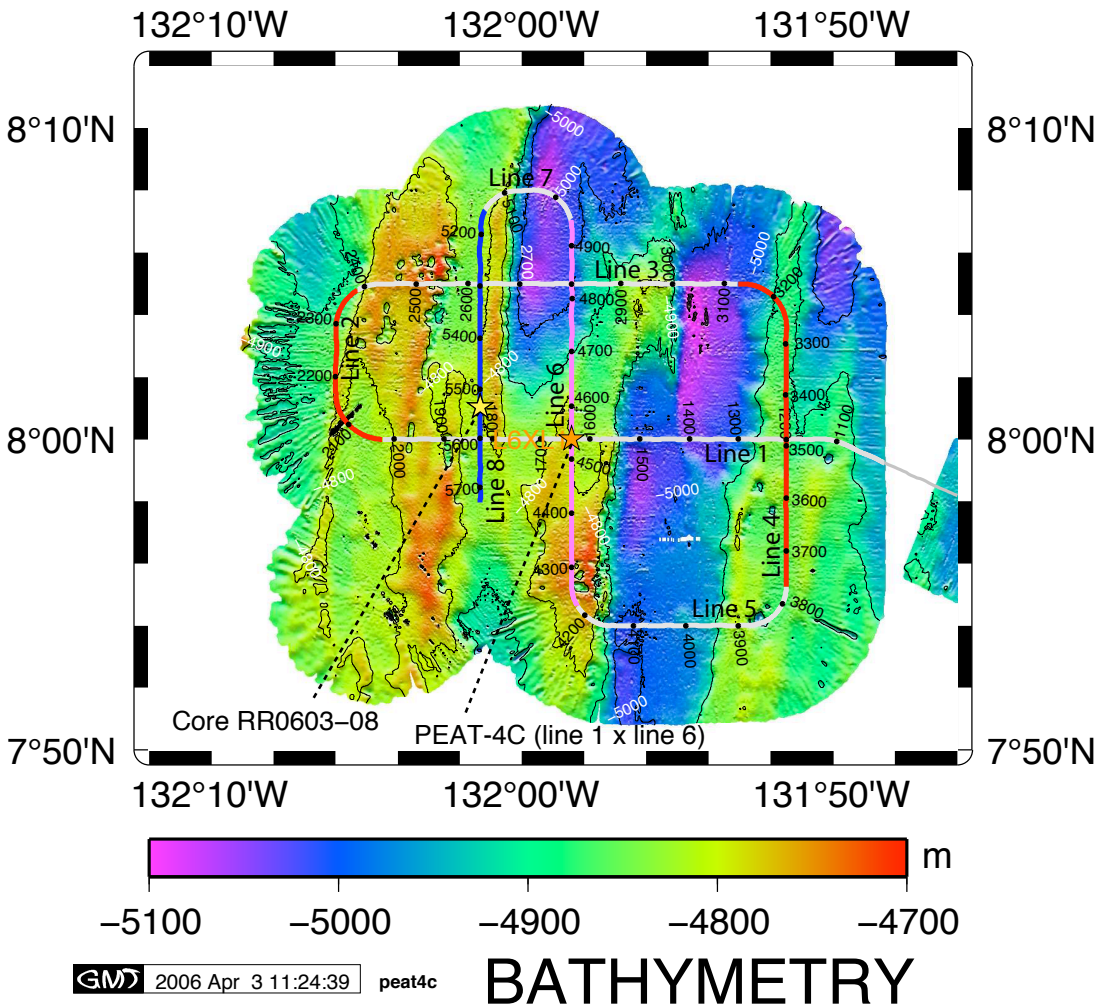
FigPEAT4C-1

# AMAT–03 PEAT–4C OVERVIEW



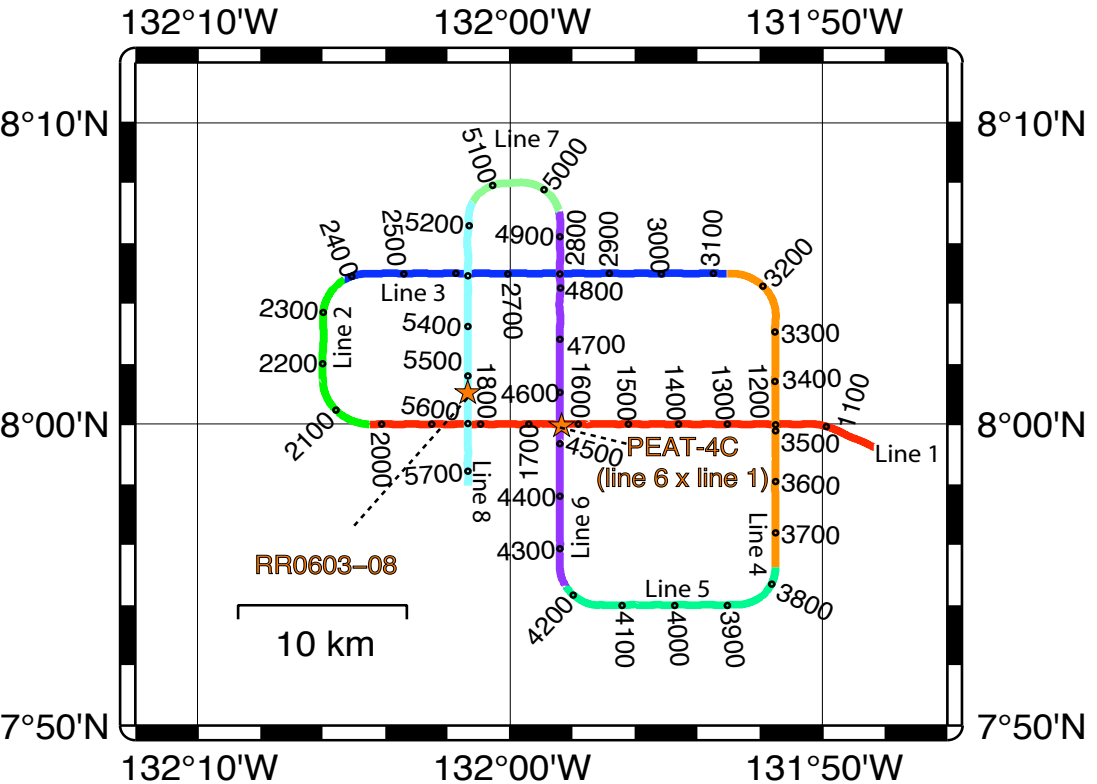
FigPEAT4C-2

# PEAT–4C



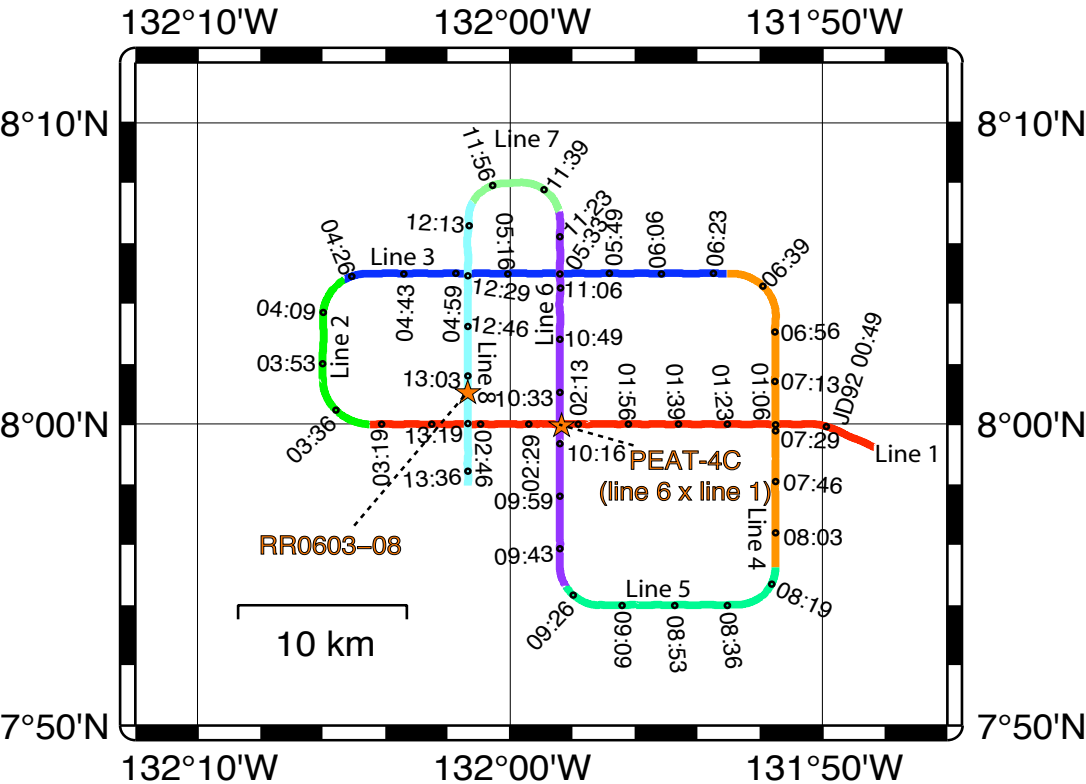
FigPEAT4C-3a

# PEAT–4C



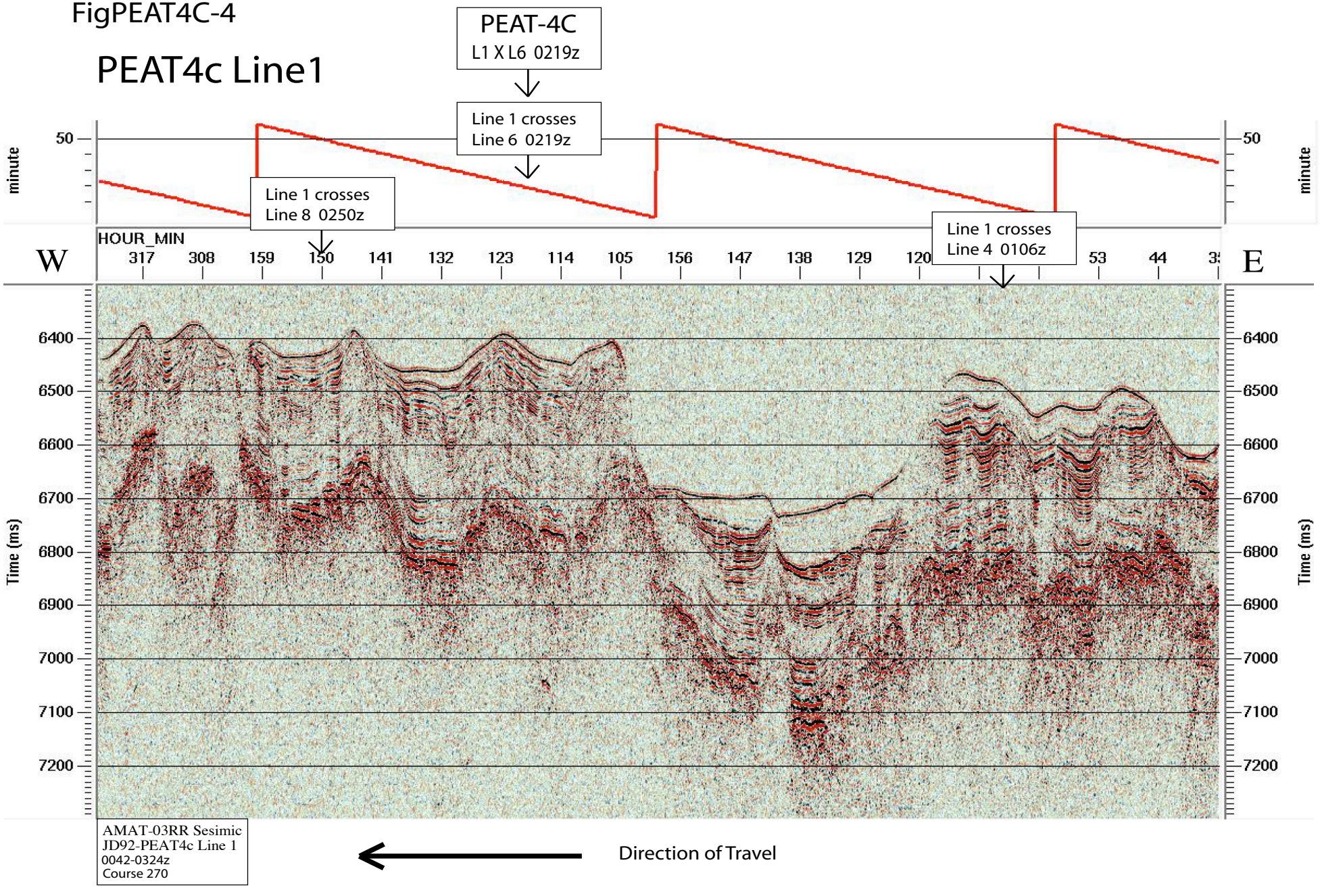
FigPEAT4C-3b

# PEAT–4C



FigPEAT4C-4

# PEAT4c Line1



FigPEAT4C-5

# PEAT4c Line1shotpoints

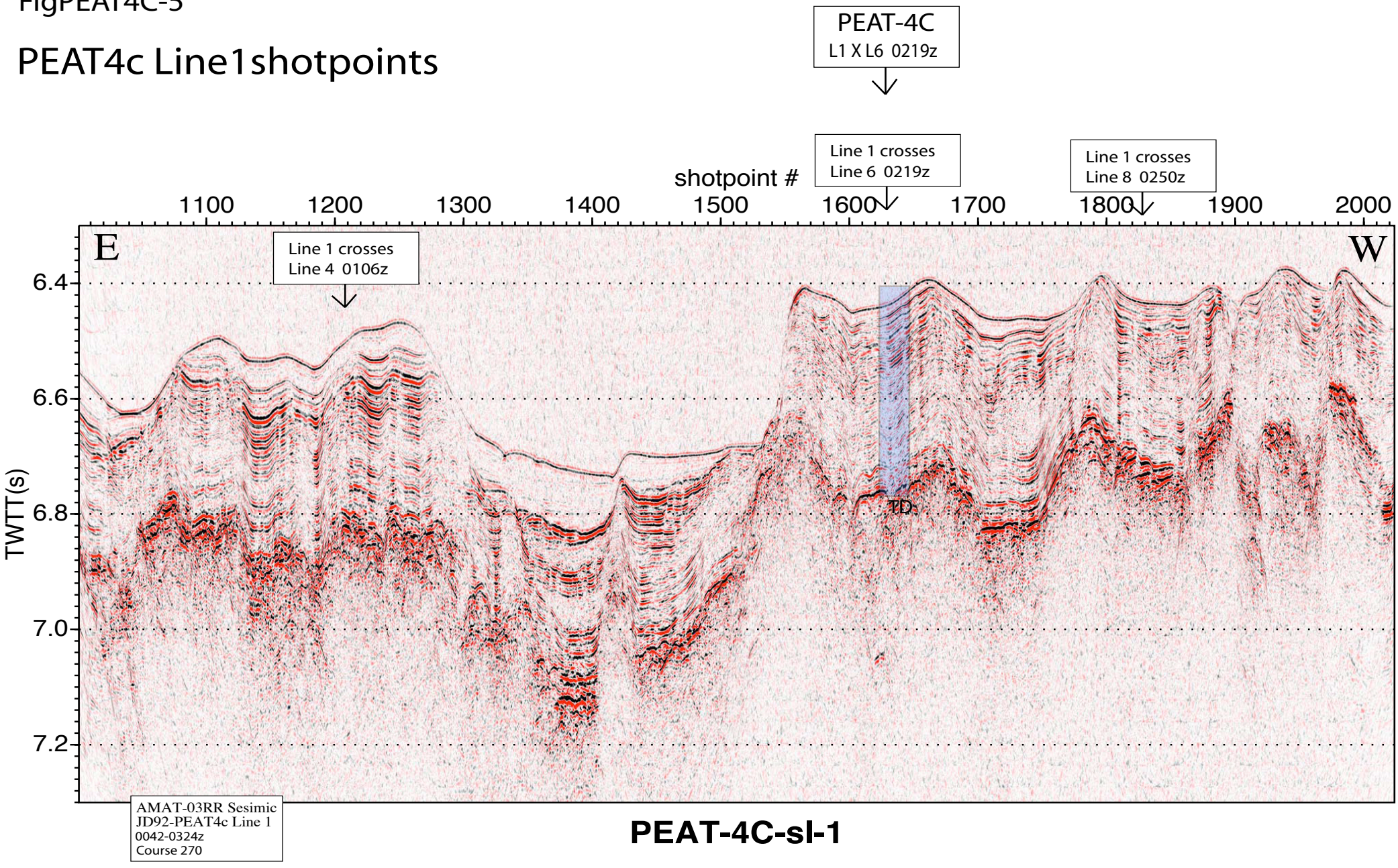


Fig PEAT4C-6

# PEAT4c Line6

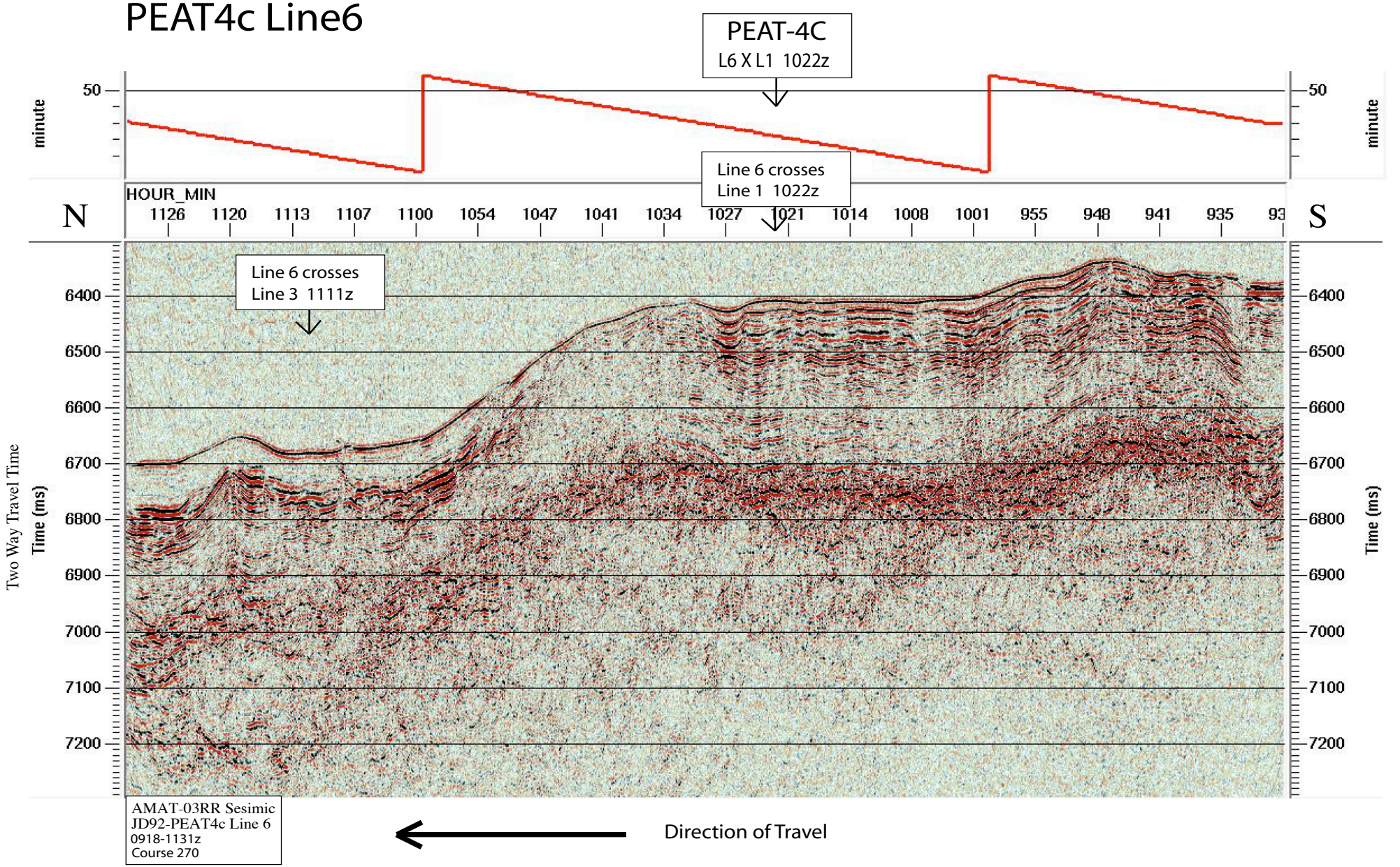


Fig PEAT4C-7

# PEAT4c Line6

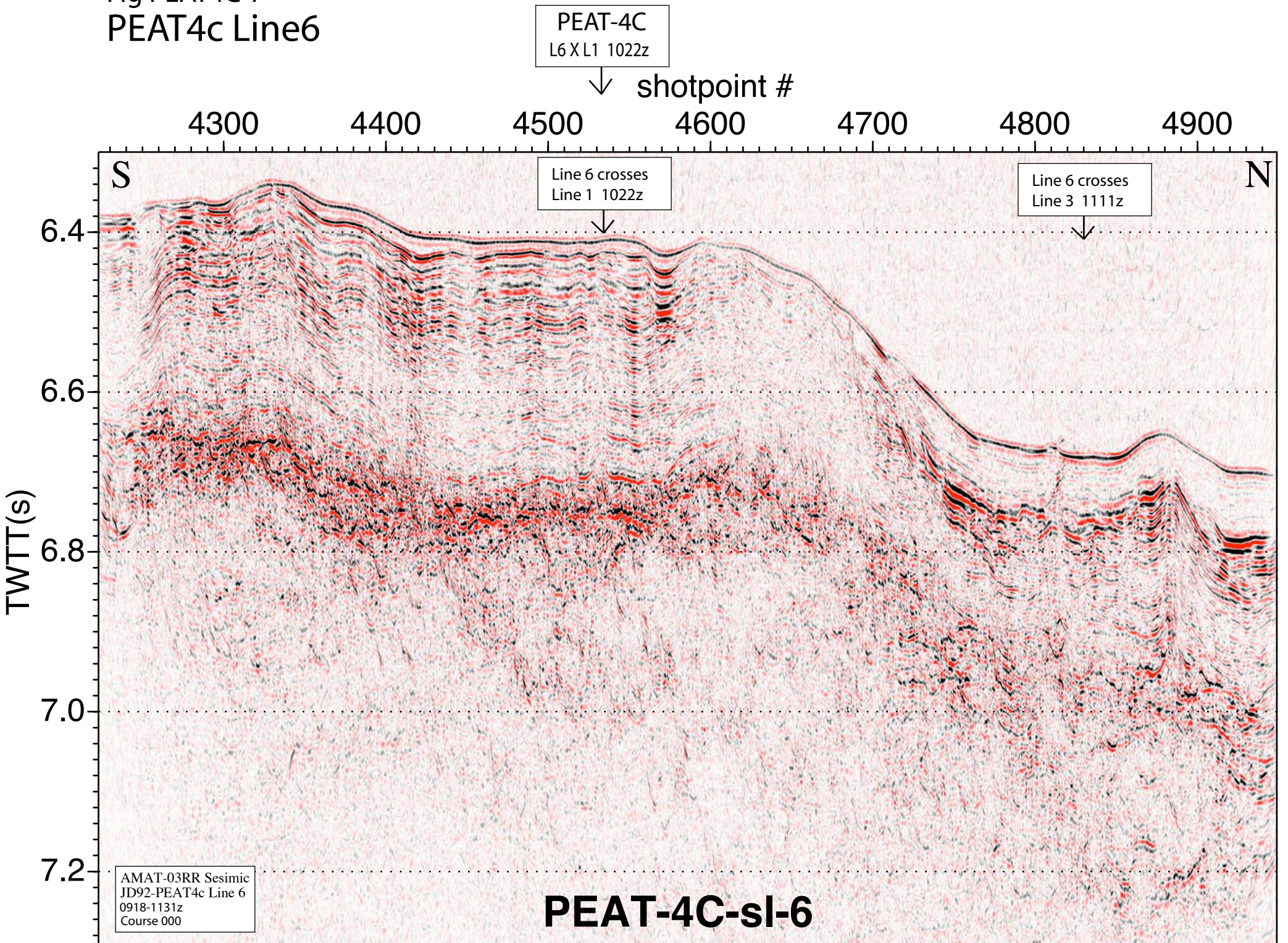


Fig PEAT4C-8

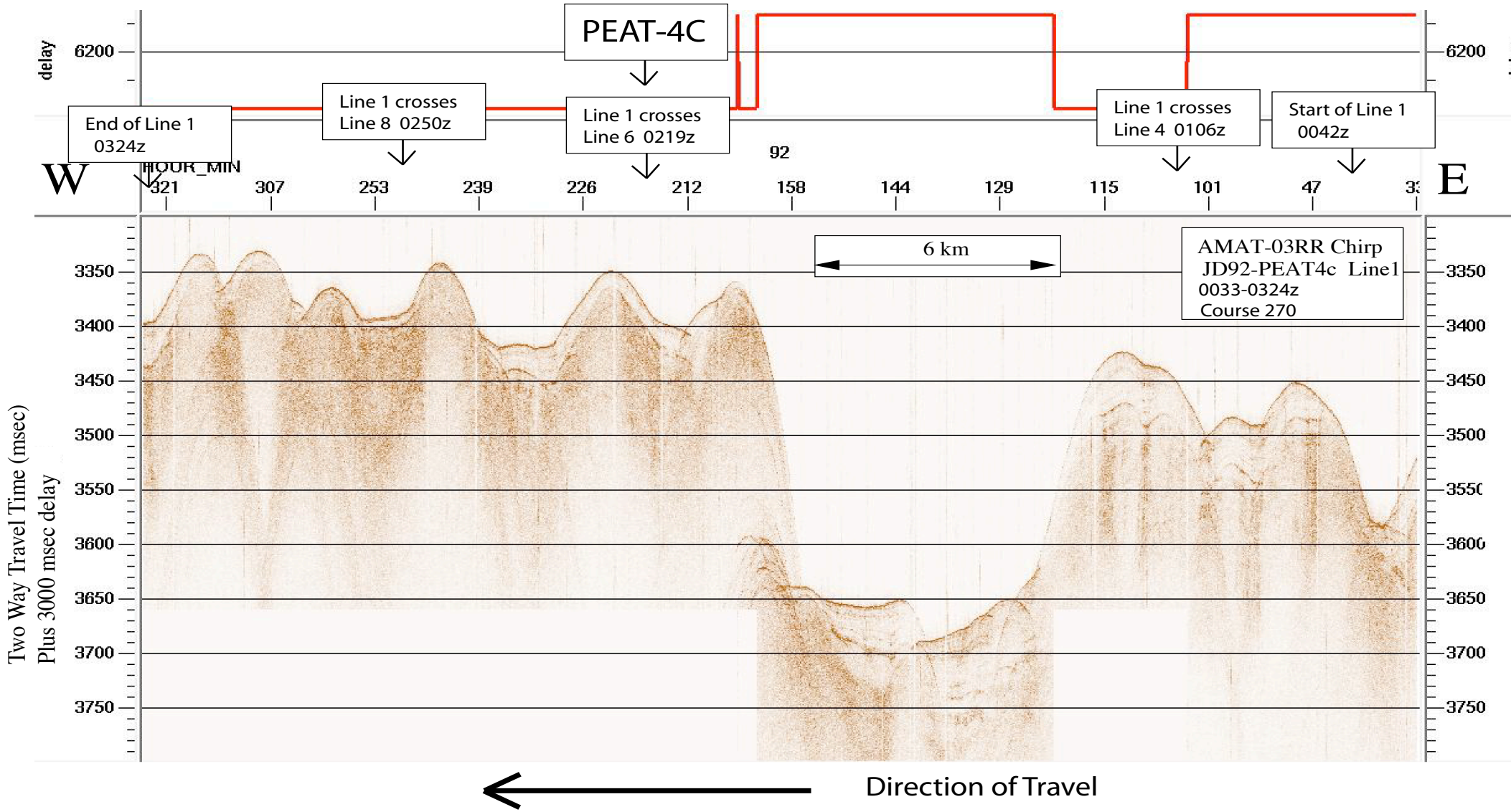
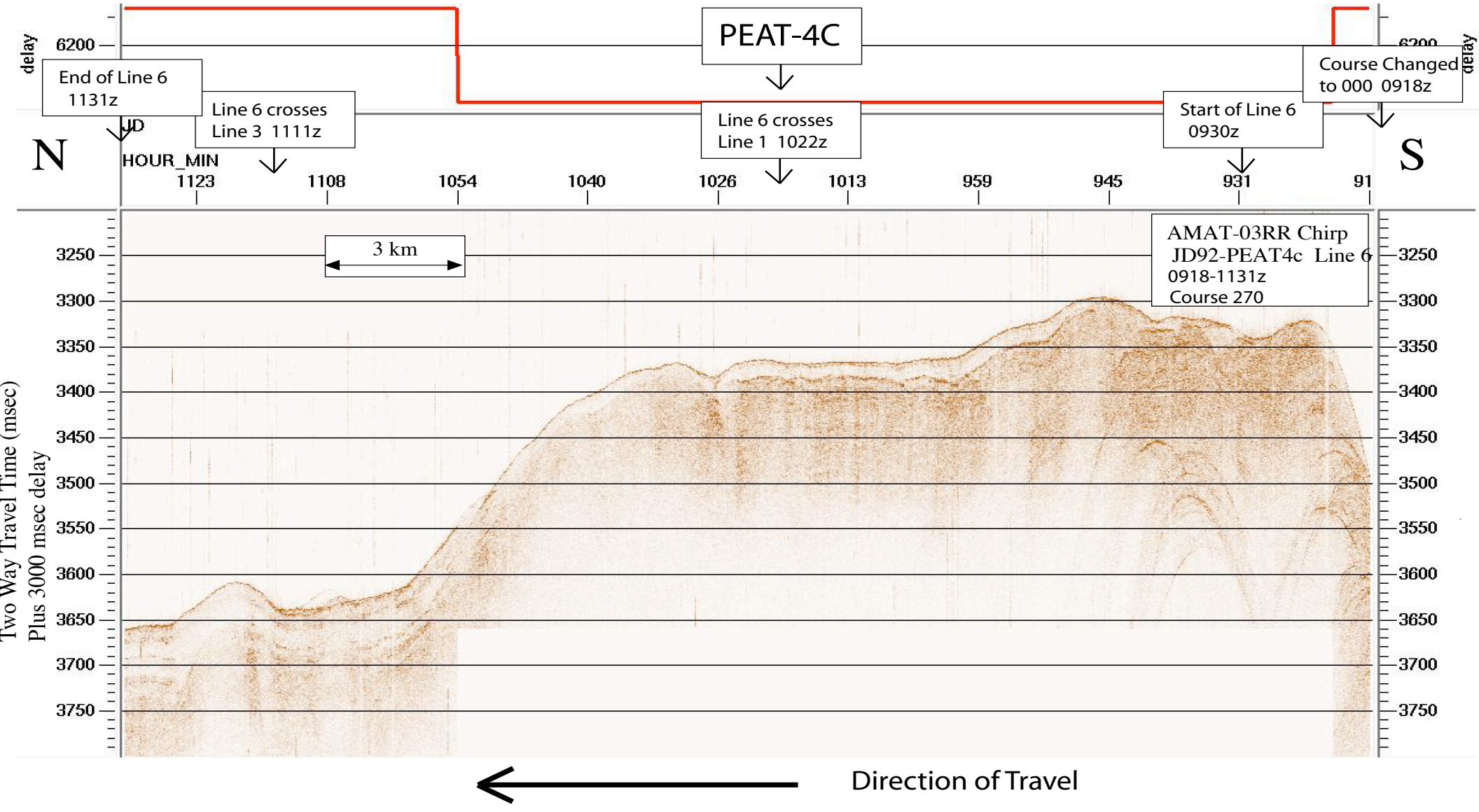
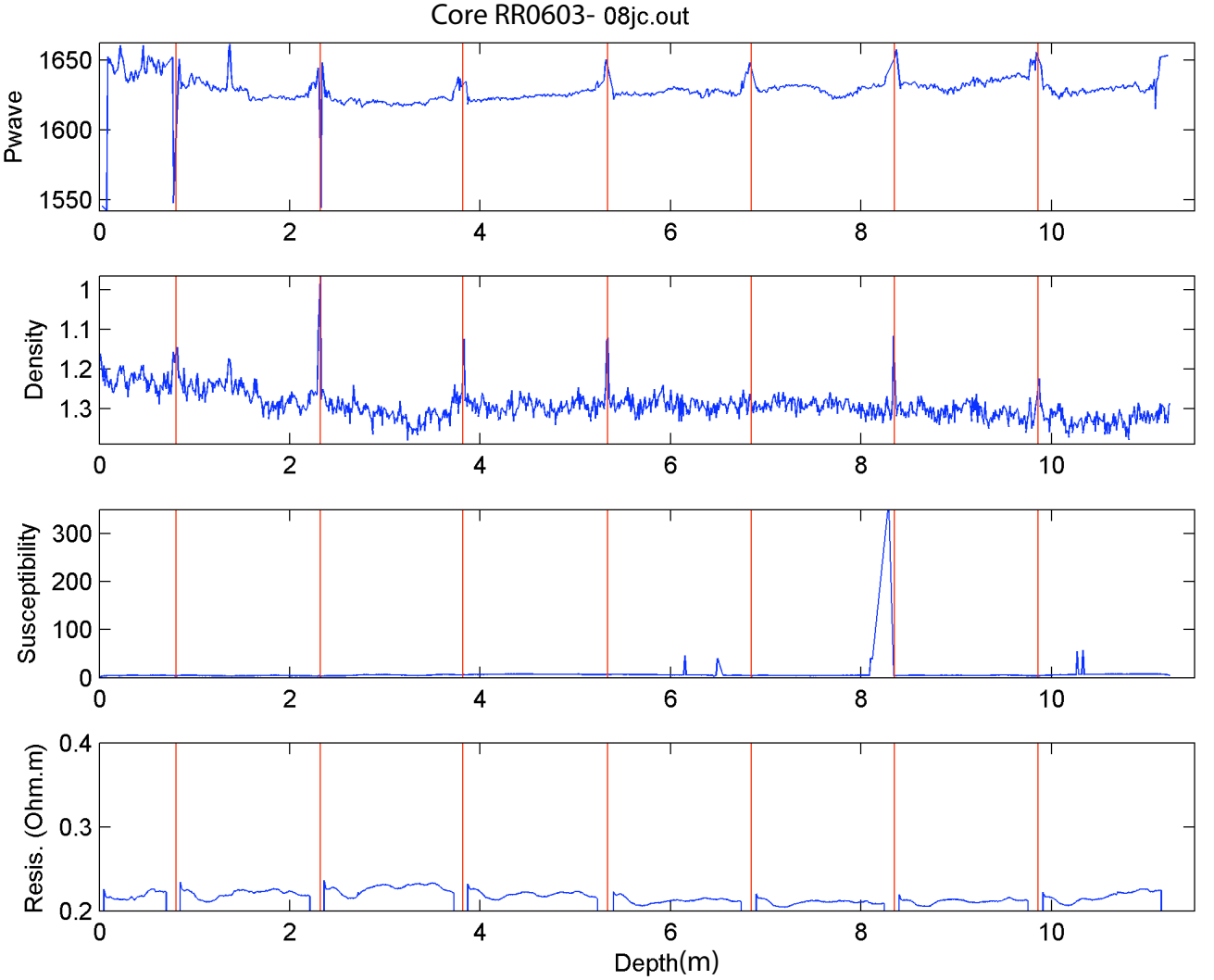

PEAT-4C
End of Line 1
0324z
Line 1 crosses
Line 8 0250z
Line 1 crosses
Line 6 0219z
Line 1 crosses
Line 4 0106z
Start of Line 1
0042z
delay
6200
W
HOUR_MIN
321
307
253
239
226
212
92
158
144
129
115
101
47
E
6 km
AMAT-03RR Chirp
JD92-PEAT4c Line1
0033-0324z
Course 270
3350
3400
3450
3500
3550
3600
3650
3700
3750
Two Way Travel Time (msec)
Plus 3000 msec delay
Direction of Travel

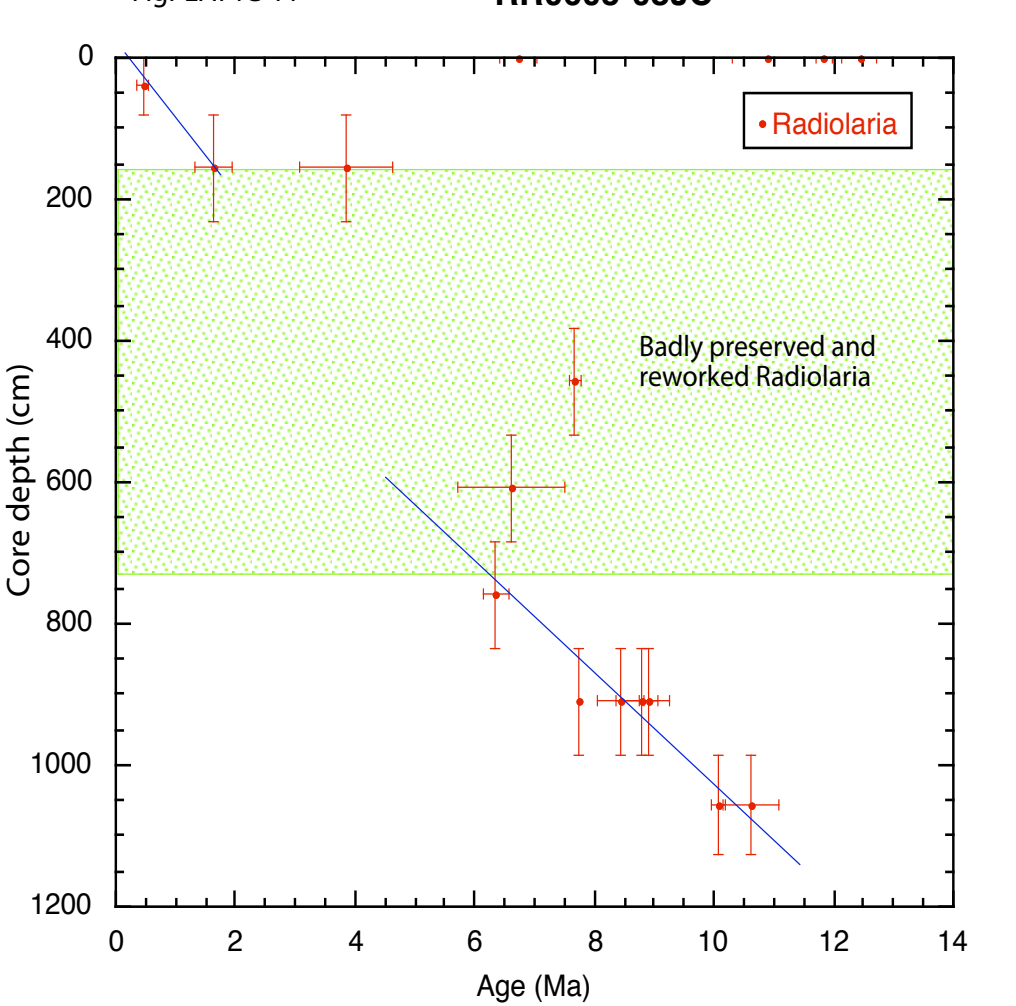
Fig PEAT4C-9


PEAT-4C
End of Line 6
1131z
Line 6 crosses
Line 3 1111z
Line 6 crosses
Line 1 1022z
Start of Line 6
0930z
Course Changed
to 000 0918z
N
S
JD
HOUR_MIN
1123
1108
1054
1040
1026
1013
959
945
931
91
delay
6200
3 km
AMAT-03RR Chirp
JD92-PEAT4c Line 6
0918-1131z
Course 270
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3750
Two Way Travel Time (msec)
Plus 3000 msec delay
Direction of Travel

FigPEAT4C-10



FigPEAT4C-11



# SITE PEAT-5C (Oligocene equator)

# 07° 42.075'N, 128° 15.254'W, 4311 mbsl

## *SITE OBJECTIVES*

Site PEAT-5C (Figure PEAT5C-1) targets the Oligocene and is located on lower Oligocene crust. This interval of time is noted for its heavy oxygen isotopes and a relatively deep CCD. There was probably ice on Antarctica during this interval, but not the large ice sheets to be found there later in the mid Miocene. There is no compelling evidence for ice sheets in the Northern Hemisphere during the Oligocene and early Miocene. Thus, there was apparently a relatively low global ice volume, relatively cold bottom waters, a relatively cold South Pole, and a relatively warm North Pole. This scenario of a "one cold pole" world has given rise to speculation on the impact of inter-hemispheric temperature imbalance on pole to equator temperature gradients and on the symmetry of the global wind systems. The extent to which such an imbalance may have affected the trade winds, the position of the Inter Tropical Convergence Zone, and the seasonal shifts in this zone, should be seen in the wind-driven currents of the equatorial region.

The older, low-resolution DSDP data indicate relatively high, but variable sediment accumulation rates during this interval and better carbonate preservation to the south of the equator (van Andel et al., 1975). In the Leg 199 equatorial transect, the highest accumulation rates encountered (>15 m/M.y.) occurred in the lower part of the Oligocene, but these were in sites north of the Oligocene equator, or on relatively old (and therefore deep) crust. Thus we expect a better preserved, thicker carbonate section at the Oligocene equator. Studies of Oligocene sections from Leg 199 and from other ODP sites (e.g., Paul et al., 2000, Zachos et al., 2001a) indicate the presence of strong eccentricity and obliquity cycles in carbonate preservation and suggest a strong (southern) high-latitude influence on the carbonate record. These cycles are leading to the development of an orbitally tuned time scale that reaches back to the base of the Oligocene. Such a time scale will make it possible to develop a very detailed picture of equatorial geochemical fluxes and of the degree of variability in the equatorial system of the Oligocene.

Following SSEP recommendations we have positioned the site to the south of the estimated paleo-equatorial position at their target ages in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole

data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

## GENERAL DESCRIPTION

PEAT-5C is located just north of the Clipperton Fracture Zone on abyssal hill topography draped with thick sediment (Fig PEAT5C-2). The location of PEAT-5C is about 17 nm north of the trace of the fracture zone. In order to maintain a position south of the 28 Ma paleoequator, we were constrained to site PEAT-5C close to the fracture zone. Nevertheless, the survey has shown that PEAT-5C is located on abyssal hill topography, with a fabric of the abyssal hills that is oriented slightly west of due N.

Water depth in the vicinity of PEAT-5C is relatively shallow for the age of the crust, ranging between 4200 and 4400 m. Surprisingly, there is little or no depth offset between the crust to the south and to the north of the Clipperton Fracture Zone, despite a depth in the middle of the fracture zone trace near 5 km. In fact, the sea floor south of the Clipperton Fracture Zone is perhaps 100 m deeper than that to the north.

## AMAT-03 Survey

PEAT-5C was surveyed on 31 March2006 with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. We used the 4-channel streamer for the site survey because we were unsure whether we might have to move the site further away from the Clipperton Fracture Zone and wanted a streamer that we could tow fast under this contingency. The site was also piston cored, and an 11.1 m core (RR0603-07JC) was recovered.

PEAT-5C is located on abyssal hill topography just north of the Clipperton Fracture Zone. A few oblique ridges and depressed topography occur in the south, showing some interaction between the fracture zone and the PEAT-5C region. The site is thickly covered with sediments (300-400 msec TWTT; Figure PEAT5C–8,–9). The site has a very thin layer of recent to middle Miocene sediments and most of the sediments are between 13 and 28 million years, Based upon correlation to the Neogene central equatorial Pacific seismic stratigraphy of Mayer et al. (1985) and the Paleogene equatorial Pacific stratigraphy of Lyle et al. (2002), there are about 120 m of Oligocene sediment (below orange horizon; Fig PEAT5C-10), for an average Oligocene sedimentation rate of 13 m/m.y. assuming a crustal age of 32 Ma. The total sediment thickness, using the velocity-depth conversion for Site 574 (Mayer et al., 1985) is 252 m.

Figures PEAT5C–8,-9 and PEAT5C–11,–12 show the primary seismic line (Line 6) and the crossline (Line 1), while Figures PEAT5C–13 and –14 show the corresponding subbottom profiler records.

## LITHOLOGIC DESCRIPTION

Nearest sediment core: RR0603-07JC & TC, 11.1m, 07°42.070'N, 128° 12.143' W, 4378 m.

Cores RR0603-07JC&TC were taken to the east of the proposed drillsite on the cross between Line 1 and Line 6. The core site is located in a modest abyssal valley where the seismic reflection profile indicated that there was about 440 msec TWTT of sediment.

The piston core overpenetrated by 120 cm but was correlated to the trigger core by an ash layer. The combined trigger/piston core lithology consists of about 3.3 m of siliceous and zeolitic clay over upper Miocene to upper middle Miocene foram-nannofossil and radiolarian-nannofossil oozes. Carbonate cycles of the core are evident from color changes , MST, and shipboard carbonate analyses (Figure PEAT5C–6). The age at the base of the core is about 12.4 Ma based on the first occurrence of *D. petterssonii* , while the upper carbonates just beneath the clay are late Miocene in age. The sedimentation rate in the carbonate interval is slow, averaging 1.3 m /m.y.., and demonstrate that they were not derived from a high productivity area (Fig PEAT5C-7).

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-5C):
**AMAT-03-PEAT5C Line 6**, 2006 JD090 (31 March 2006) 11:07:48UTC, SP 42593.
Nearest crossing :
**crossing of PEAT5C Line 1**, 2006 JD090 03:27:49UTC, SP 39833 (Line 1)
2006 JD090 11:36:58UTC, SP 42768 (Line 6)

Crustal age: 31 to 32 Ma
Ship location @ SP42593: 7°42.062'N 128°15.188'W
PEAT-7C Location (SP minus 4): 7°42.075'N, 128°15.254'W
Site water depth: 4311 m (5.748 sec TWTT)
Basement depth: 4564 m (6.064 sec TWTT)
Sediment thickness: 252 m (0.316 sec TWTT
Proposed Drilling Depth: to basement (estimated 252 m) + tag basement
Used velocity model: from DSDP Site 574:

| Interval | Interval velocity |
|---|---|
| 0-100msec | 1520 m/s |
| 100-193msec | 1613 m/s |
| 193-410msec | 1650 m/s |
| >410msec | 1970 m/s |

Alternate Site (PEAT-5D):
**AMAT-03-PEAT5C Line 6**: 2006 JD090 (31 March 2006) 12:31:09UTC, SP 43093.
Nearest crossing :
**crossing of PEAT5C Line 3**: 2006 JD090 6:44:19UTC, SP 41012

Crustal age: 31 to 32 Ma
Ship location @ SP43093: 7°42.072'N 128°06.497W
PEAT-7D Location (SP minus 4): 7° 42.069'N, 128° 06.568'W
Site water depth: 4400 m (5.867 sec TWTT)
Basement depth: 4696 m (6.234 sec TWTT)
Sediment thickness: 295 m (0.367 sec TWTT) using Site 574 velocity
Proposed Drilling Depth: to basement (estimated 295m) + tag basement

PEAT-5C was chosen near the intersection of Lines 6 and 1 from the AMAT-03 survey (Figure PEAT5C-5 and –7). PEAT-5C was chosen on the hill to the west of the crossing because the lower section was better imaged and the basement was distinct. In addition, the additional thickness at the cross of line 6 and line 1 was primarily caused by additional Miocene sediment on top, and not by the section of primary interest below. Sediment thickness was estimated using interval velocities published for Site 574 by Mayer et al. (1985). The subbottom profiler sections (Figures PEAT5C-8, -9) image about 60m of layered sediments in the upper sediment column. We also provide an alternate Site as a contingency measure, here unofficially labeled 5D. This location provides about the same sediment column in the basal section, but has a total thickness of 295m in slightly deeper water.

## ***GEOLOGIC HAZARDS

There are no known geologic hazards: pelagic sediments over oceanic basalts.

## ***OTHER HAZARDS

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-5C Line 1
PEAT-5C Line 2
PEAT-5C Line 3
PEAT-5C Line 4
PEAT-5C Line 5
PEAT-5C Line 6
PEAT-5C Line 7
PEAT-5C Line 8

## *FIGURES*


Fig PEAT5C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-5C is marked.

Fig PEAT5C-2: Swathmap bathymetry showing PEAT-5C in relation to Clipperton Fracture Zone. Site positions are marked.

Fig PEAT5C-3: Swathmap bathymetry for the PEAT-5C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-07JC are marked.

Fig PEAT5C-4: Map of shotpoints and seismic lines in the PEAT-5C AMAT-03 site survey. Proposed drill site, alternate drill site and location of piston-core RR0603-07JCare marked.

Fig PEAT5C-5: Map of survey times and seismic lines in the PEAT-5C AMAT-03 site survey. Proposed drill site, alternate drill site and location of piston-core RR0603-07JC are marked.

Fig PEAT5C-6: MST physical properties data for core RR0603-07JC plotted versus depth. Section breaks are marked by red vertical lines. Upper panel: P-wave bulk sediment velocity in m/s. Upper middle panel: sediment wet bulk density as estimated by GRA correlation (in grams /cubic centimeter). Lower middle panel: Magnetic susceptibility (in SI units $x10^{-6}$). Lower panel : electrical resistivity (Ohm x meter). All data were lightly "cleaned" prior to plotting, taking out most of the extreme outliers that occur near section breaks.

Fig PEAT5C-7: Sedimentation rates for RR0603-07JC based on shipboard radiolarian biostratigraphy

Fig PEAT5C-8: Seismic profile PEAT-5C Line 6 across PEAT-5C and the alternate PEAT-5D, from AMAT-03, vs. survey time.

Fig PEAT5C-9: Seismic profile PEAT-5C Line 6 across PEAT-5C and the alternate PEAT-5D, from AMAT-03, vs. shotpoint.

Fig PEAT5C-10: Comparison between Site 574 seismic horizons and those on seismic profile PEAT-5C line 6. Surface offset is due to the beginning of the sedimentary section in the middle Miocene (see core description)

Fig PEAT5C-11: Crossline seismic profile PEAT-5C Line 1 from AMAT-03, vs survey time. Site was moved west of the crossline to an area with better defined older seismic horizons.

Fig PEAT5C-12: Crossline seismic profile PEAT-5C Line 1 from AMAT-03, vs shotpoints.

Fig PEAT5C-13: Chirp subbottom profile from line 6 across PEAT-5C, from AMAT-03. Proposed drill site is marked.

Fig PEAT5C-14: Chirp subbottom profile from line 1, with projection from PEAT-5C, from AMAT-03. Proposed drill site is marked.

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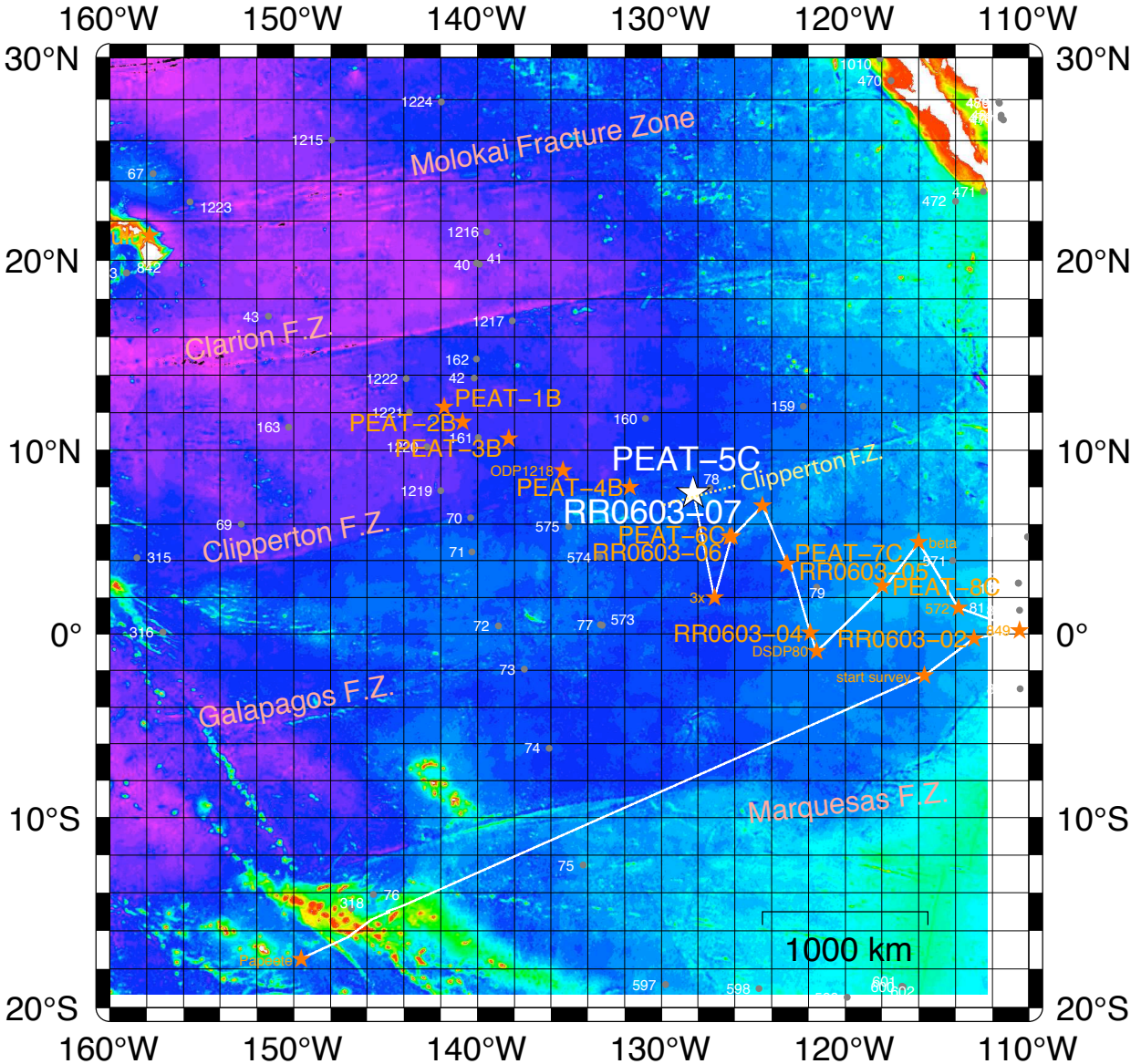
FigPEAT5C-1

# AMAT–03 PEAT-5C Overview







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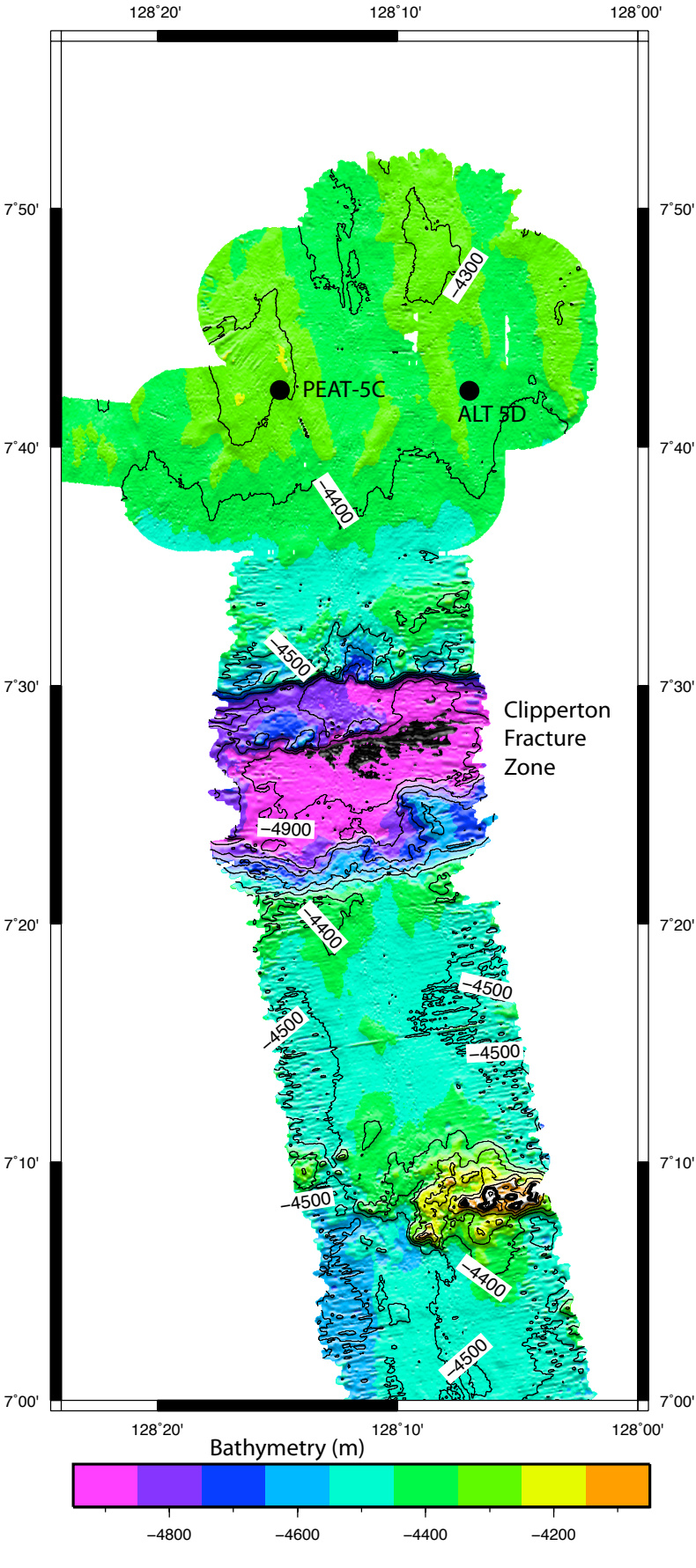
BATHYMETRY

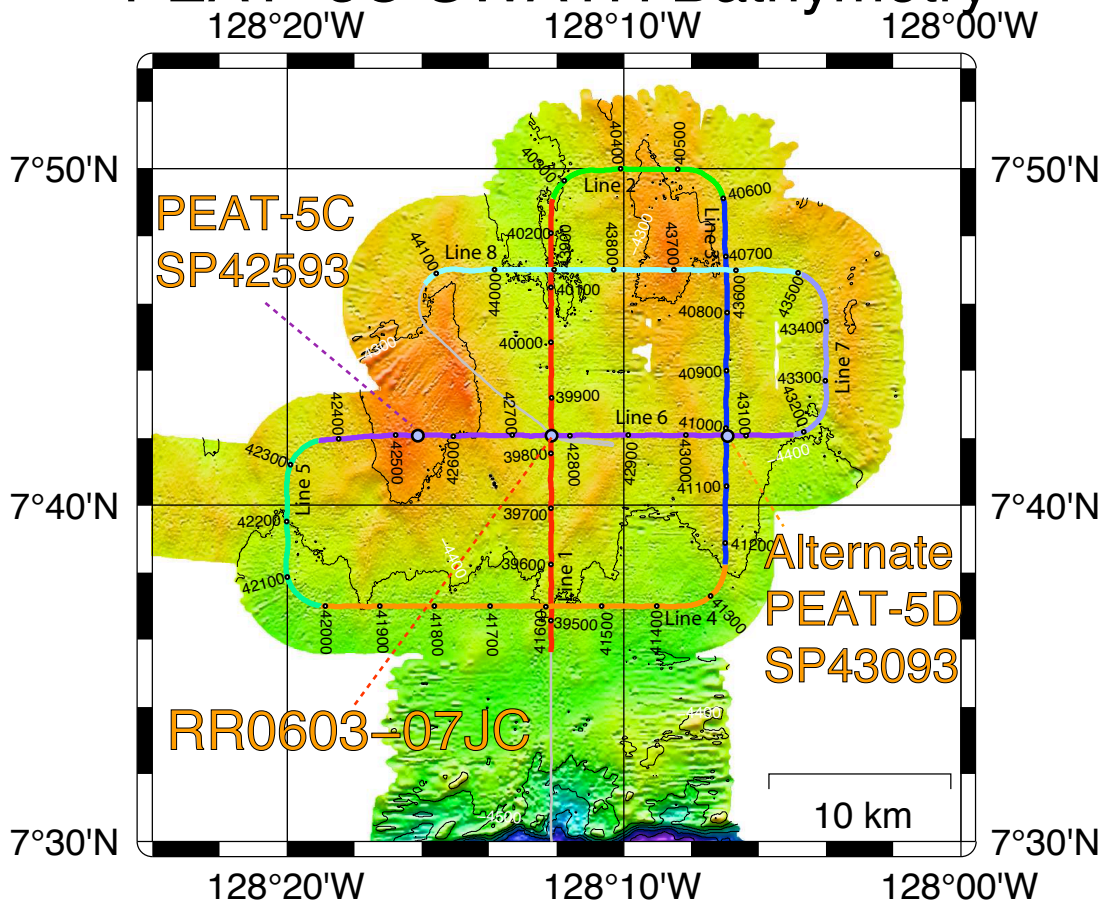
FigPEAT5C-2

# AMAT–03 PEAT-5 and Fracture Zone



FigPEAT5C-3

# PEAT–5C SWATH Bathymetry




m

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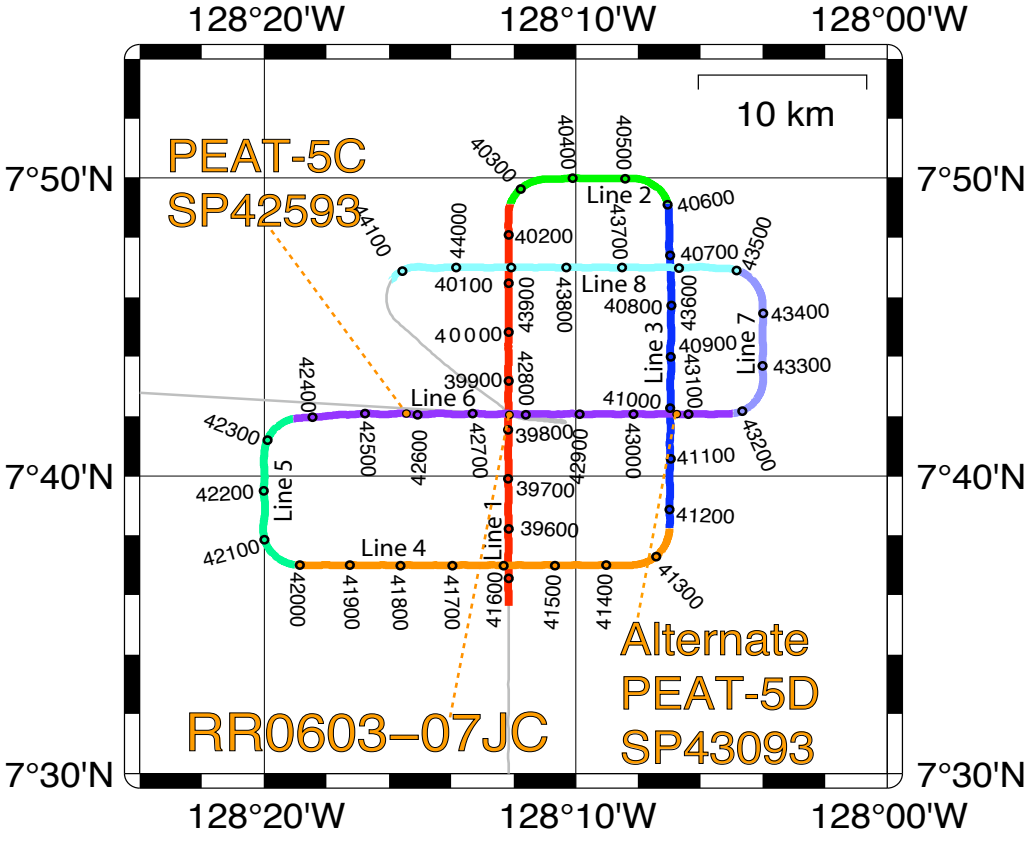
GMT 2006 Apr 1 15:46:43 peat5c

BATHYMETRY

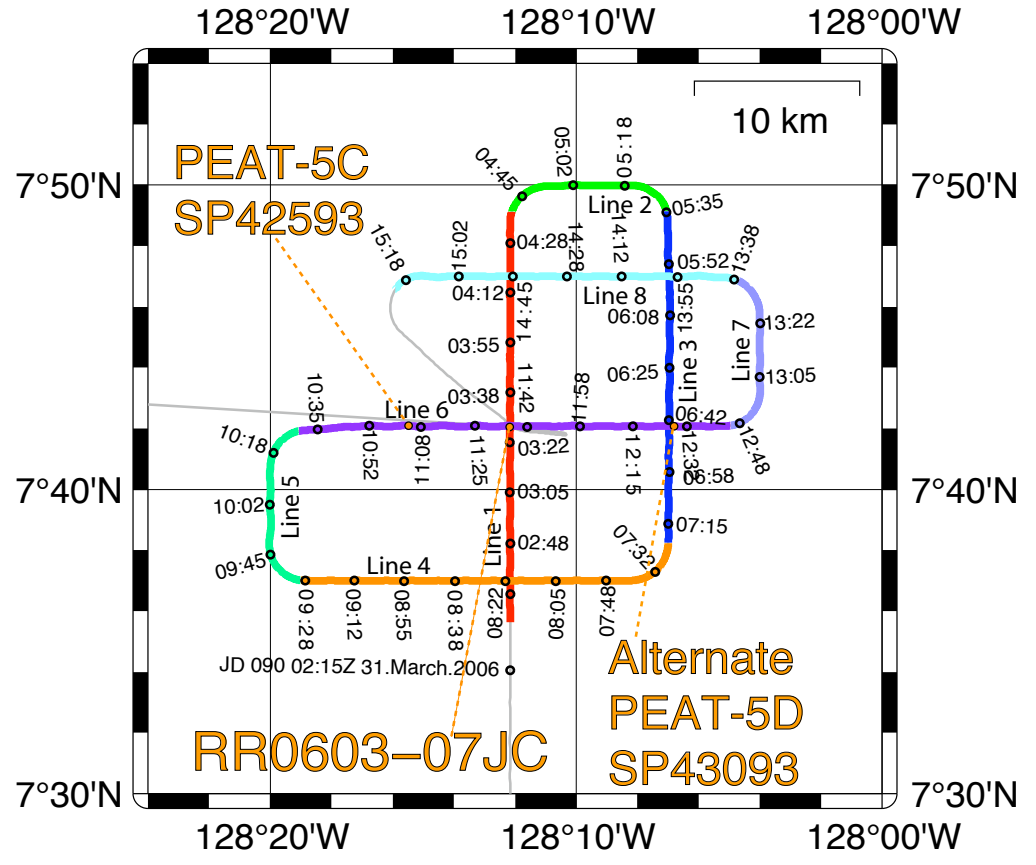
FigPEAT5C-4

# PEAT–5C Seismic Survey shotpoints

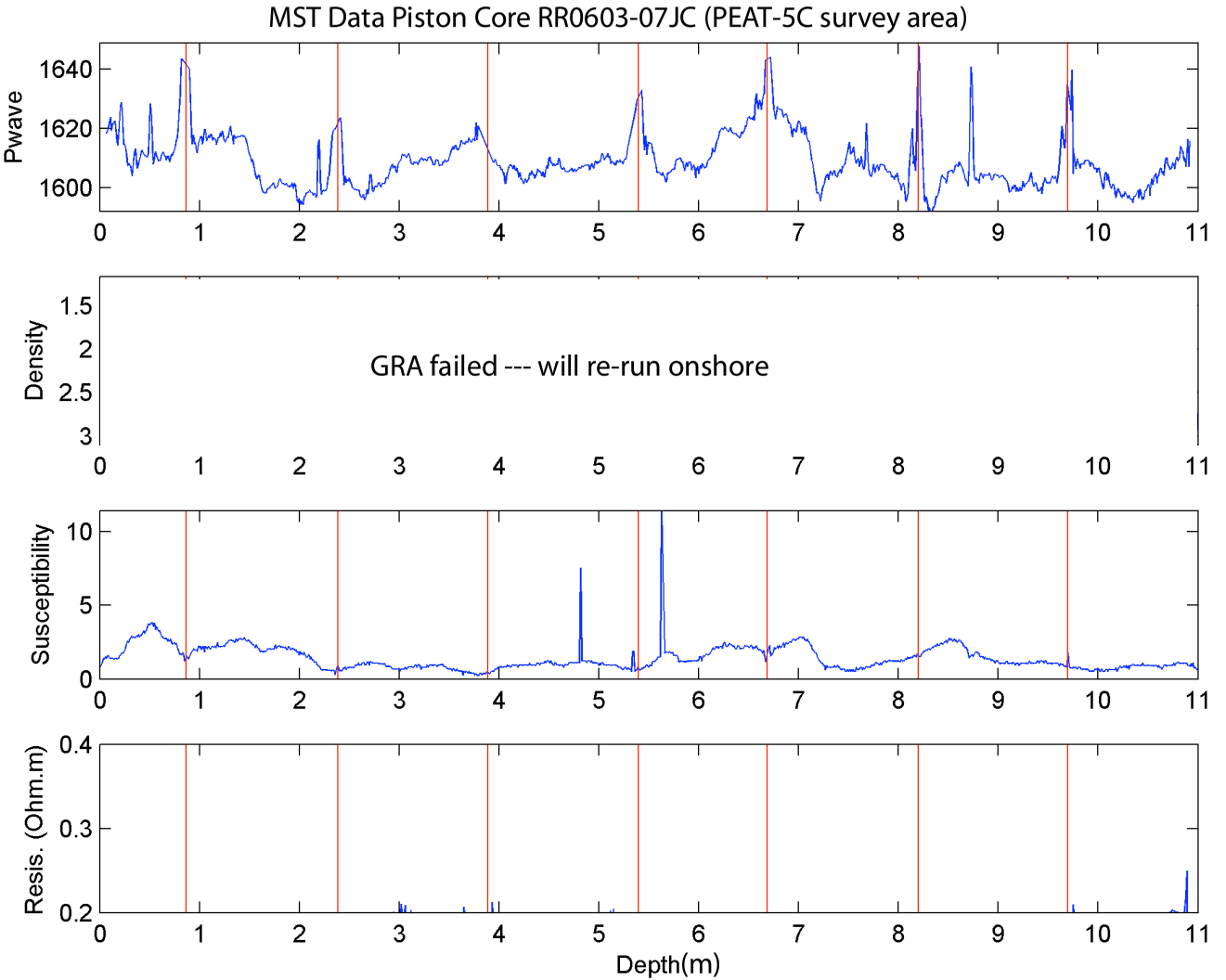


FigPEAT5C-4

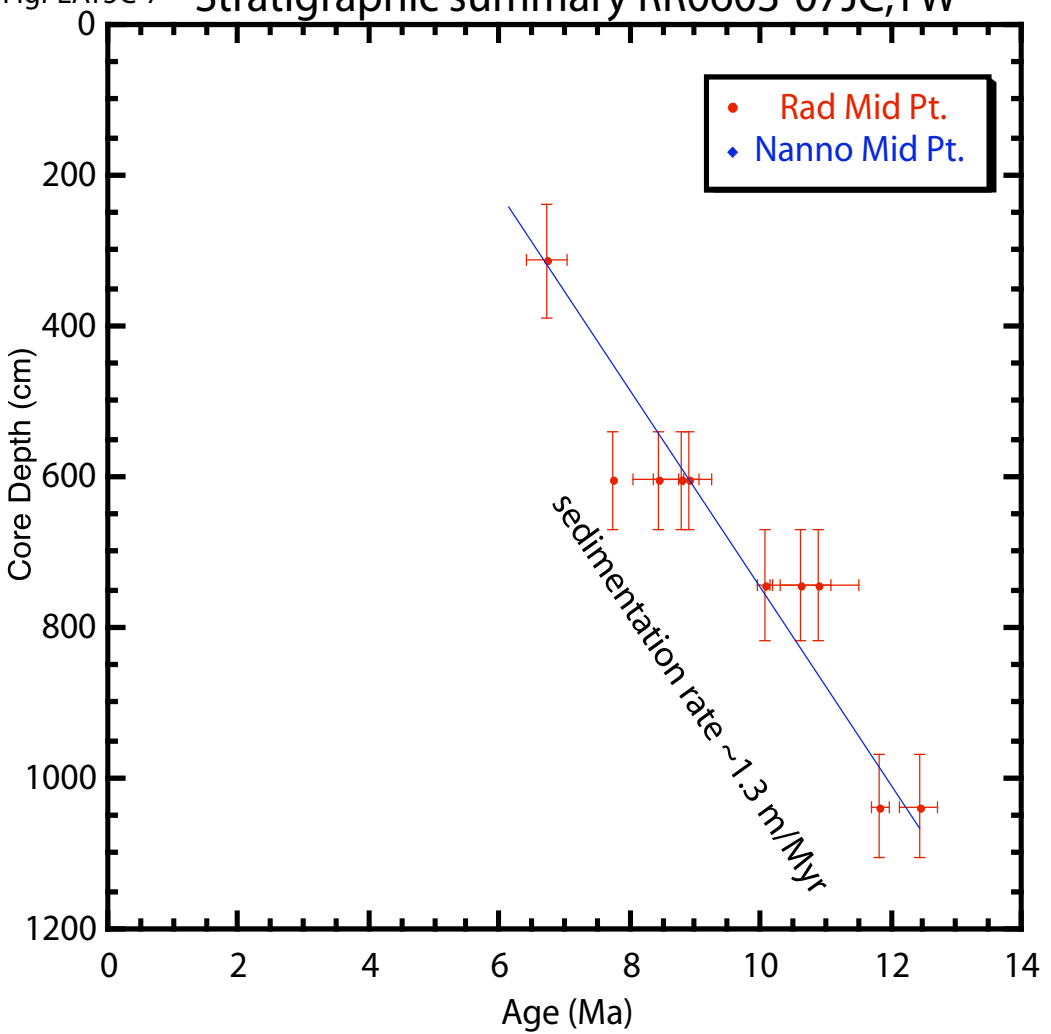
# PEAT–5C Seismic Survey shotpoints (time)



FigPEAT5C-6

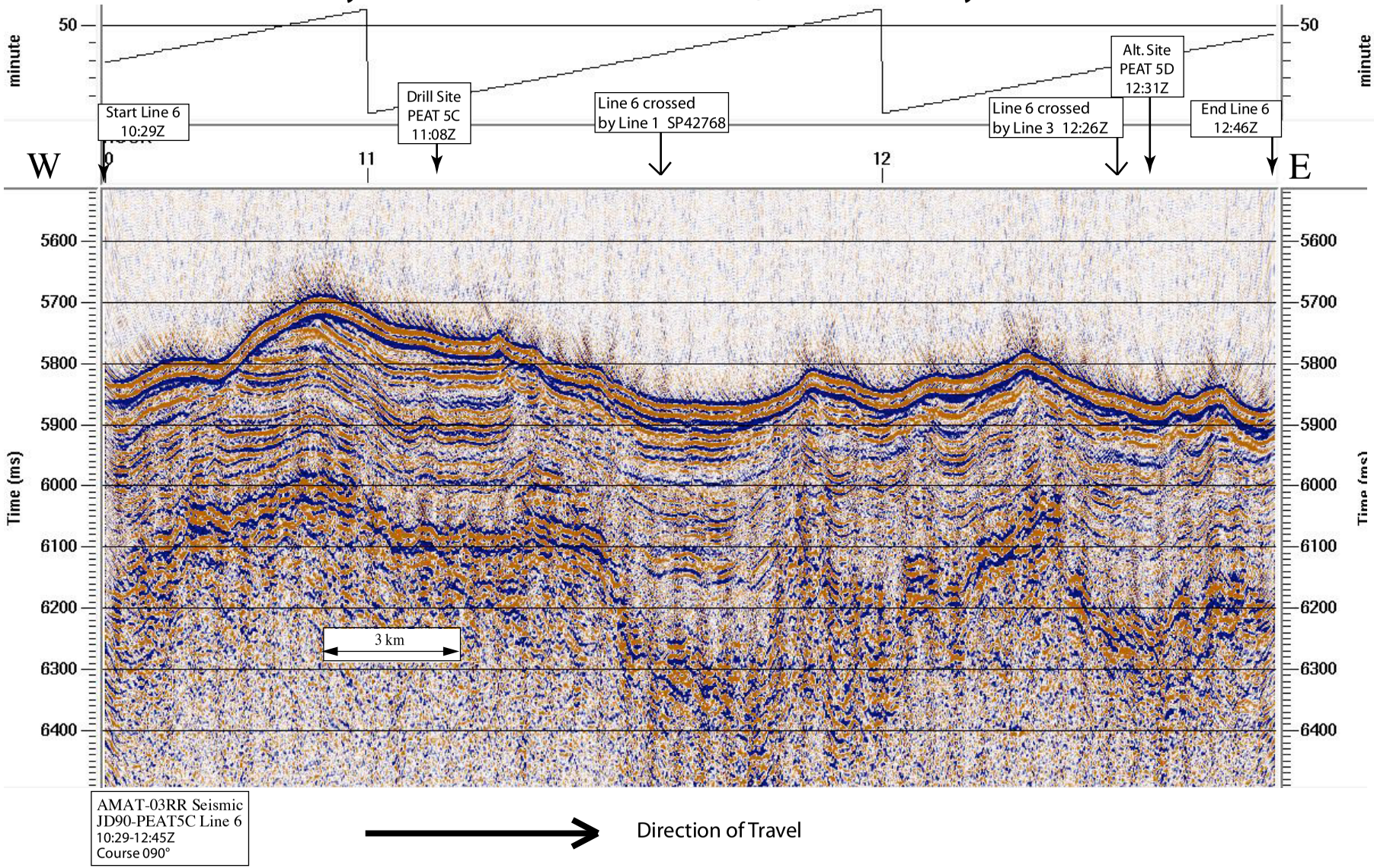

MST Data Piston Core RR0603-07JC (PEAT-5C survey area)
Pwave
1640
1620
1600
0 1 2 3 4 5 6 7 8 9 10 11
Density
1.5
2
2.5
3
GRA failed --- will re-run onshore
0 1 2 3 4 5 6 7 8 9 10 11
Susceptibility
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
Resis. (Ohm.m)
0.4
0.3
0.2
0 1 2 3 4 5 6 7 8 9 10 11
Depth(m)

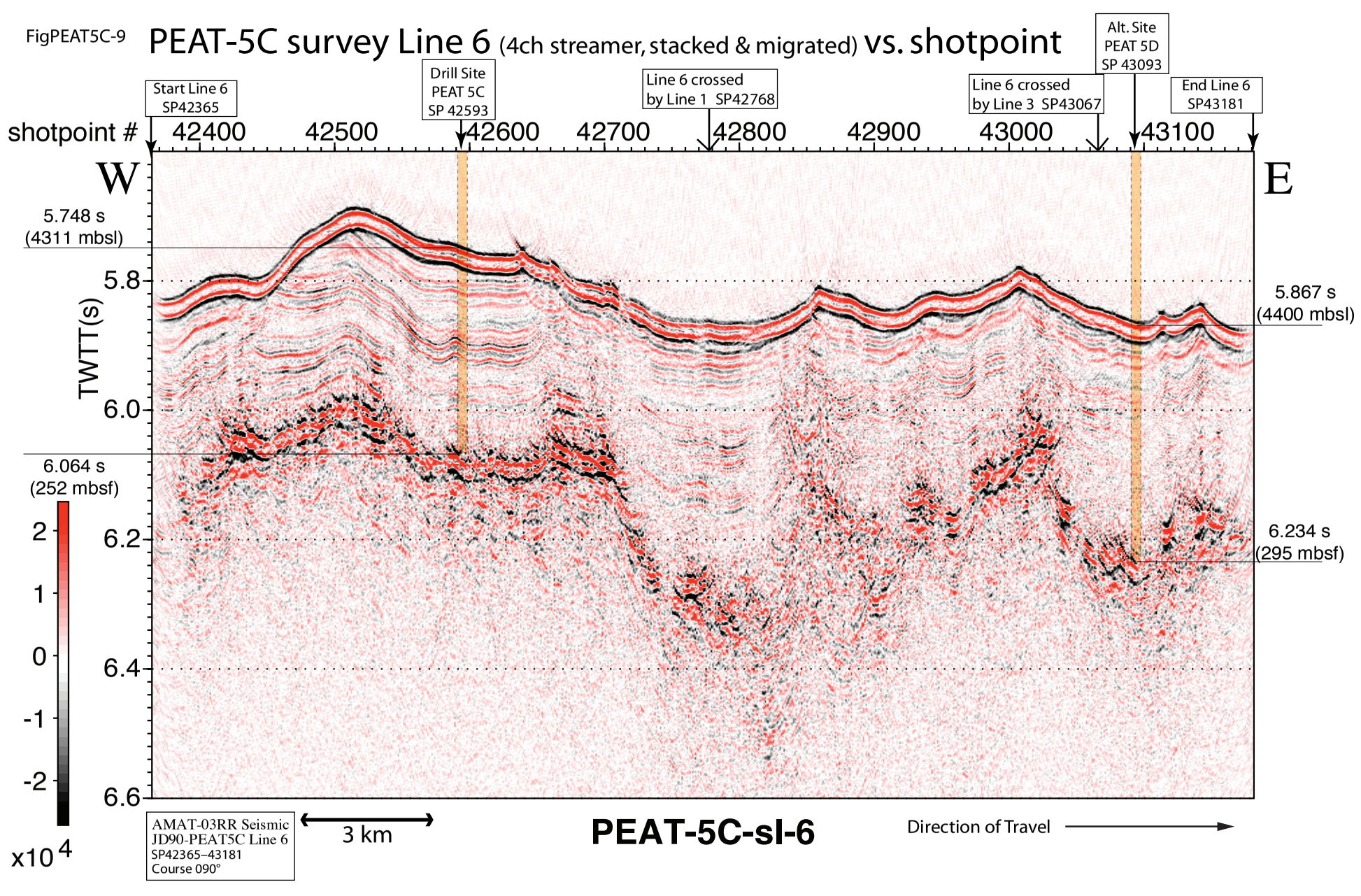
FigPEAT5C-7


Stratigraphic summary RR0603-07JC,TW
Rad Mid Pt.
Nanno Mid Pt.
sedimentation rate ~1.3 m/Myr
Core Depth (cm)
Age (Ma)
0
200
400
600
800
1000
1200
0
2
4
6
8
10
12
14

FigPEAT5C-8

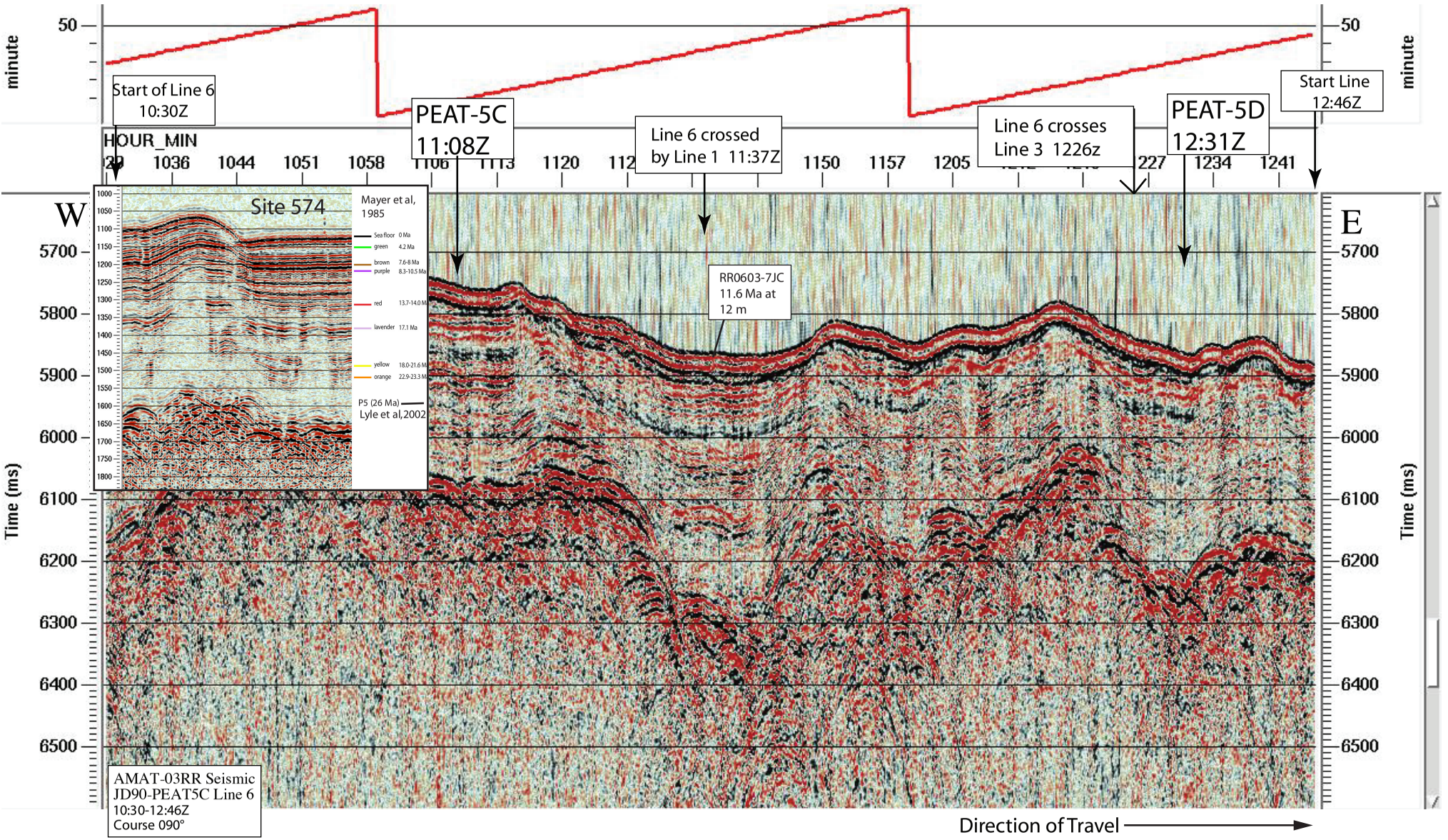
# PEAT-5C survey Line 6 (4ch streamer, stacked & migrated) vs. survey time




FigPEAT5C-9
PEAT-5C survey Line 6 (4ch streamer, stacked & migrated) vs. shotpoint
Start Line 6
SP42365
Drill Site
PEAT 5C
SP 42593
Line 6 crossed
by Line 1 SP42768
Line 6 crossed
by Line 3 SP43067
Alt. Site
PEAT 5D
SP 43093
End Line 6
SP43181
shotpoint #
42400
42500
42600
42700
42800
42900
43000
43100
W
E
5.748 s
(4311 mbsl)
5.867 s
(4400 mbsl)
6.064 s
(252 mbsf)
6.234 s
(295 mbsf)
TWTT(s)
5.8
6.0
6.2
6.4
6.6
2
1
0
-1
-2
x10 4
AMAT-03RR Seismic
JD90-PEAT5C Line 6
SP42365–43181
Course 090°
3 km
PEAT-5C-sI-6
Direction of Travel

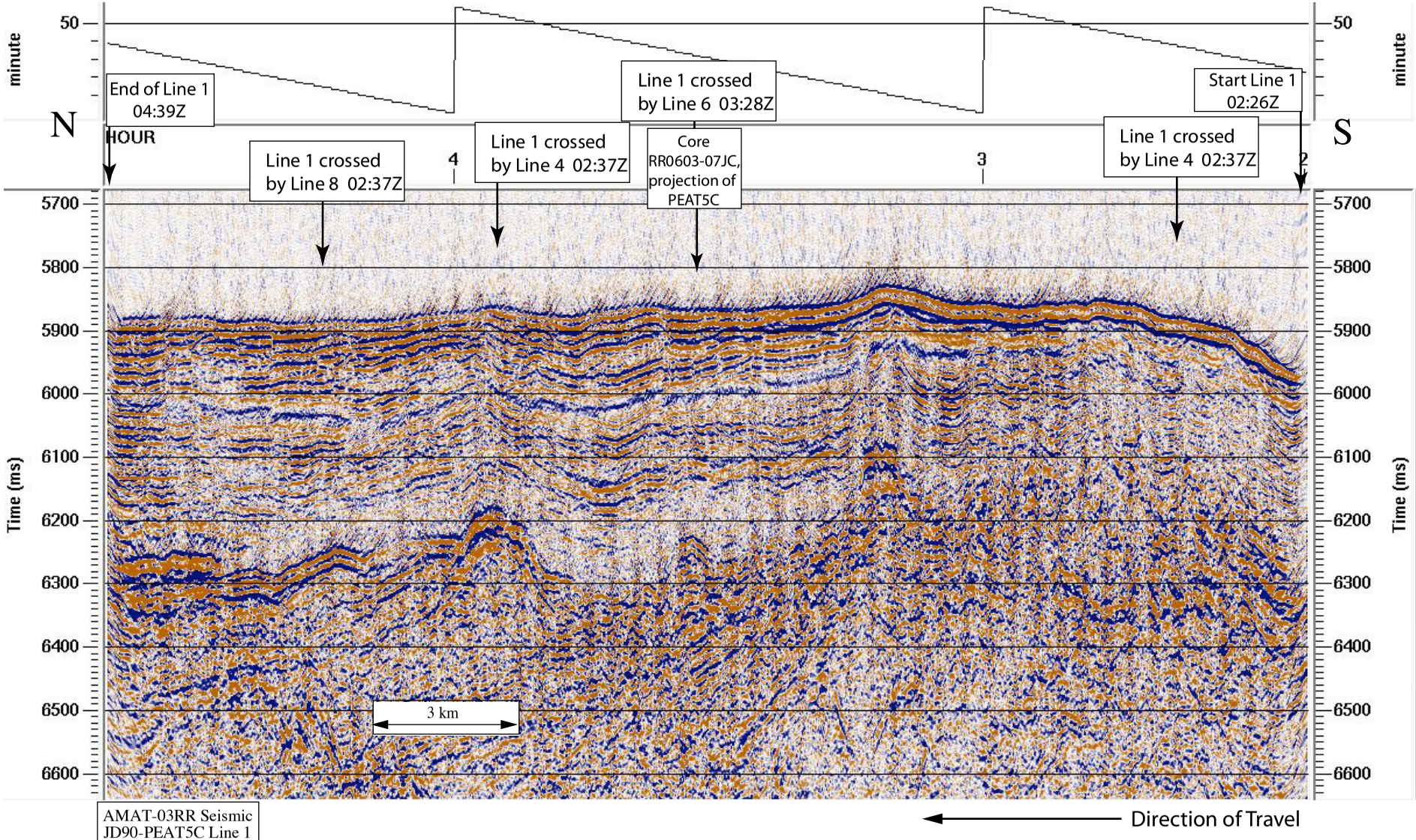
FigPEAT5C-10

# PEAT-5C survey Line 6 (4ch streamer, stacked & migrated) vs. survey time and DSDP 574



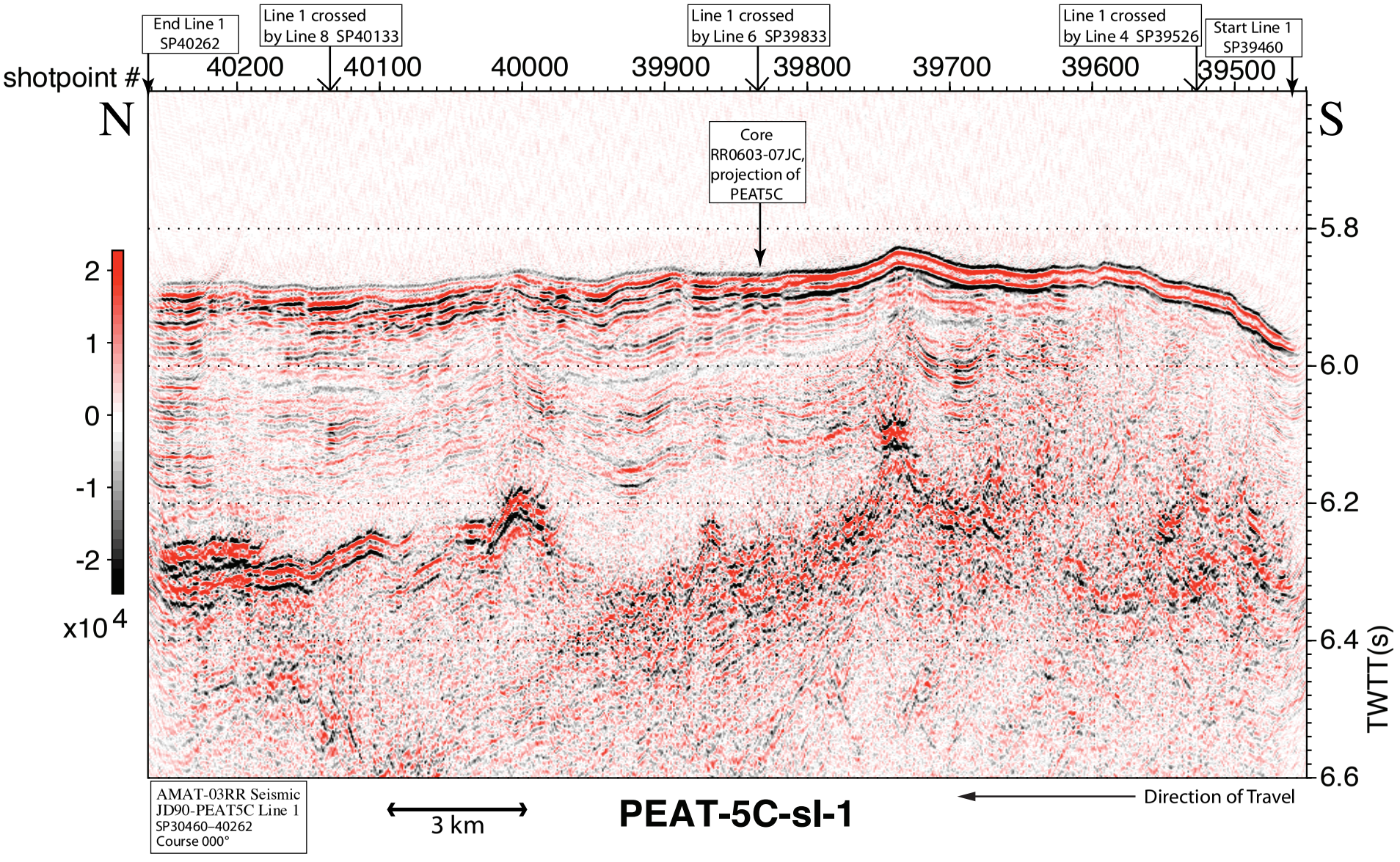
FigPEAT5C-11

# PEAT-5C survey Line 1 (4ch streamer, stacked & migrated) vs. survey time



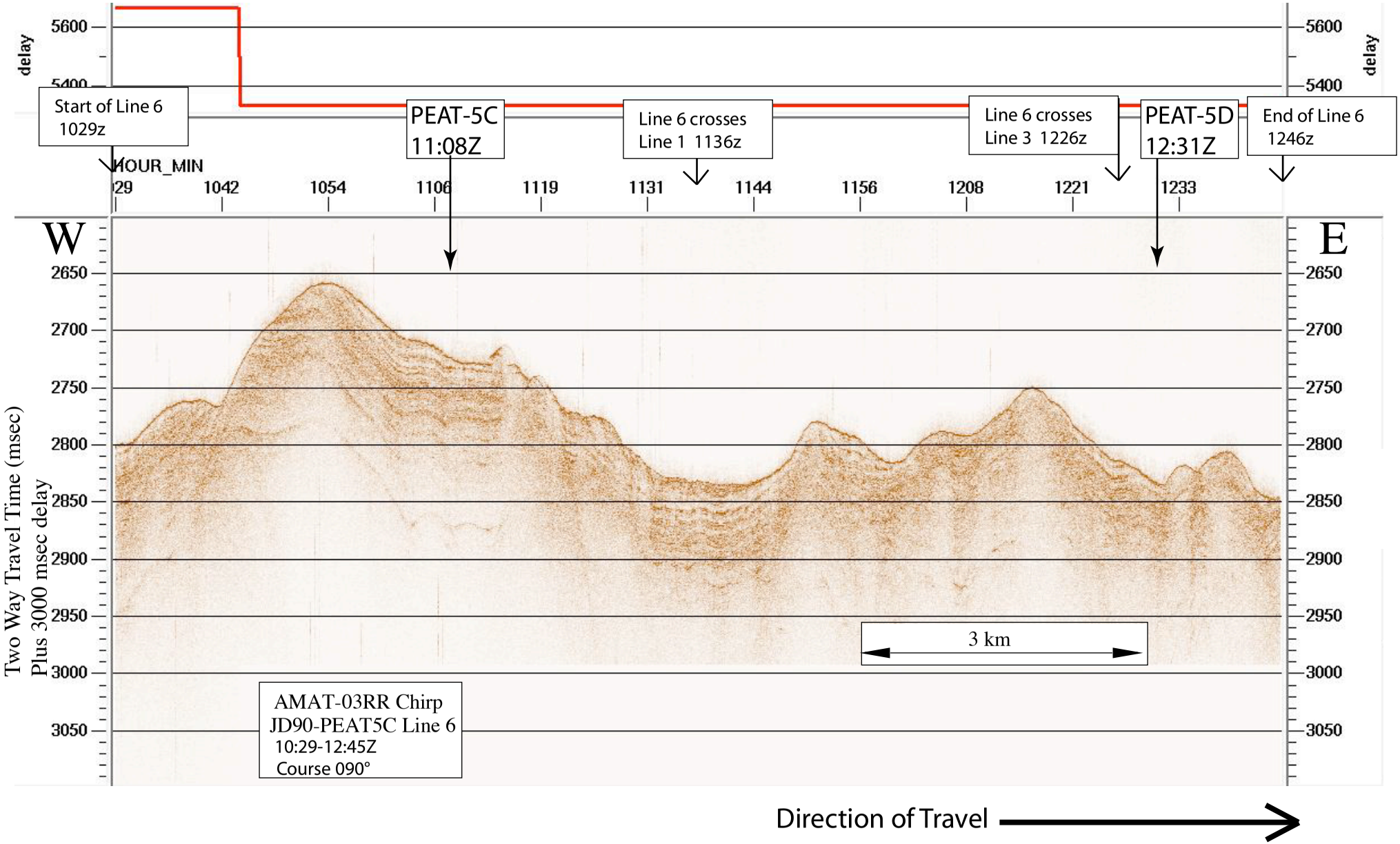
FigPEAT5C-12

# PEAT-5C survey Line 1 (4ch streamer, stacked & migrated) vs. shotpoint



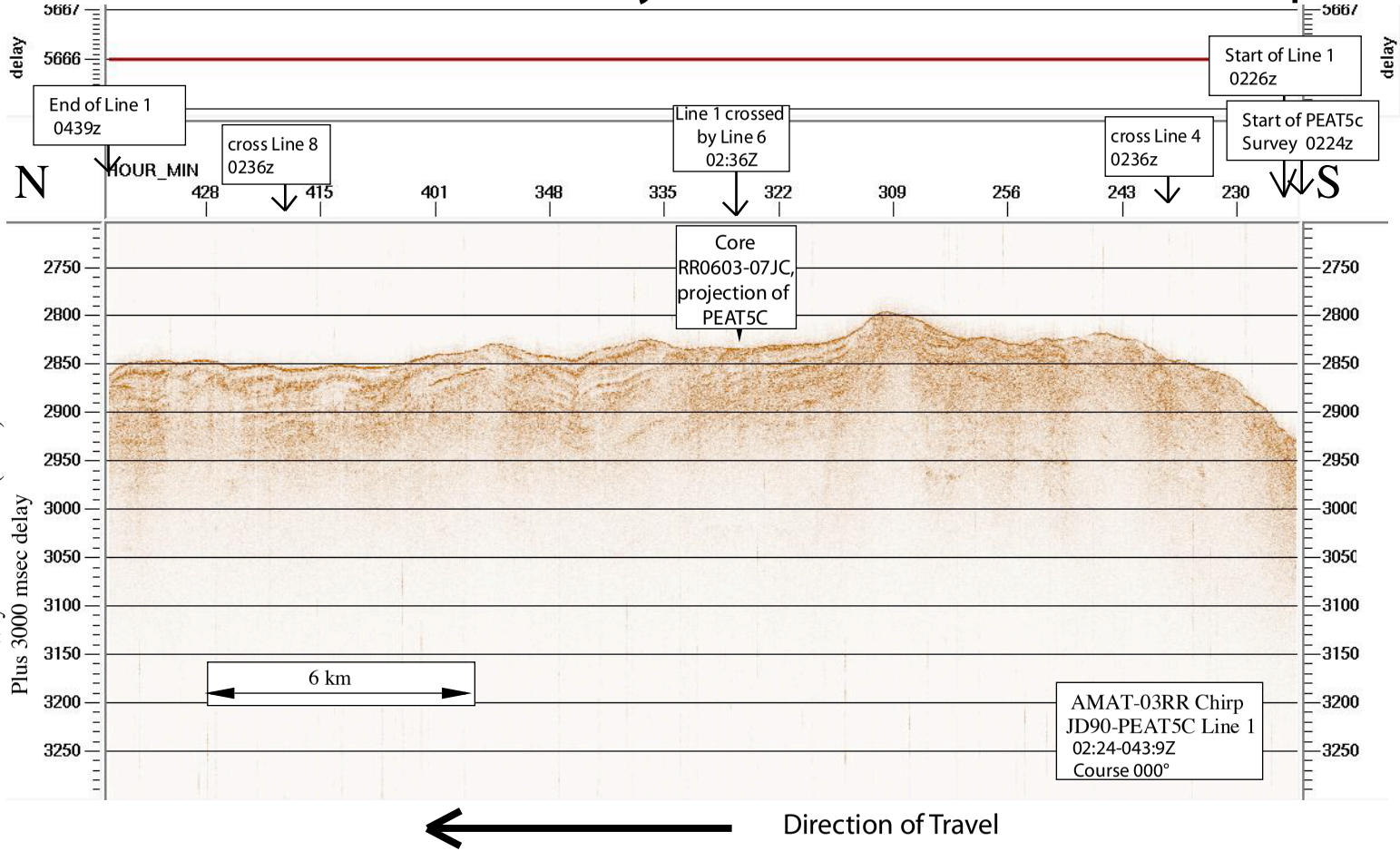
FigPEAT6C-13

# PEAT-5C survey Line 6 (CHIRP subbottom profiler)



FigPEAT6C-14

# PEAT-5C survey Line 1 (CHIRP subbottom profiler)



# SITE PEAT-6C (Oligocene–Miocene transition)

# 05° 18.736'N, 126° 16.997'W, 4362 mbsl

## *SITE OBJECTIVES*

PEAT-6C is proposed for drilling to focus on the paleoceanographic events in the late Oligocene and into the early and middle Miocene, including and focusing on the climatically significant Oligocene–Miocene transition and its recovery. In conjunction with PEAT-5C and 7C it is also designed to provide a latitudinal transect for early Miocene age slices.

At the end of the Oligocene there is a significant multi-Myr long rise in the oxygen isotope record (Lear et al., 2004), which is closely followed by a relatively short, sharp increase in oxygen isotope values that has been interpreted as a major glacial episode (Mi-1; Zachos et al. 1997, 2001a,b; Pälike et al., 2006) and correlated to a pronounced drop in sea level (Miller et al., 1991). This event is very close to the Oligocene-Miocene boundary, and has now been astronomically age calibrated in several ocean basins (Shackleton et al., 2000; Billups et al., 2004). Although there are clear periodic isotopic signals indicating major changes in ice volume, ocean temperatures and/or ocean structure, this biostratigraphic boundary has always been somewhat of an enigma. Unlike the major changes in the isotopic stratigraphy, the biostratigraphies of the planktonic microfossils show very little change at all across this boundary. In fact it is one of the most difficult epoch boundaries to pick using solely the microfossil biostratigraphies.

In Sites 1218 and 1219 of ODP Leg 199 this interval was well recovered; however, carbonate preservation still presented a problem for the classic foraminiferal stratigraphy. Both sites were deep and well within the lysocline, making the application of temperature proxies such as Mg/Ca ratios in foraminiferal tests more difficult (C.H. Lear, personal communication 2006). At the time Mio-Oligocene sediments were deposited, Site 1218 already resided on 18 Myr-old crust and was about 4100 m deep. Site 1219 was on about 34 Myr-old crust and was about 4500 m deep. There was a relative increase in the large diatoms near this boundary in the siliceous course fraction, suggesting increased productivity; however detailed, high-resolution flux rates across this interval have yet to be determined. A well recovered section on the latest Oligocene equator, near the late Oligocene ridge-crest as targeted by PEAT-6C, should provide both the resolution and the preservation required to better describe the changes in the equatorial ocean taking place at this time.

GENERAL DESCRIPTION

PEAT-6C is situated in the central tropical Pacific on a broad deep within NNW-trending abyssal hill topography, about 15 and 30 km west and 20km north of three sea mounts (Figure PEAT6C–1,–2). Thick sediment deposits cover the abyssal hills, with a thinning sediment cover on the hills. Based on stage-pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, and magnetic

anomaly maps (Cande et al., 1989), we determined that PEAT-6C is located on 26 to 27 Ma crust. The best age control is provided by information from Site 79, located 4.5° to the east and 3° to the south of PEAT-6C, apparently on the same fracture zone segment, with the Clipperton Fracture Zone to the north. The base of Site 79 reaches the Miocene-Oligocene boundary, or 23 Ma on the most recent astronomically calibrated timescales.

Water depth in the vicinity of PEAT-6C is between 4300 and 4400mbsl, apart from the topography around three sea-mounts that are 15 to 30km away from the proposed drill site. Sediment cover is relatively thick, but varies around ridges and deeps.

## *AMAT-03 Survey*

PEAT-6C was surveyed on 27th and 28th March 2006 (Julian Days 086-087) with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. The site was also piston cored, and a 12.67 m piston core (RR0603-06JC) was recovered.

PEAT-6C is located along the flank of a wide NNW trending valley, on high ground above the abyss and moat of the sea-mounts. (Fig. PEAT6C-2). Sediment cover is thick in the entire region, ranging from 300 to 500 msec TWTT. The sea floor is relatively flat because the sediment has filled in the basement topography (around 200 msec TWTT). Figures PEAT6C–7, and –8 show the primary seismic line (line 8), while Figures PEAT6C–9,–10 show the crossline (line 1).

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-06JC & TC 05°19.998'N, 126° 10.527' W 4376m (uncorr.) 12.67 m sediment from AMAT-03RR.

RR0603-06JC (12.67 m recovered) and TC (2.75 m recovered) were taken approximately 12km the east of the proposed drillsite (see Figures PEAT6C–2,3). The cores recovered mottled brown to light brown cyclic carbonates and siliceous biogenic sediments with carbonate contents of between 20 to 85%. The sediments range from foraminiferal-nannofossil oozes with radiolaria and diatoms to radiolarian-diatom oozes with forams and nannofossils. All the microfossils showed signs of dissolution. In addition, significant numbers of reworked middle Miocene radiolaria were found in the sediments.

The age of the sediment was assessed via nannofossil and radiolarian biostratigraphy. Based on the biostratigraphic ages, the cyclic variations in carbonate (as shown by density variability) could be correlated to a global oxygen isotope stratigraphy. The combined data indicate a basal age slightly older than 2.4 Ma for Core RR0603-06JC and a relatively constant sedimentation rate of 6.5 m/Myr in the upper half of the core, and 5m/Myr in the lower half. This is significantly less than the average estimated sedimentation rate of about 12.5 m/ Myr since crust was formed, and compatible with a reduced sedimentation rate for the younger parts of the core as the site moved north out of the equatorial high productivity zone, with higher sedimentation rates in the lower parts of the section.

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-6C):
**AMAT-03-PEAT6C line 8**, 2006 JD087 (28 March) 08:14:59UTC, SP 19103.
Nearest crossing:
**crossing of PEAT6C line 1** 2006 JD087 08:26:19, SP SP16216
(SP19171 on line 8 using ship's position)

Crustal age: 26–27 Ma
Ship location @ SP19103: 05° 18.807' N, 126° 16.998'W
PEAT-6C Location (SP minus 4): 5°18.736' N, 126° 16.997'W
Site water depth: 4362 m (5.816 sec TWTT)
Basement depth: 4723 m (6.257 sec TWTT)
Sediment thickness: 361 m (0.441 sec TWTT)
Proposed Drilling Depth: to basement (estimated 361 m) + tag basement
Used velocity model: from DSDP Site 574:

| Interval | Interval velocity |
|---|---|
| 0-100msec | 1520 m/s |
| 100-193msec | 1613 m/s |
| 193-410msec | 1650 m/s |
| >410msec | 1970 m/s |

PEAT-6C was initially chosen near the intersection of lines 1 and 8 from the AMAT-03 survey (Figures PEAT6C–2, –3, –8, –10). The section is typical in thickness of the deposits in basins along the seismic lines. The site was then moved south along seismic line 8 where it was originally located in order to obtain a better-imaged basement reflector, and to capture the slightly expanded lower target section. Sediment thickness was estimated using interval velocities published for Site 574 by Mayer et al. (1985). The subbottom profiler sections (Figures PEAT6C-11, -12) image about 100m of layered sediments in the upper sediment column.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts, geological setting not known for overpressure. Significantly younger sites further to the east (ODP Site 849) have encountered chert near basement.

## *OTHER HAZARDS*

There are no known manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-6C Line 1
PEAT-6C Line 2
PEAT-6C Line 3
PEAT-6C Line 4
PEAT-6C Line 5
PEAT-6C Line 6
PEAT-6C Line 7
PEAT-6C Line 8

## *FIGURES*

Fig PEAT6C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-6C is marked.

Fig PEAT6C-2: Swathmap bathymetry for the PEAT-6C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-06JC are marked.

Fig PEAT6C-3: Location of seismic lines in PEAT-6C region vs. shotpoints, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-06JC are marked.

Fig PEAT8C-4: Location of seismic lines in PEAT-6C region vs. survey time, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-06JC are marked.

Fig PEAT6C-5: MST physical properties data for RR0603-06JC plotted versus depth. Section breaks are marked by red vertical lines. Upper panel: P-wave bulk sediment velocity in m/s. Upper middle panel: sediment wet bulk density as estimated by GRA correlation (in grams /cubic centimeter). Lower middle panel: Magnetic susceptibility (in SI units $x10^{-6}$). Lower panel : electrical resistivity (Ohm x meter). All data were lightly "cleaned" prior to plotting, taking out most of the extreme outliers that occur near section breaks.

Fig PEAT6C-6: Shipboard biostratigraphy for RR0603-06JC

Fig PEAT6C-7: Seismic profile PEAT-6C Line 8 across PEAT-6C, from AMAT-03, vs. survey time. Proposed drill site is marked.

Fig PEAT6C-8: Seismic profile PEAT-6C Line 8 across PEAT-6C, from AMAT-03, vs. shotpoint. Proposed drill site is marked.

Fig PEAT6C-9: Crossline seismic profile PEAT-6C Line 1 from AMAT-03, vs. survey time. Site was moved west of the crossline to avoid the basement deep.

Fig PEAT6C-10: Crossline seismic profile PEAT-6C Line 1 from AMAT-03, vs. shotpoint. Site was moved west of the crossline to avoid the basement deep.

Fig PEAT6C-11: Chirp subbottom profile from Line 8 across PEAT-6C, from AMAT-03, vs. survey time. Proposed drill site is marked.

Fig PEAT6C-12: Chirp subbottom profile from Line 1 across PEAT-6C, from AMAT-03, vs. survey time. Proposed drill site is marked.

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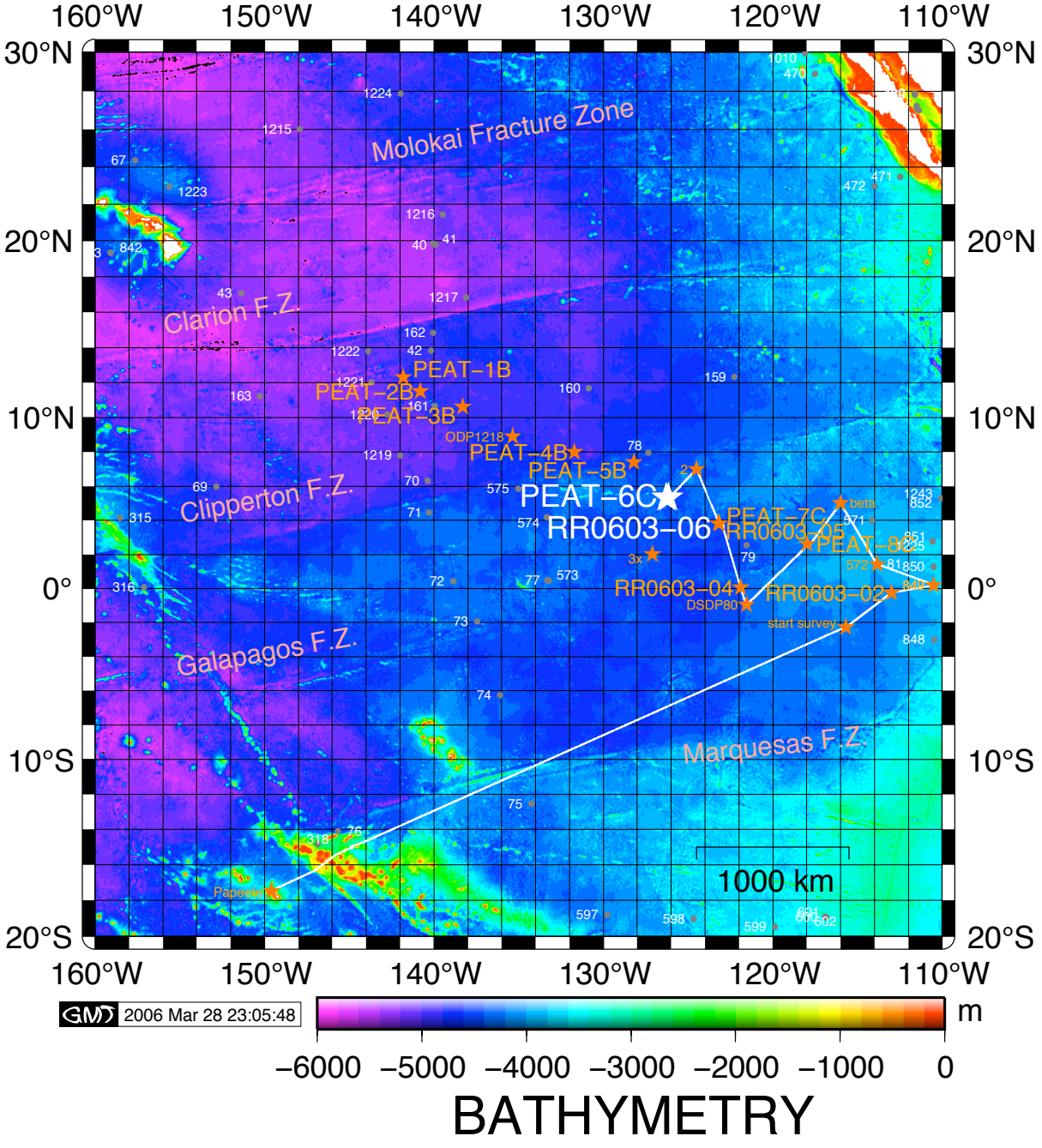
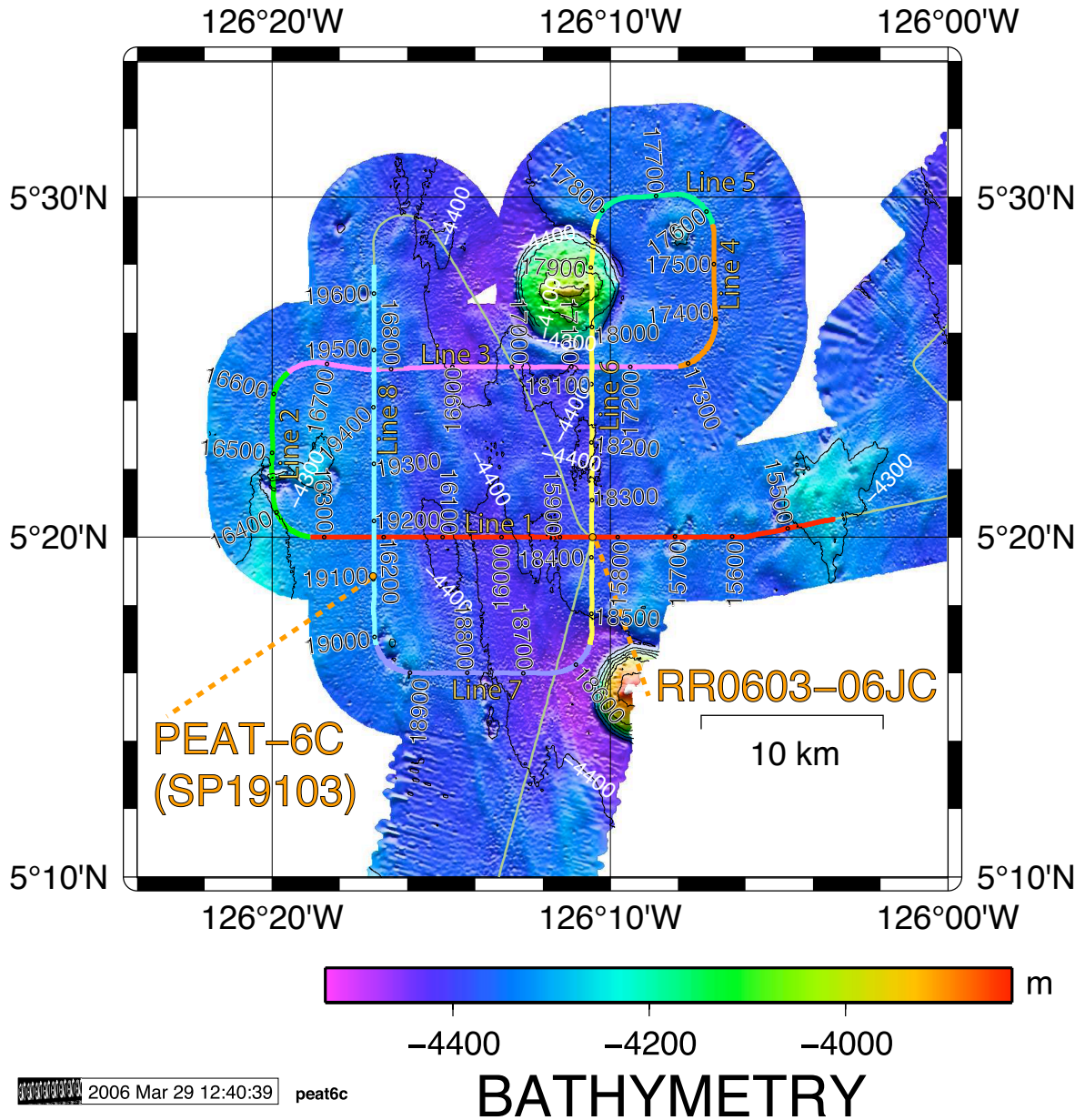
FigPEAT6C-1

# AMAT–03 PEAT-6C Overview



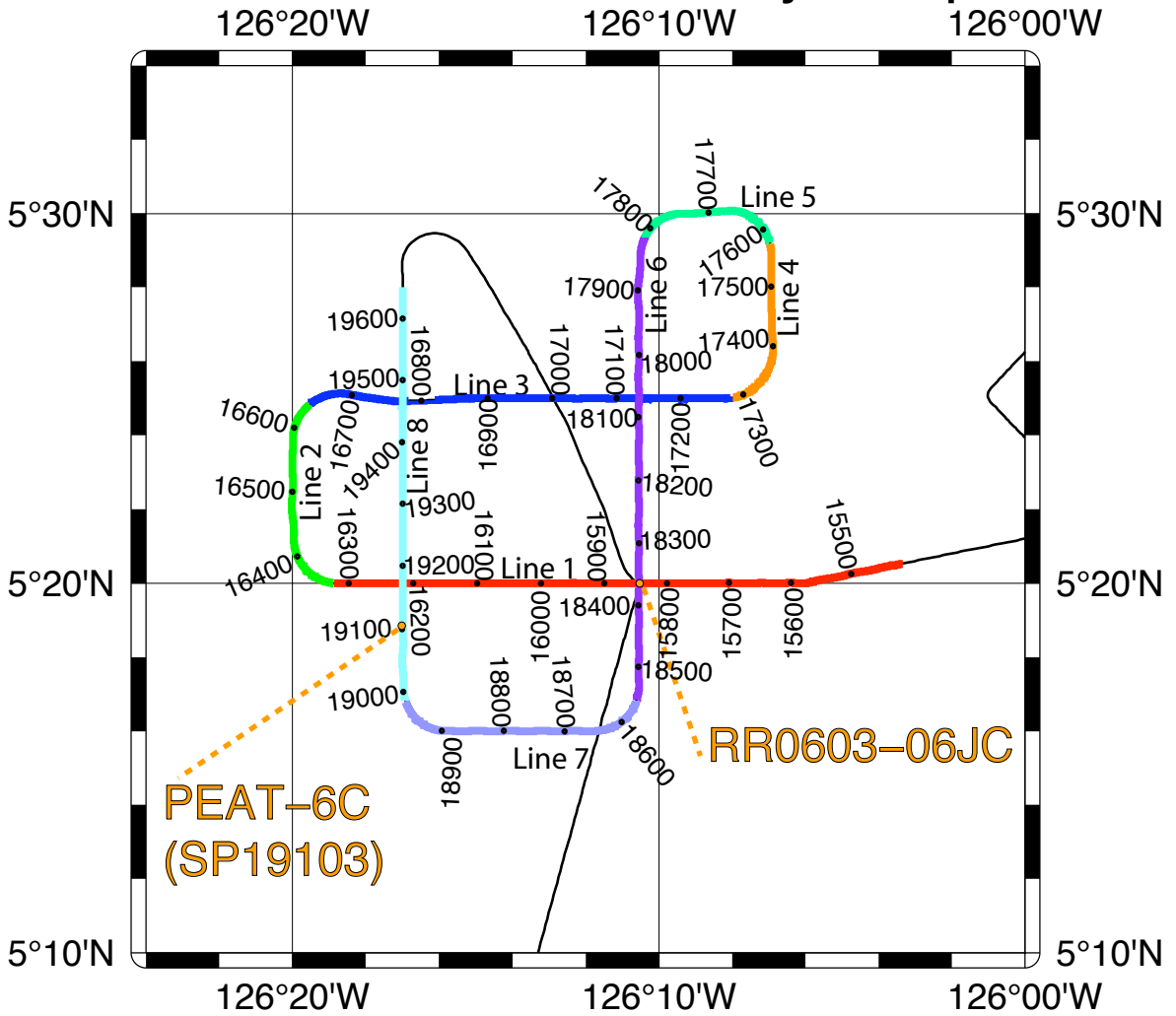
FigPEAT6C-2

# PEAT–6C SWATH Bathymetry



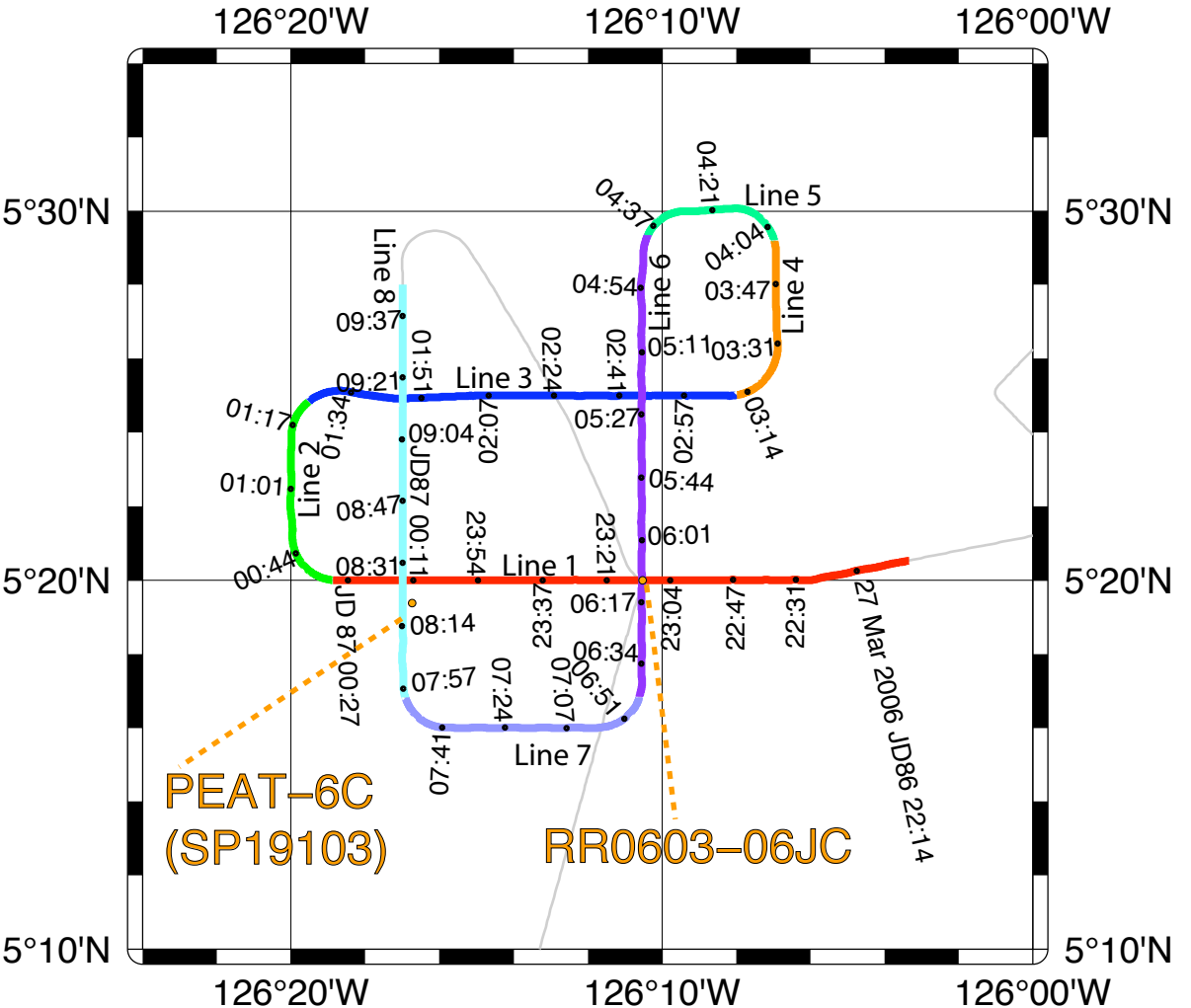
FigPEAT6C-3

# PEAT–6C Seismic Survey shotpoints

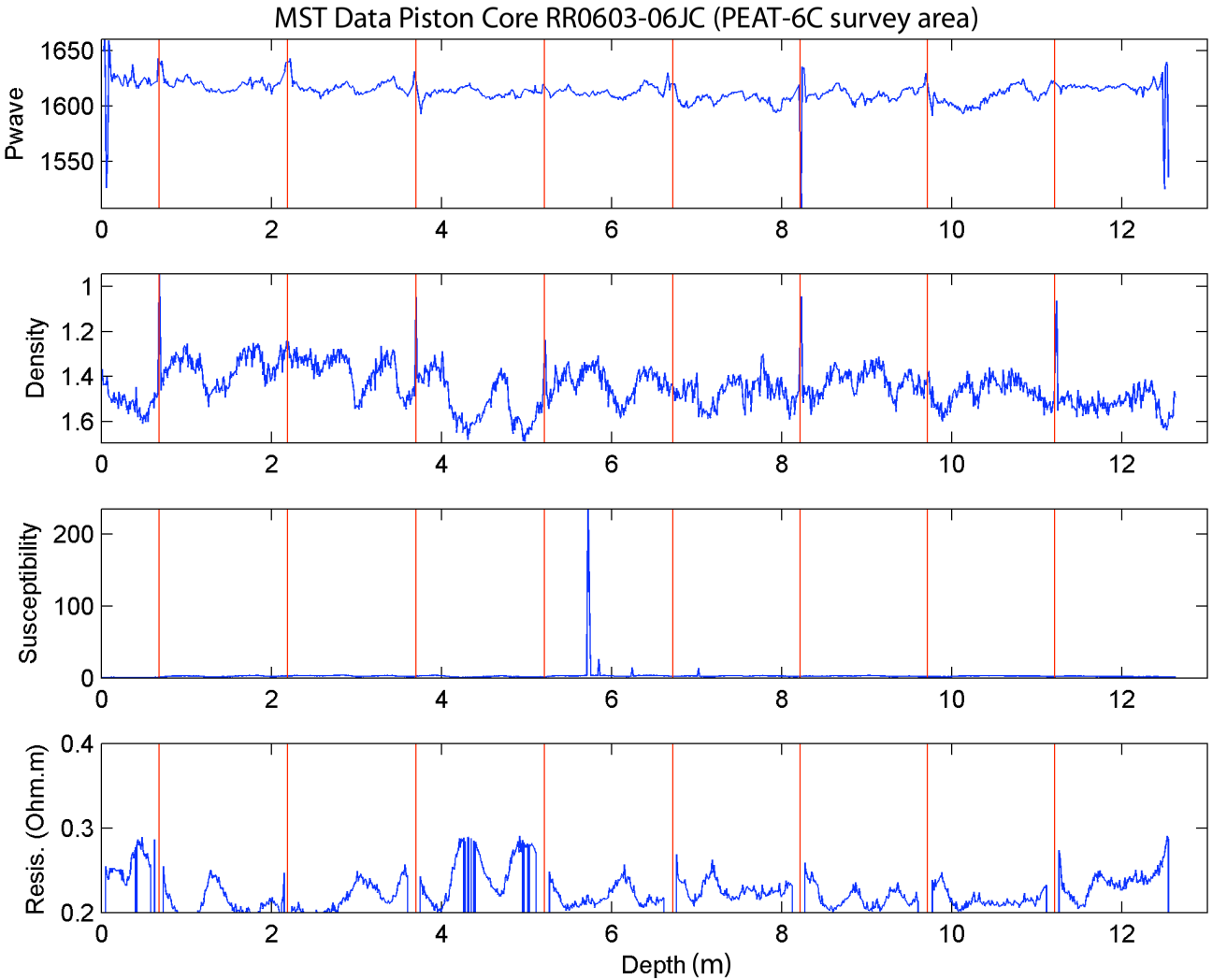


FigPEAT6C-4

# PEAT–6C Seismic Survey shotpoints (time)

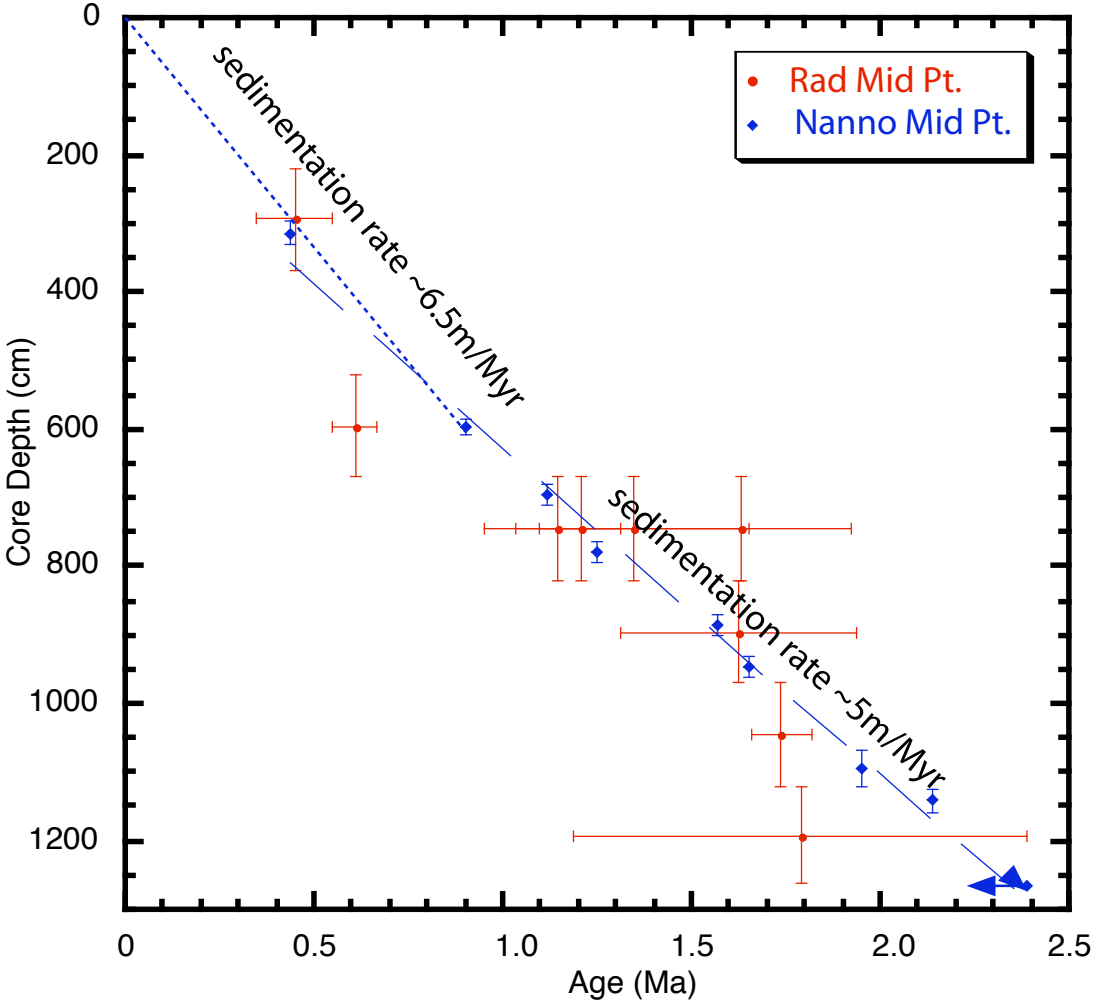


FigPEAT6C-5


MST Data Piston Core RR0603-06JC (PEAT-6C survey area)
Pwave
1650
1600
1550
Density
1
1.2
1.4
1.6
Susceptibility
200
100
0
Resis. (Ohm.m)
0.4
0.3
0.2
0
2
4
6
8
10
12
Depth (m)

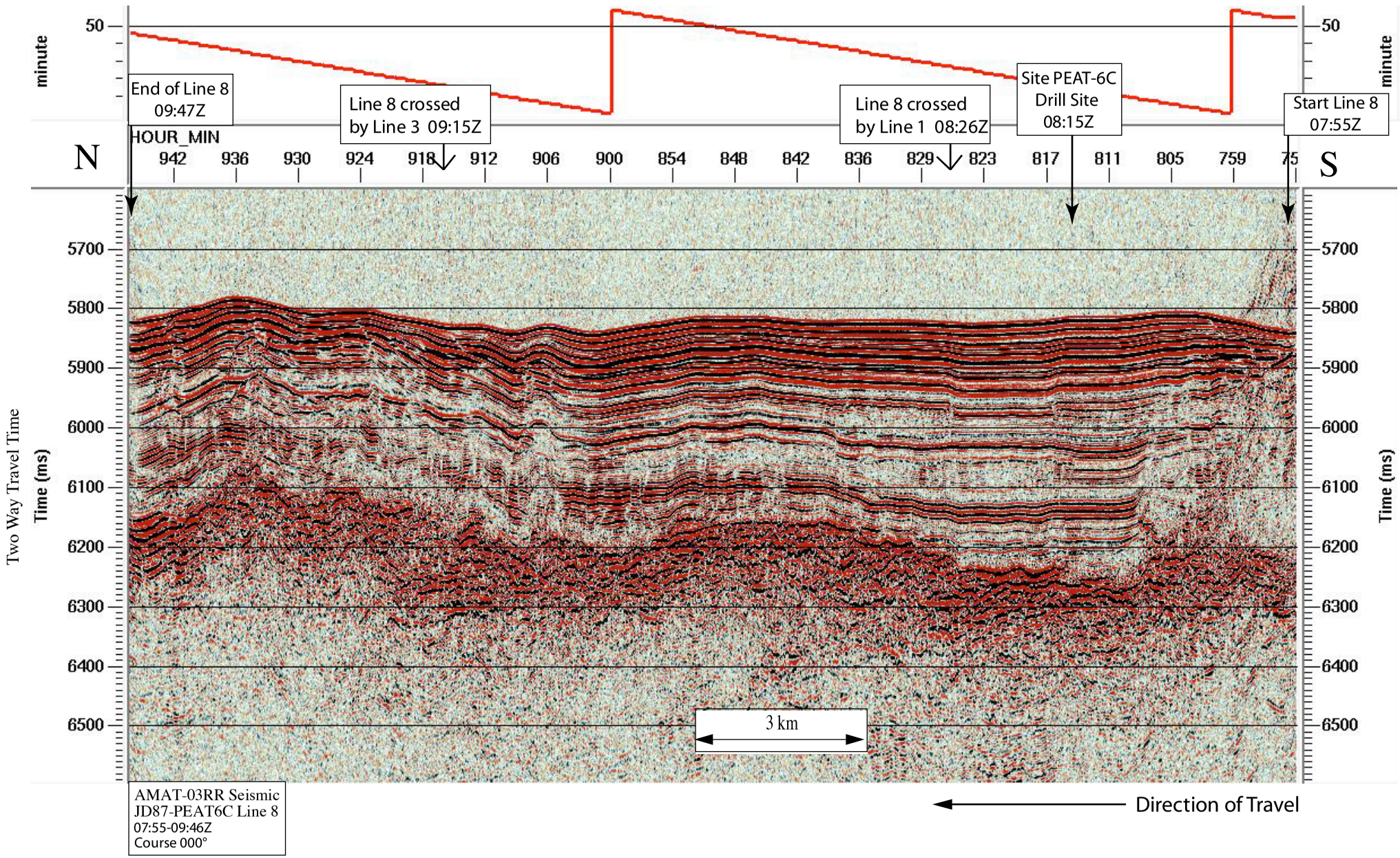
FigPEAT6C-6

# Stratigraphic summary RR0603-06JC,TW



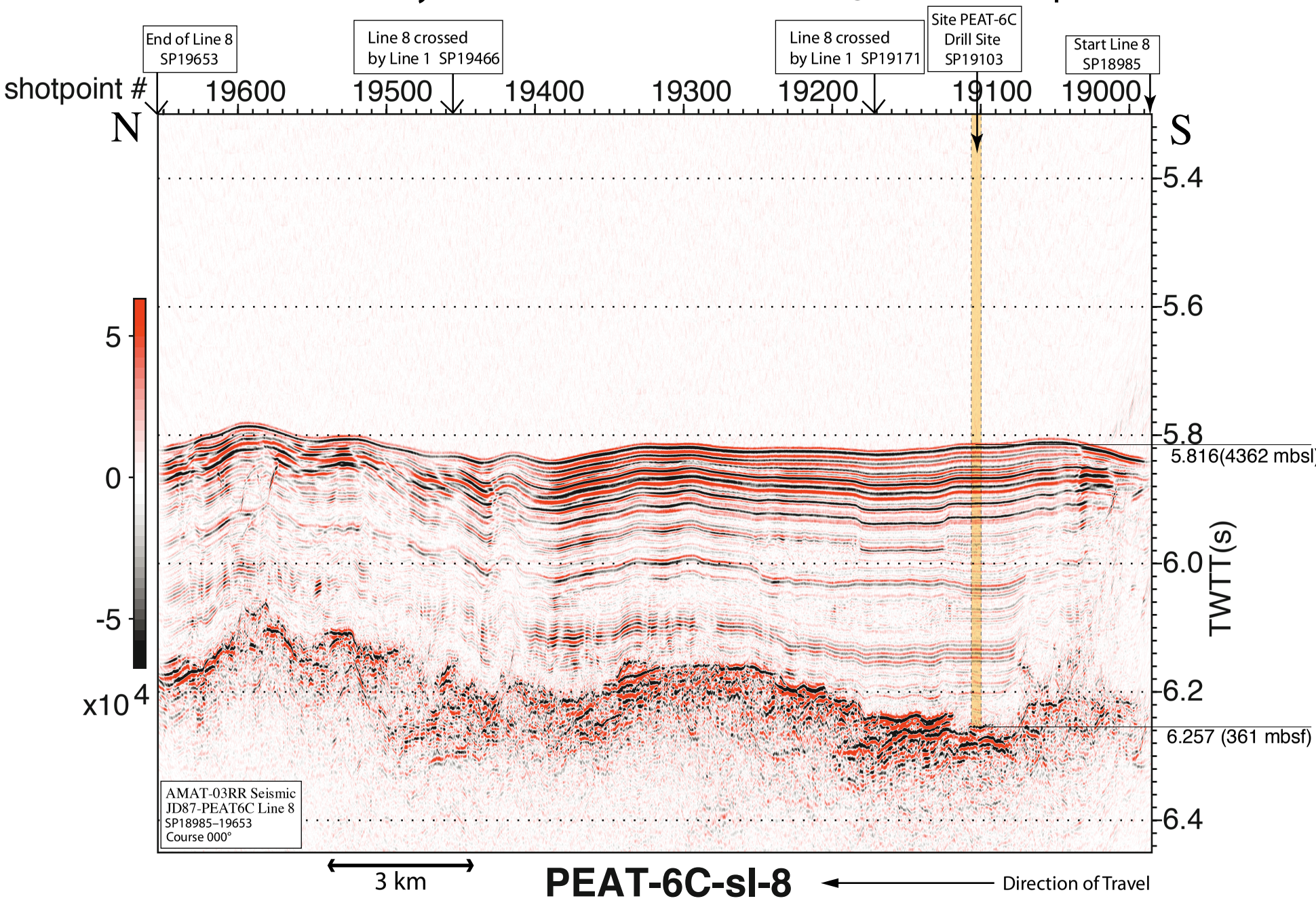
FigPEAT6C-7

# PEAT-6C survey Line 8 (48ch streamer, stacked & migrated) vs. survey time



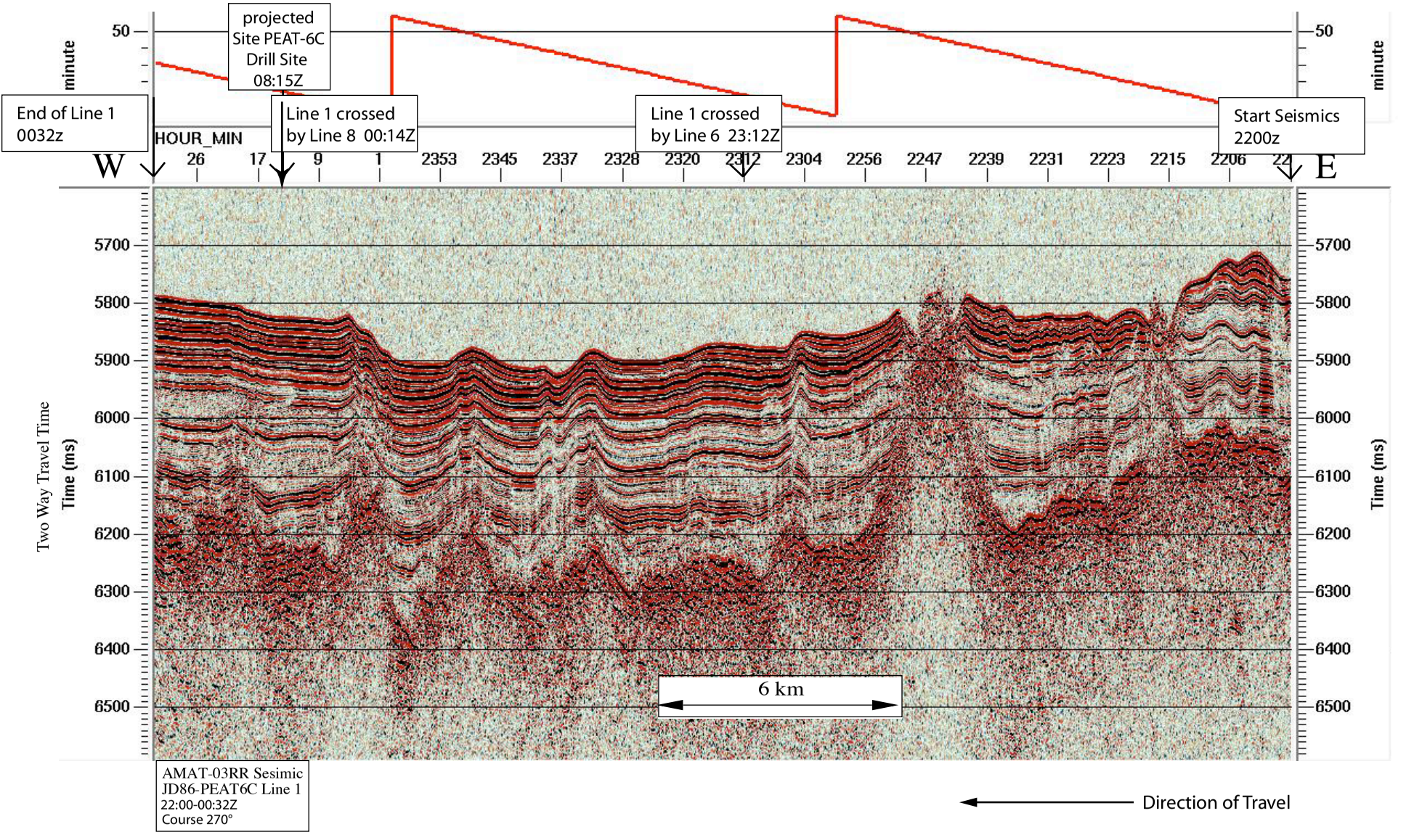
FigPEAT6C-8

# PEAT-6C survey Line 8 (48ch streamer, stacked & migrated) vs. shotpoint



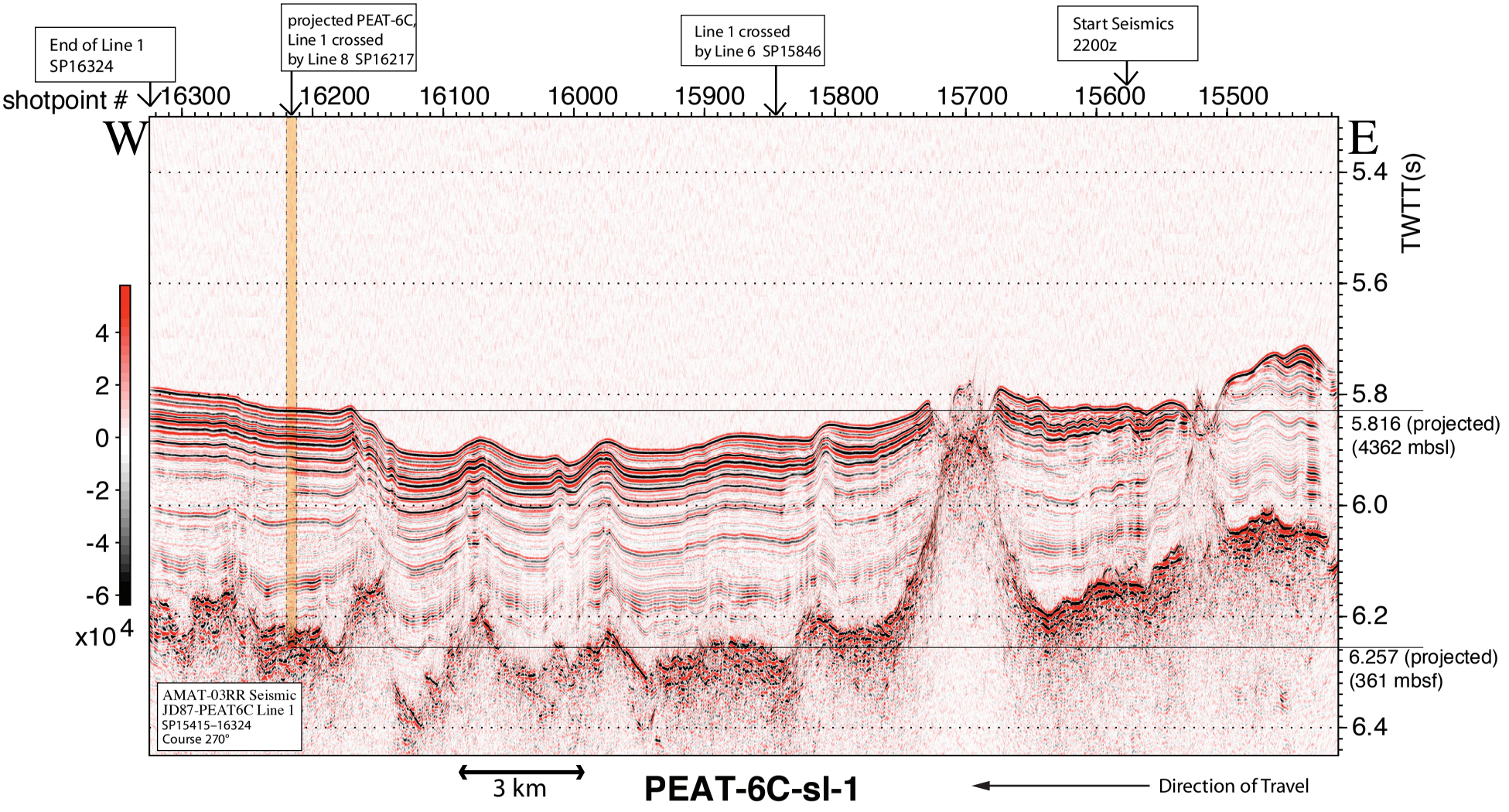
FigPEAT6C-9

# PEAT-6C survey Line 1 (48ch streamer, stacked & migrated) vs. survey time



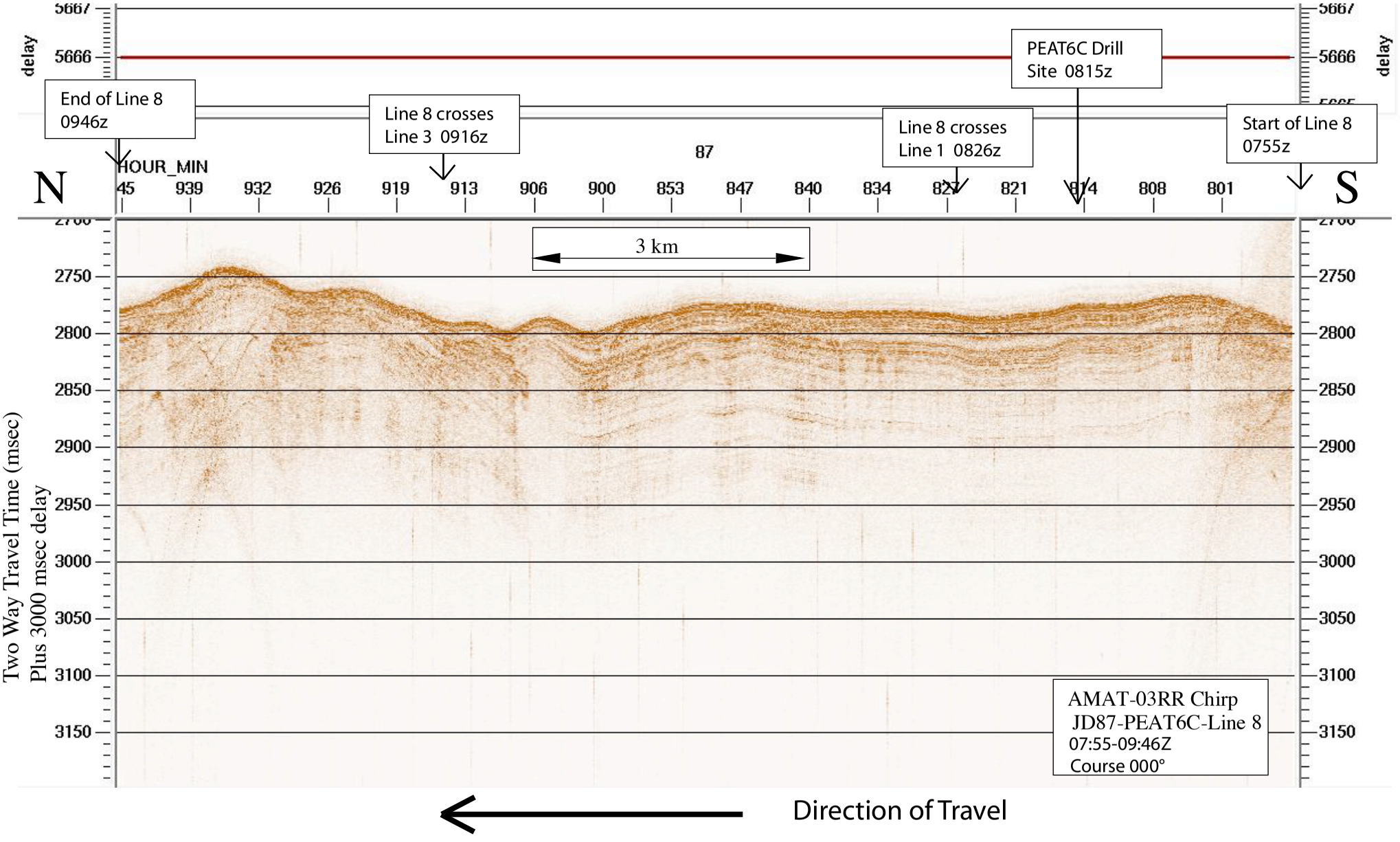
FigPEAT6C-10

# PEAT-6C survey Line 1 (48ch streamer, stacked & migrated) vs. shotpoint



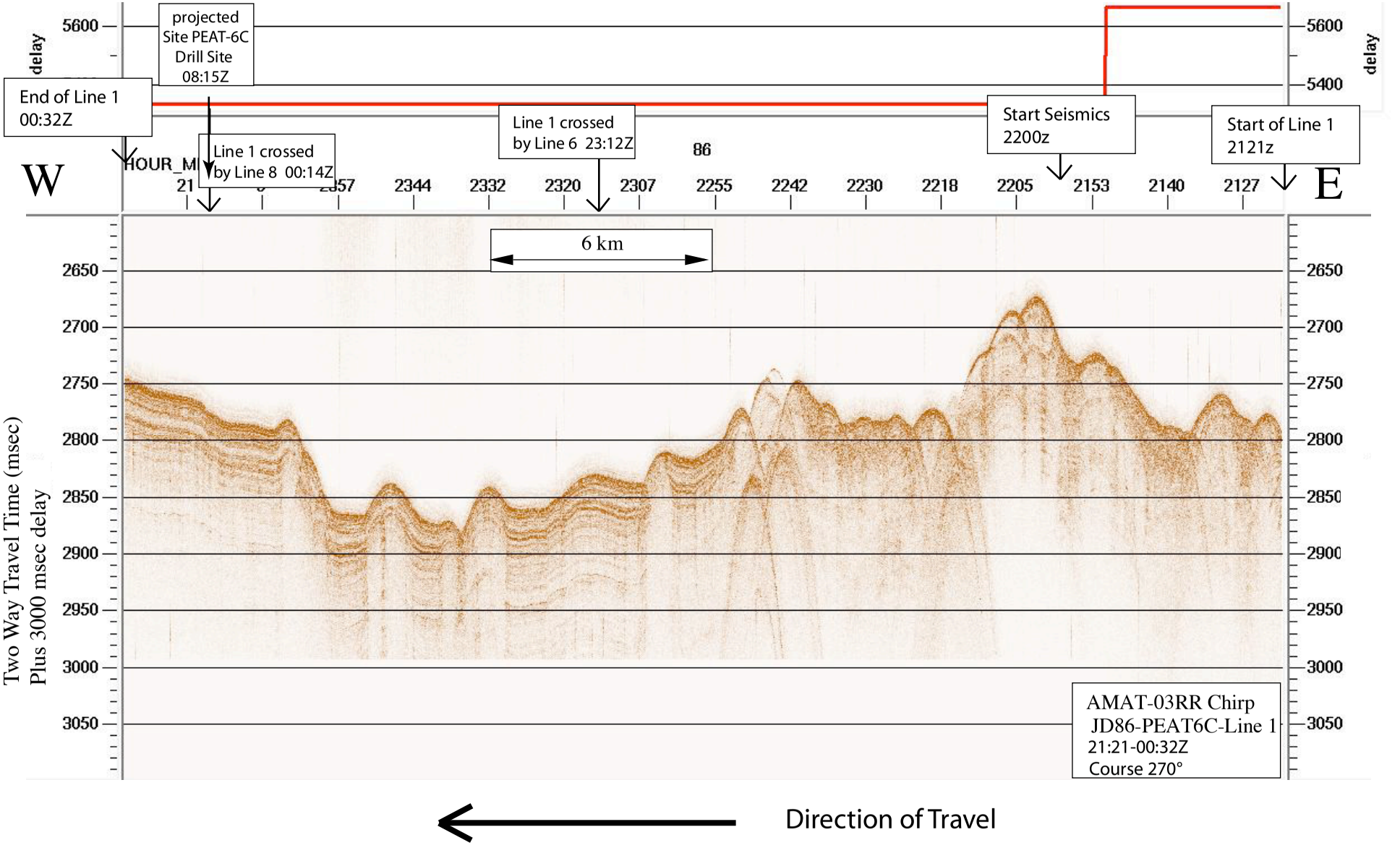
FigPEAT6C-11

# PEAT-6C survey Line 8 (CHIRP subbottom profiler)



FigPEAT6C-12

# PEAT-6C survey Line 1 (CHIRP subbottom profiler)



# SITE PEAT-7C (early to mid- Miocene equator)
# 03° 50.009'N, 123° 12.352'W, 4491 mbsl

## *SITE OBJECTIVES*

PEAT-7C is proposed for drilling to focus on the paleoceanographic events in the early and middle Miocene. The latest Oligocene through to the mid Miocene appears to have been a time of relative warmth comparable to the latest Eocene. However, the variability in the isotopic record of the early to mid Miocene appears to be larger than that of the Eocene and may indicate more variability in climate and in global ice volume. The climatic "optimum" at about 15 Ma comes just before the major development of ice sheets on Antarctica and the marked increase in ice rafted debris in circum-Antarctic sediments. The early Miocene also marks a major evolutionary change from the relatively static Oligocene planktonic biota. In the equatorial Pacific, the early Miocene marks the beginning of abundant diatoms in the stratigraphic record (J. Barron, personal communication) and implies a major change in carbon cycling as well.
The only major ocean boundary change proposed for the time near the Oligocene-Miocene boundary was the opening of the Drake passage to deep flow; however, there is some debate as to the exact timing of this event (Barker, 2001; Pagani et al., 1999, Lawver and Gahagan, 2003, Scher & Martin, 2006), and its direct impact on the tropical ocean is uncertain. It may be that, as in the Eocene–Oligocene boundary section, the link lies in the shallow intermediate waters that provide nutrients to lower latitude upwelling regions. For the equatorial region, an even more pertinent question is, what changes were occurring in the Miocene tropical ocean that led to this burst of Miocene evolution?

Following SSEP recommendations we have positioned the Miocene sites to the south of the estimated paleo-equatorial position at their target ages in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. We located the site using the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

## *GENERAL DESCRIPTION*

PEAT-7C (Figure PEAT7C-1) is situated in the central tropical Pacific on a broad plateau within NNE-trending abyssal hill topography. Thick sediment deposits cover the abyssal hills, but these deposits are being eroded at the edge of the plateau. Based on stage-pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, and magnetic anomaly maps (Cande et al., 1989), we determined

that PEAT-7C is located on 24.5 Ma crust. The best control on age is information from Site 79, located 1.5° to the east of PEAT-7C. The base of Site 79 reaches the Miocene-Oligocene boundary, or 23 Ma.

Water depth in the vicinity of PEAT-7C is below 4500 mbsl, marking regionally deep basement. Sediment cover is relatively thick, but varies radically around ridges and deeps.

## *AMAT-03 Survey*

PEAT-7C was surveyed on 25 March 2006 with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. The site was also piston cored, and a 14.1 m core (RR0603-05JC) was recovered.

PEAT-7C is located on a plateau between high topography to the south of the site, a gentle but pockmarked ridge to the north and a deep to the east (Figure PEAT7C-2). Sediment cover is thick on the plateau but is highly variable along the edges. Figure PEAT7C-5 shows the variable sedimentation along the eastern edge and the thick sediment cover on the plateau ranging from 300 to 600 msec TWTT. Nevertheless, the sea floor is relatively flat because the sediment has filled in the basement topography, of around 200 msec TWTT. To the north, along PEAT7C Line 6, the sea floor is dissected by a series of karst-like holes which cut through the seismic layering (Figure PEAT7C-2, –9). Based upon correlation to the central equatorial Pacific seismic stratigraphy of Mayer et al. (1985), middle Miocene sediment has been exposed (figure PEAT7C-9). Figures PEAT7C-7,8 and PEAT7C-10,11 show the primary seismic line (Line 4) and the crossline (Line 10) and delineate the lens of sediment around PEAT-7C.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-05JC & TC 03° 05.102'N, 123° 10.249' W 4495m (uncorr.) 14.09 m sediment from AMAT-03.

RR0603-5JC and TC were taken to the east of the proposed drillsite (see Figure PEAT7C-2). They recovered 14.1 meters of brown to light brown cyclic carbonates and siliceous biogenic sediments. The sediments ranged from foraminifera-nannofossil oozes with radiolaria and diatoms to radiolarian-diatom oozes with forams and nannofossils. All the microfossils showed signs of dissolution. In addition, significant numbers of reworked middle Miocene radiolaria were found in the sediments.

Age of the core was assessed via nannofossil and radiolarian biostratigraphy (Figure PEAT7C-5,6). Based on the biostratigraphic ages, the cyclic variations in carbonate (as shown by density variability, Figure PEAT7C-5) could be correlated to oxygen isotope stratigraphy. The combined data indicate a basal age slightly older than 1.0 Ma for 5JC and a relatively constant sedimentation rate of 14 m/Myr, slightly less than the average estimated sedimentation rate of about 20 m/ Myr since crust was formed ,

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-7C):
**AMAT-03-PEAT7C Line 4**, 2006 JD084 16:53:48UTC, SP 1756.
Nearest crossing :
**crossing of PEAT7C Line 10**, 2006 JD084 23:20:59UTC, SP 4071

Crustal age: 24.5 Ma
Ship location @ SP1756: 3° 50.006' N, 123° 12.403'W
PEAT-7C Location (SP minus 3): 3° 50.009' N, 123° 12.352'W
Site water depth: 4491 m (5.988 sec TWTT)
Basement depth: 4966 m (6.522 sec TWTT)
Sediment thickness: 452 m (0.534 sec TWTT)
Proposed Drilling Depth: to basement (estimated 452m) + tag basement
Used velocity model: from DSDP Site 574:

| Interval | Interval velocity |
|---|---|
| 0-100msec | 1520 m/s |
| 100-193msec | 1613 m/s |
| 193-410msec | 1650 m/s |
| >410msec | 1970 m/s |

PEAT-7C was chosen near the intersection of lines 4 and 10 from the AMAT-03 survey (Figure PEAT7C–7,–8 and –9,–10). The section is typical in thickness of the deposits within the small basins imaged along Line 4. The site was moved to the west side of the basin from which it was originally located in order that it be over well-imaged basement. Sediment thickness was estimated using interval velocities published for DSDP Site 574 by Mayer et al. (1985). The subbottom profiler sections (Figures PEAT7C-12, -13) image about 80m of layered sediments in the upper sediment column.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts. Significantly younger sites (ODP Site 849) have encountered chert near basement.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-7C Line 1
PEAT-7C Line 2
PEAT-7C Line 3
PEAT-7C Line 4
PEAT-7C Line 5
PEAT-7C Line 6
PEAT-7C Line 7
PEAT-7C Line 8
PEAT-7C Line 9
PEAT-7C Line 10

## *FIGURES*

Fig PEAT7C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-7C is marked.

Fig PEAT7C-2: Swathmap bathymetry for the PEAT-7C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-05JC are marked.

Fig PEAT7C-3: Location of seismic lines in PEAT-7C region vs. shotpoints, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-05JC are marked.

Fig PEAT8C-4: Location of seismic lines in PEAT-7C region vs. survey time, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-05JC are marked.

Fig PEAT7C-5: MST physical properties data for RR0603-05JC.

Fig PEAT7C-6: Shipboard biostratigraphy for RR0603-05JC

Fig PEAT7C-7: Seismic profile PEAT-7C Line 4 across PEAT-7C, from AMAT-03, vs. survey time. Proposed drill site is marked.

Fig PEAT7C-8: Seismic profile PEAT-7C Line 4 across PEAT-7C, from AMAT-03, vs. shotpoint. Proposed drill site is marked.

Fig PEAT7C-9: Seismic profile PEAT-7C Line 6, to the north of the proposed drillsite, showing outcropping Miocene seismic horizons, and the correlation to DSDP Site 574 (Mayer et al., 1985)

Fig PEAT7C-10: Crossline seismic profile PEAT-7C Line 10 from AMAT-03, vs. survey time. Site was moved west of the crossline to avoid the basement deep.

Fig PEAT7C-11: Crossline seismic profile PEAT-7C Line 10 from AMAT-03, vs. shotpoint. Site was moved west of the crossline to avoid the basement deep.

Fig PEAT7C-12: Chirp subbottom profile from line 4 across PEAT-7C, from AMAT-03, vs. survey time. Proposed drill site is marked.

Fig PEAT7C-13: Chirp subbottom profile from line 10 across PEAT-7C, from AMAT-03, vs. survey time. Proposed drill site is marked.

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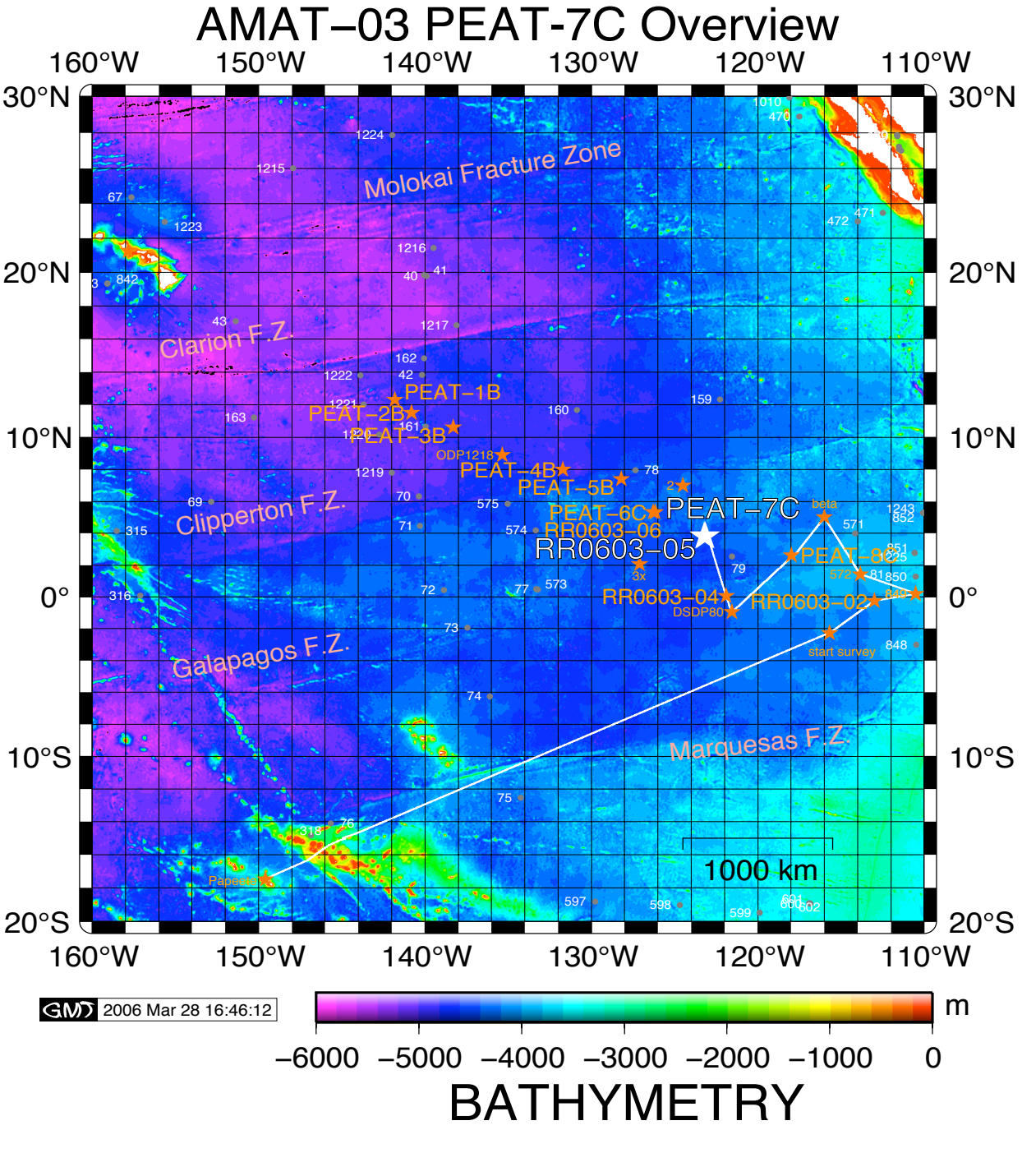
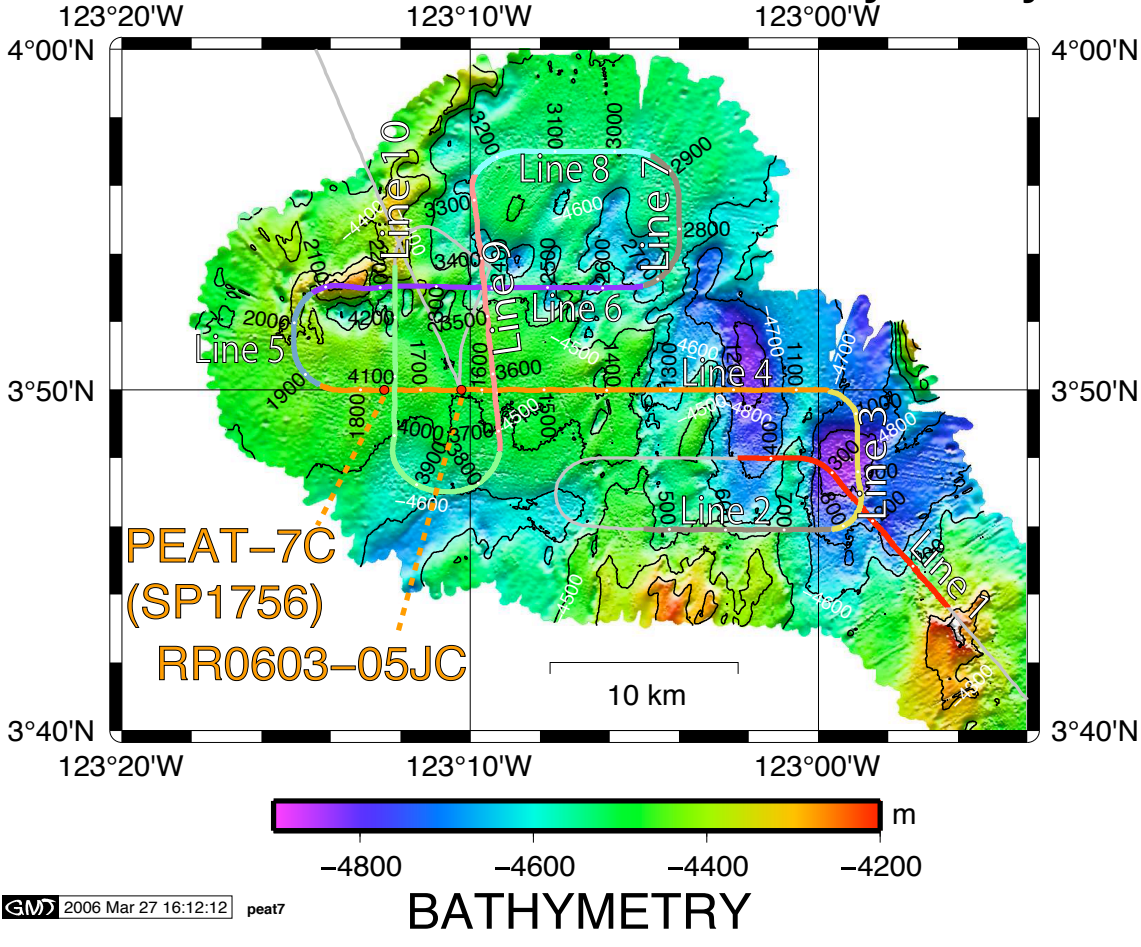
FigPEAT7C-1


AMAT–03 PEAT-7C Overview
160°W
150°W
140°W
130°W
120°W
110°W
30°N
20°N
10°N
0°
10°S
20°S
Molokai Fracture Zone
Clarion F.Z.
Clipperton F.Z.
Galapagos F.Z.
Marquesas F.Z.
PEAT–1B
PEAT–2B
PEAT–3B
ODP1218
PEAT–4B
PEAT–5B
PEAT–6C
PEAT–7C
RR0603–06
RR0603–05
RR0603–04
RR0603–02
PEAT–8
DSDP80
start survey
beta
1000 km
2006 Mar 28 16:46:12
m
–6000
–5000
–4000
–3000
–2000
–1000
0
BATHYMETRY

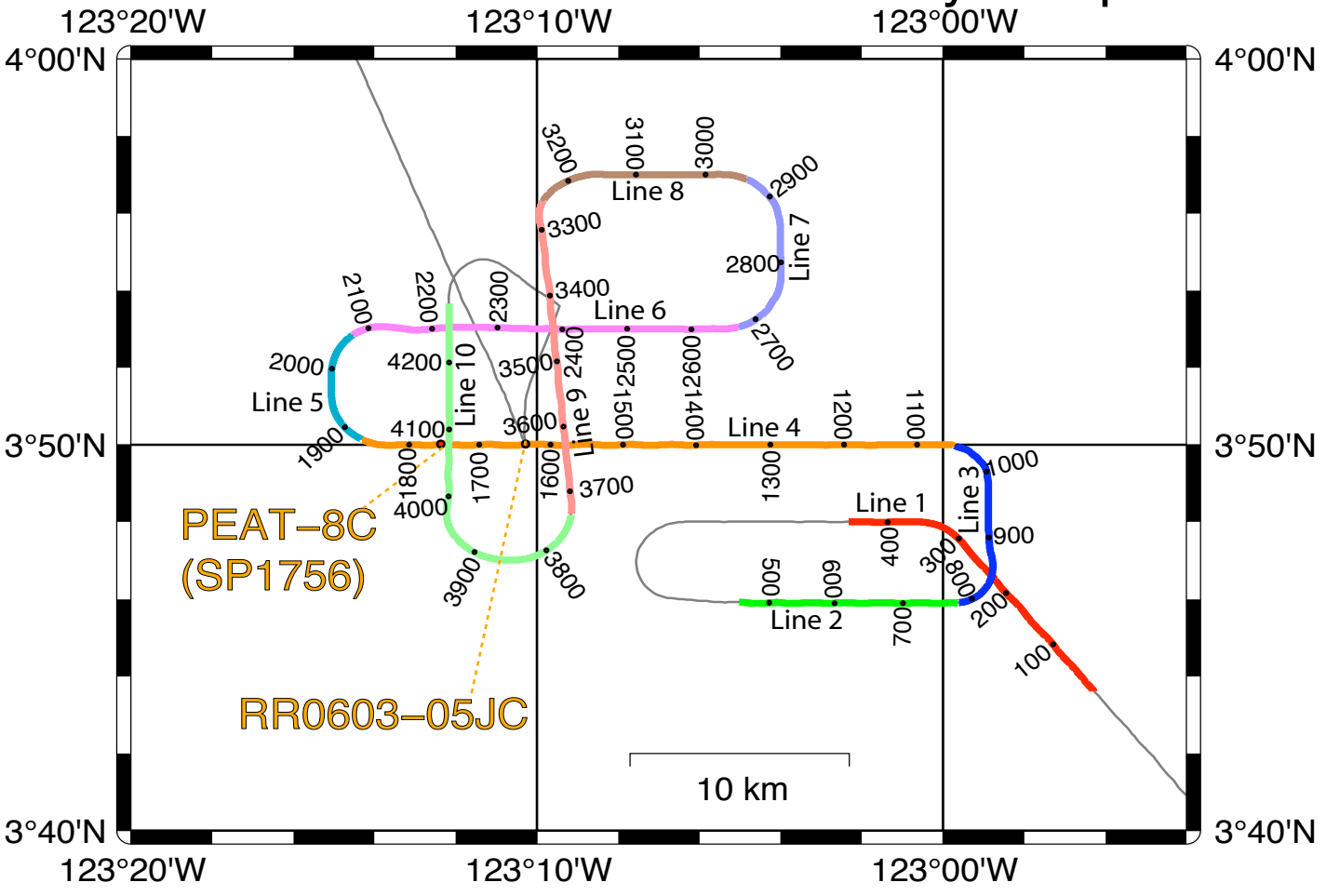
FigPEAT7C-2

# PEAT–7C SWATH Bathymetry



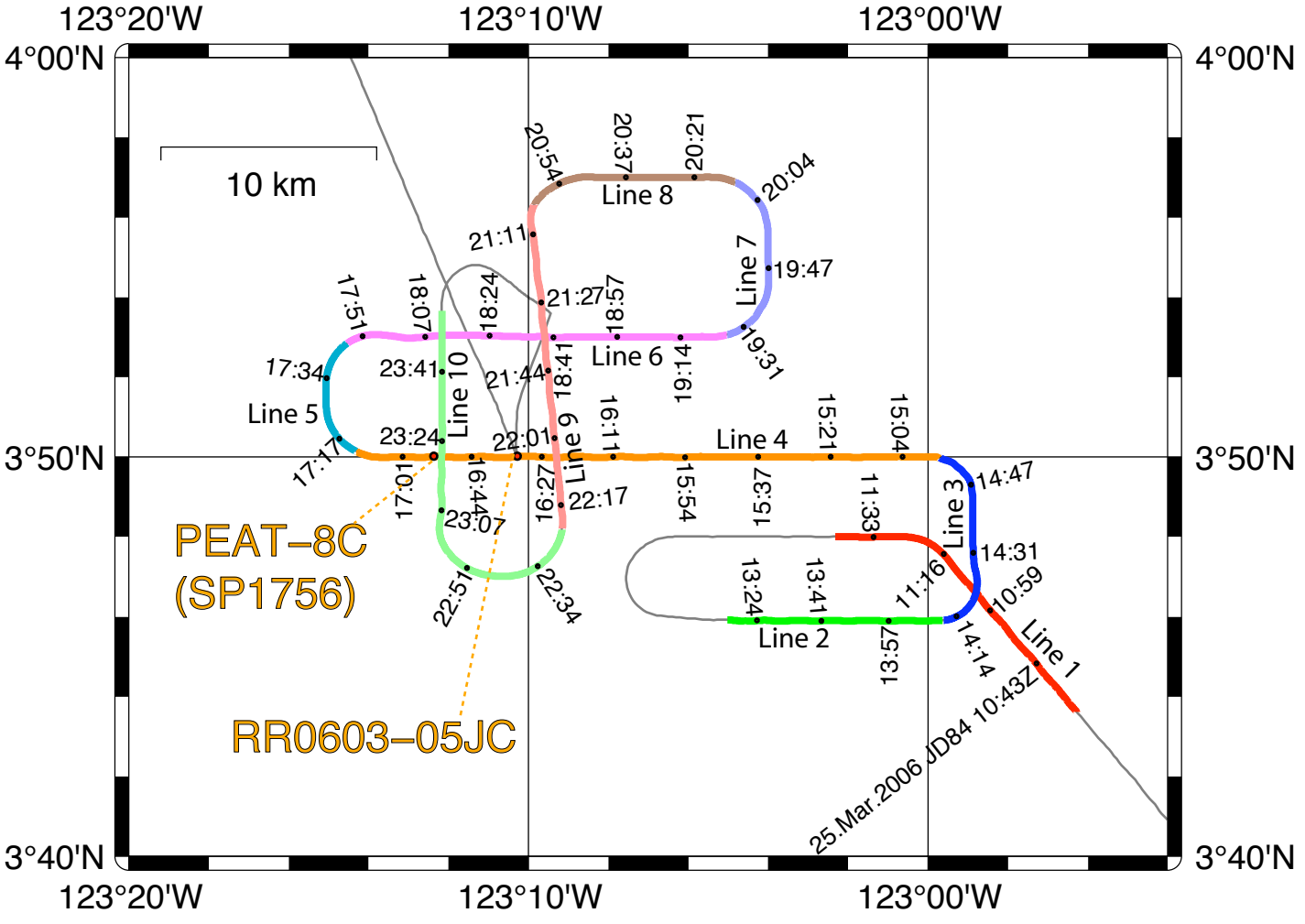
FigPEAT7C-3

# PEAT–7C Seismic Survey shotpoints

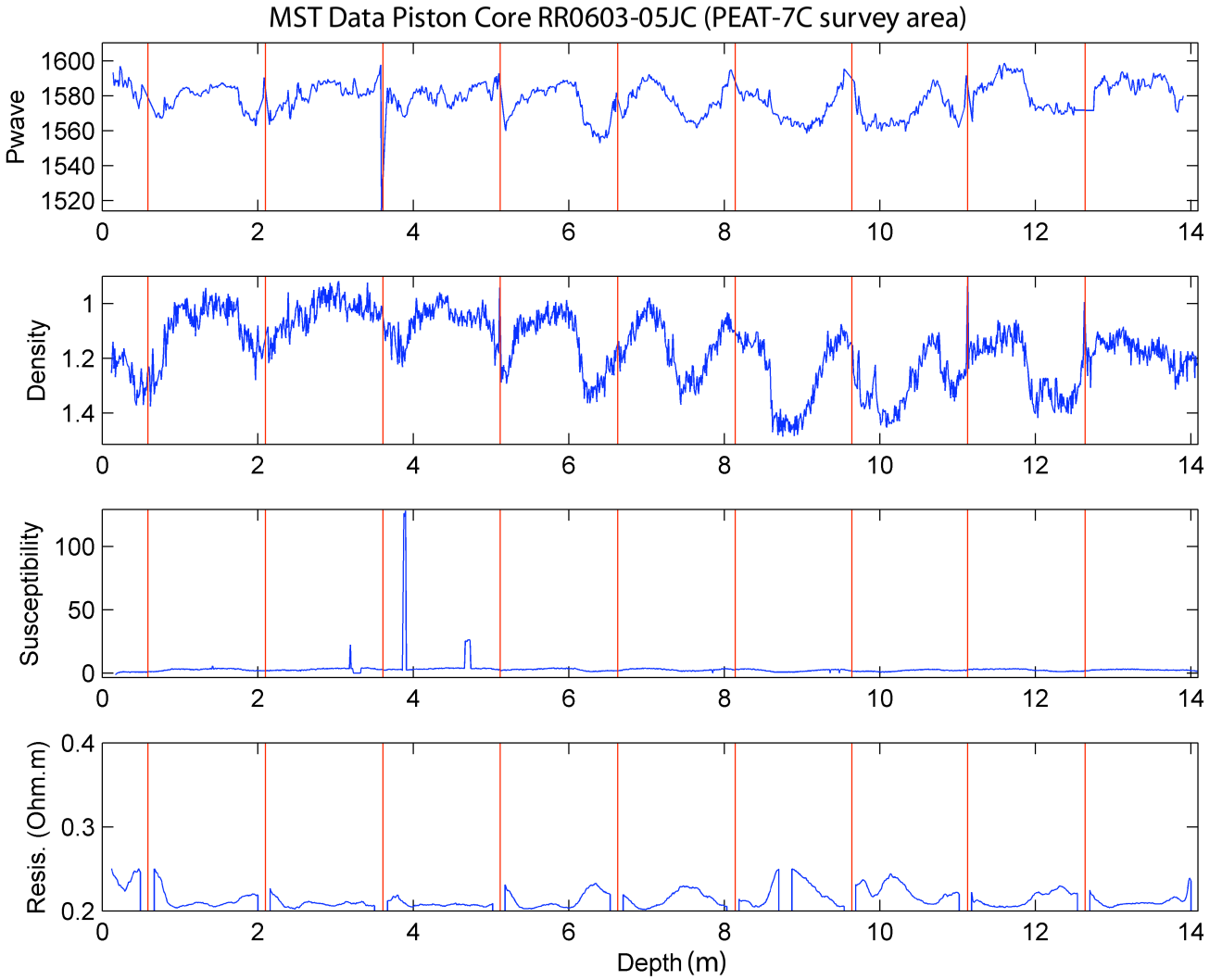


FigPEAT7C-4

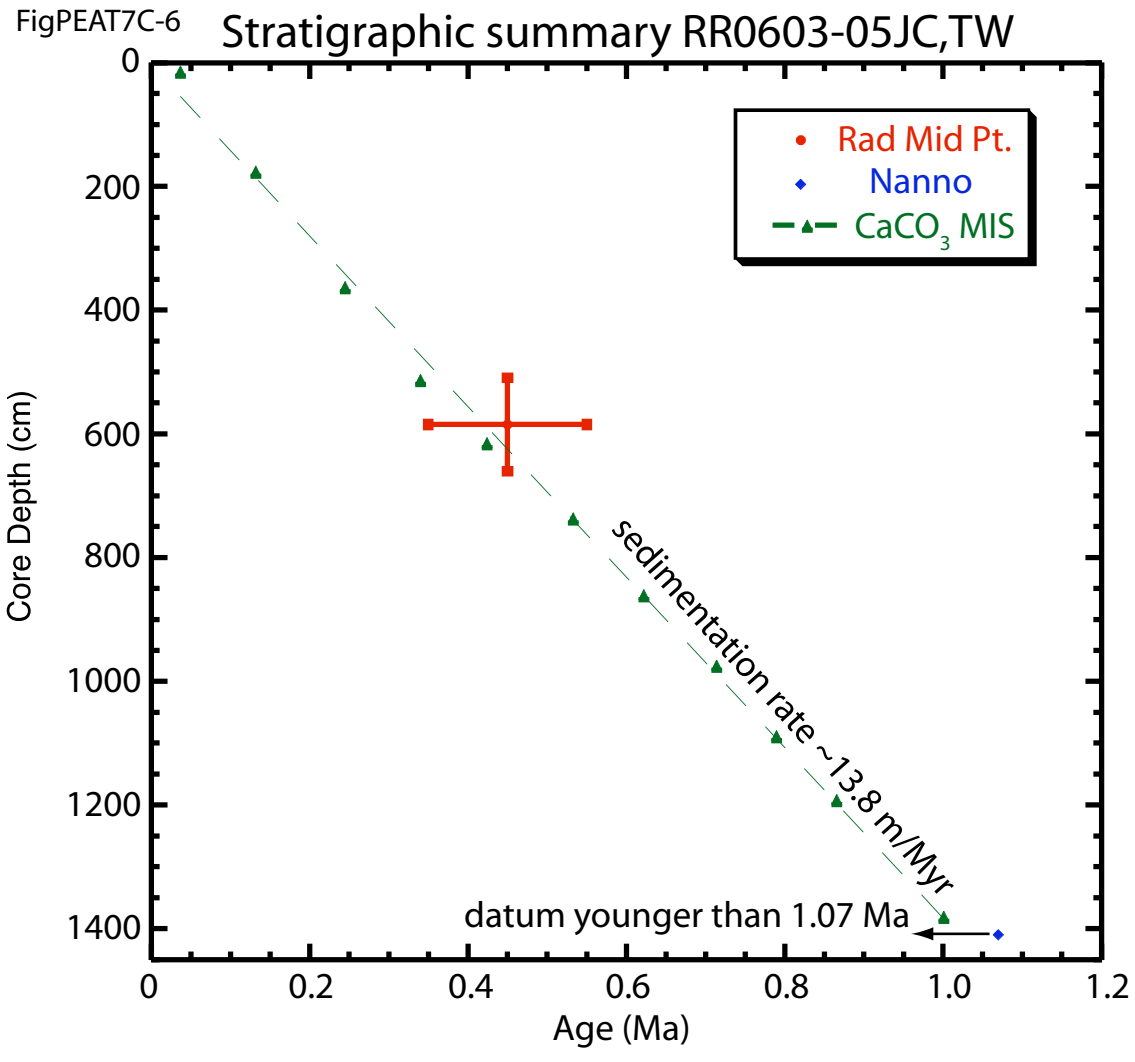
# PEAT–7C Seismic Survey shotpoints (time)



FigPEAT7C-5

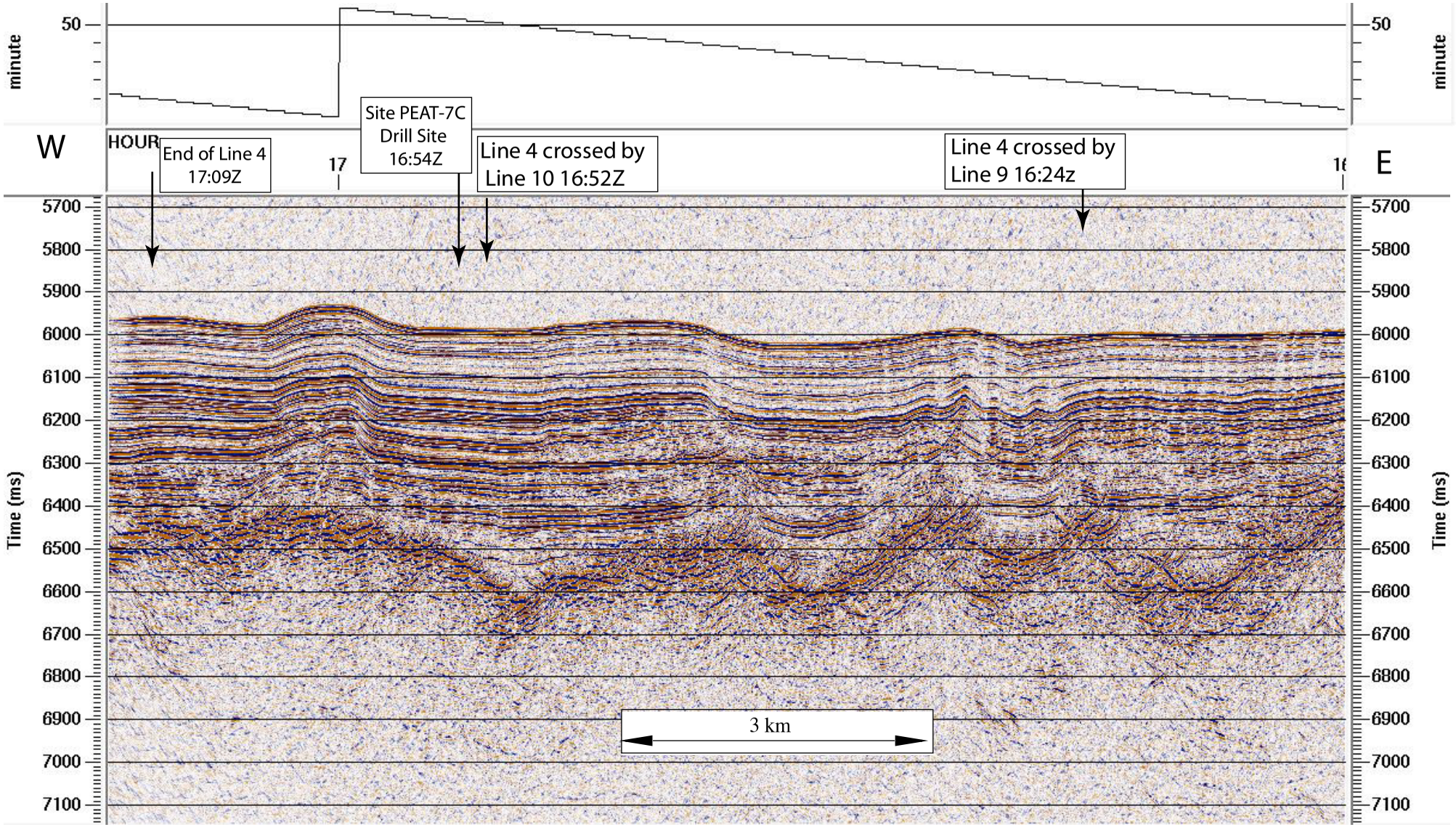

MST Data Piston Core RR0603-05JC (PEAT-7C survey area)
Pwave
1600
1580
1560
1540
1520
Density
1
1.2
1.4
Susceptibility
100
50
0
Resis. (Ohm.m)
0.4
0.3
0.2
0
2
4
6
8
10
12
14
Depth (m)

FigPEAT7C-6


Stratigraphic summary RR0603-05JC,TW
Rad Mid Pt.
Nanno
CaCO3 MIS
sedimentation rate ~13.8 m/Myr
datum younger than 1.07 Ma
Core Depth (cm)
Age (Ma)
0
200
400
600
800
1000
1200
1400
0
0.2
0.4
0.6
0.8
1.0
1.2

FigPEAT7C-7

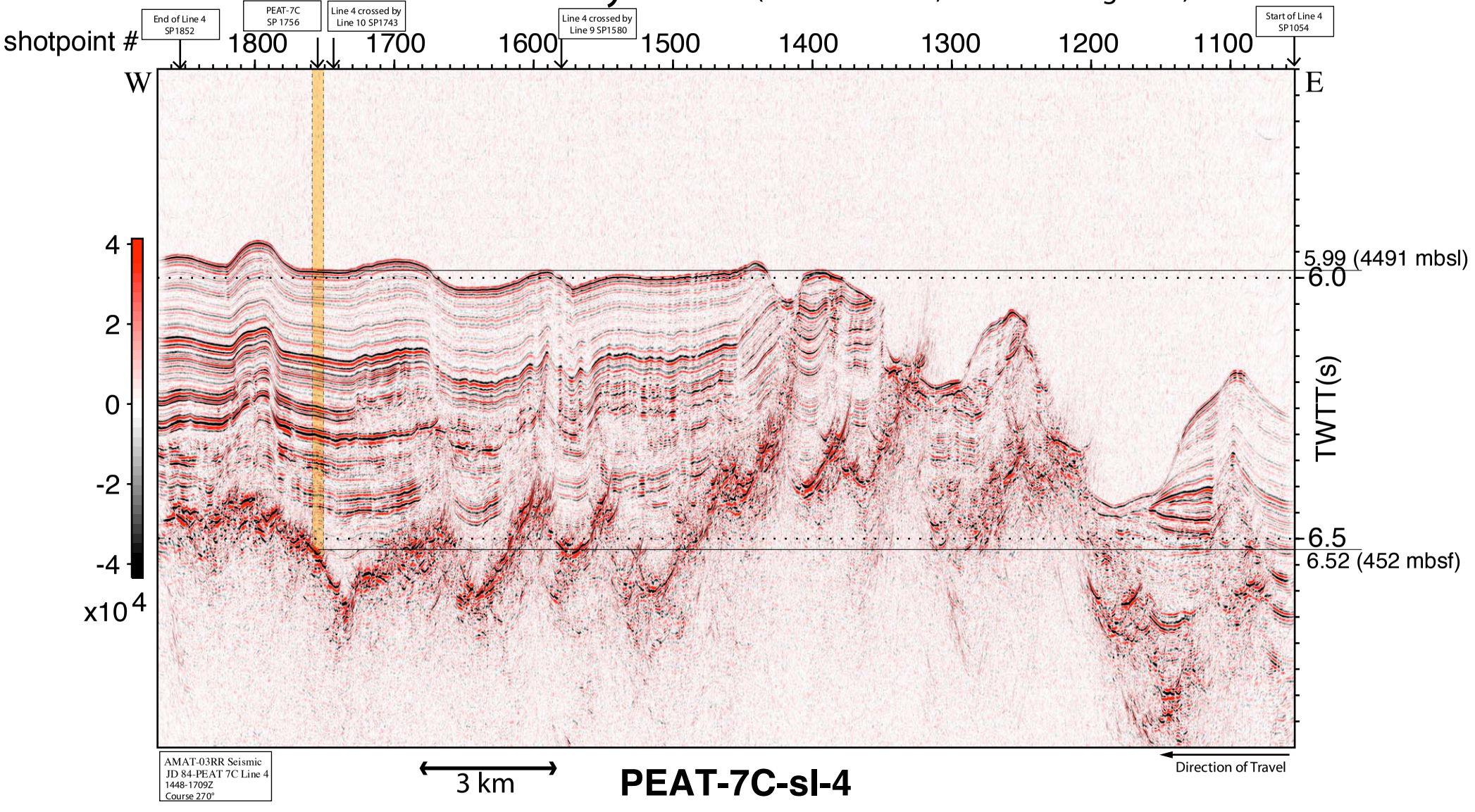
# PEAT_7C survey Line 4 (west)




AMAT-03RR Seismic
JD84-PEAT7C Line 4
1456-1709Z
Course 270°

FigPEAT7C-8

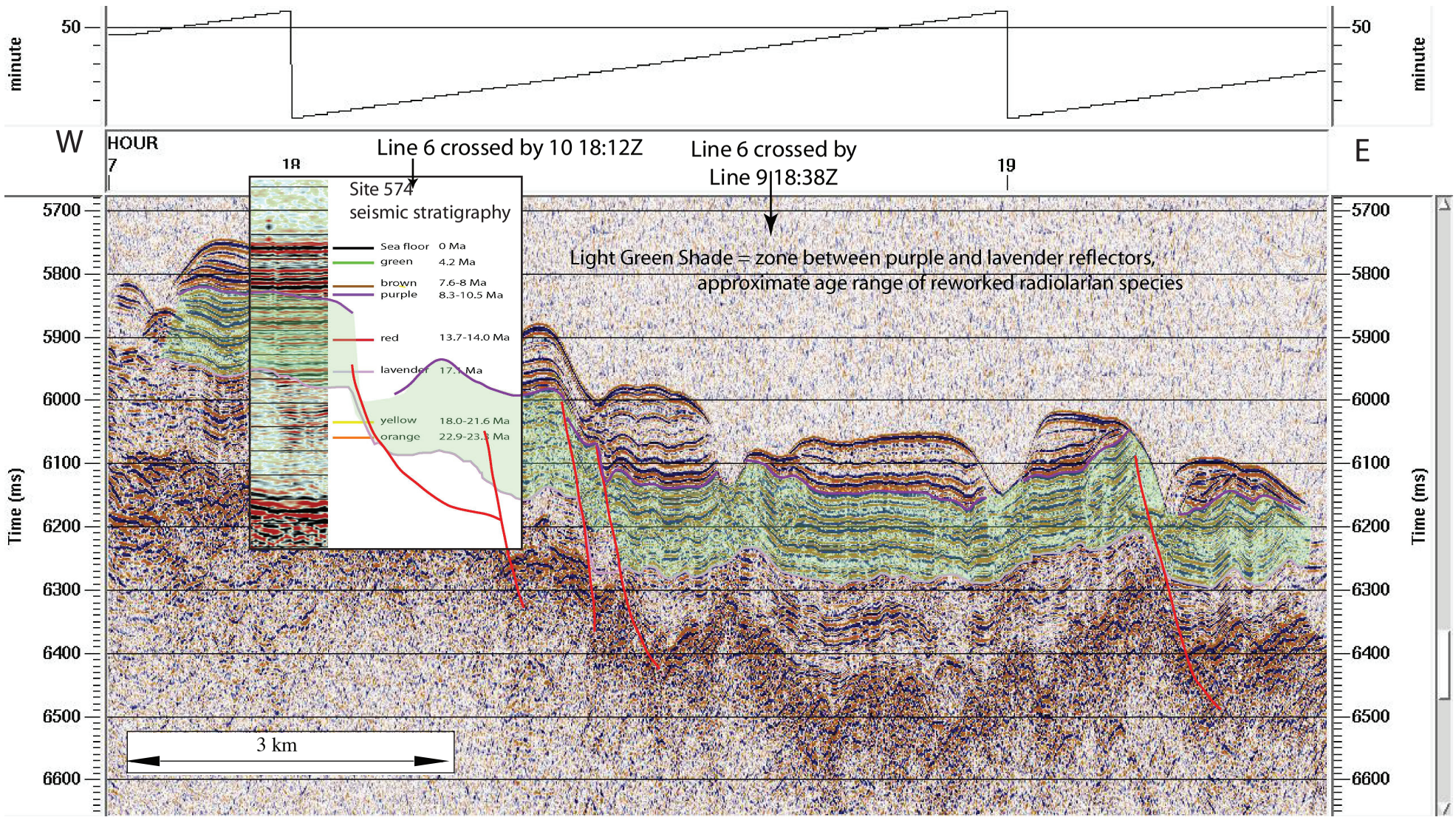
# PEAT-7C survey Line 4 (48ch streamer, stacked & migrated)




**PEAT-7C-sl-4**

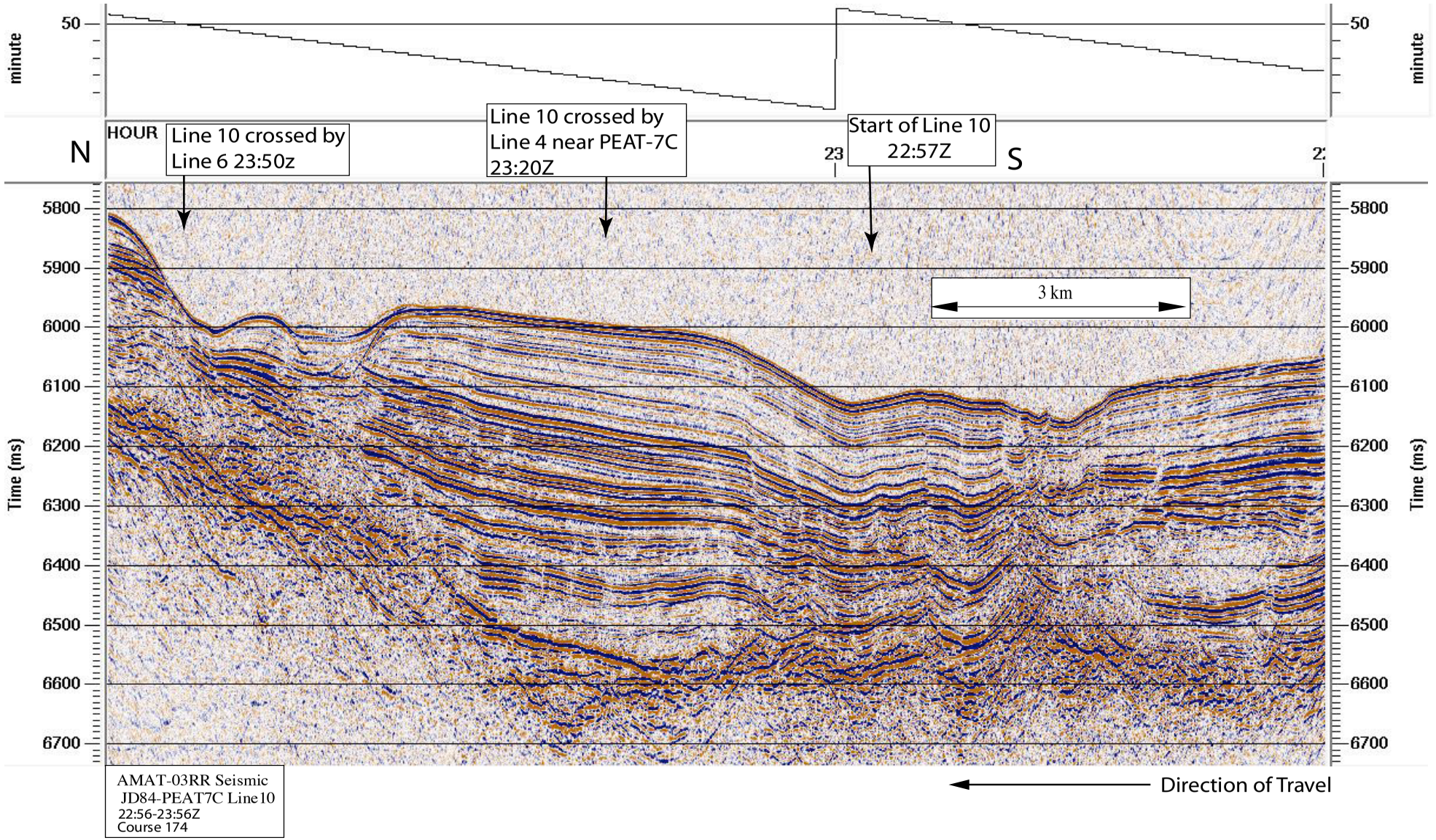
FigPEAT7C-9

# PEAT-7C survey Line 6 (48ch streamer, stacked & migrated) compared with DSDP Site 574



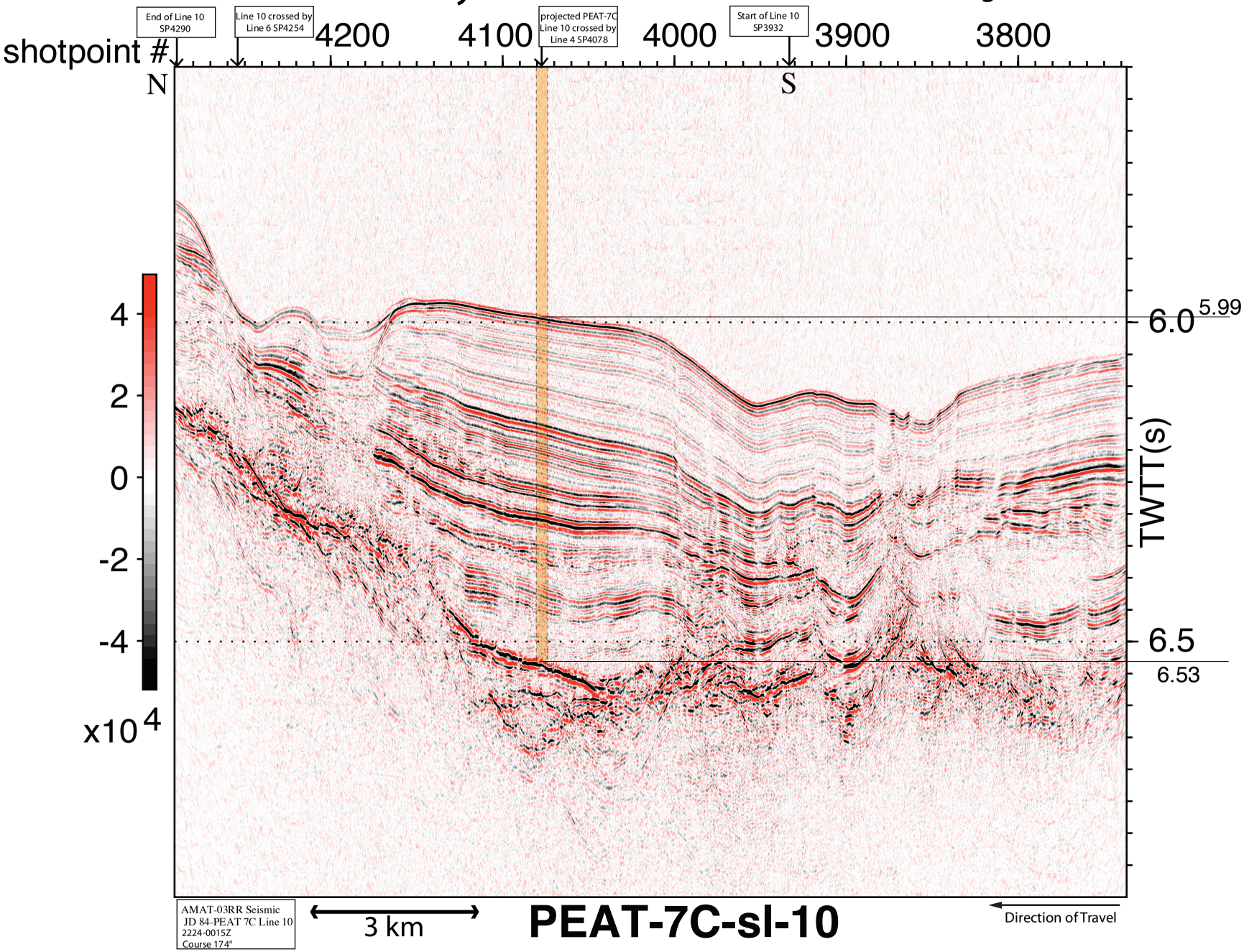
FigPEAT7C-10

# PEAT-7C seismic Line10



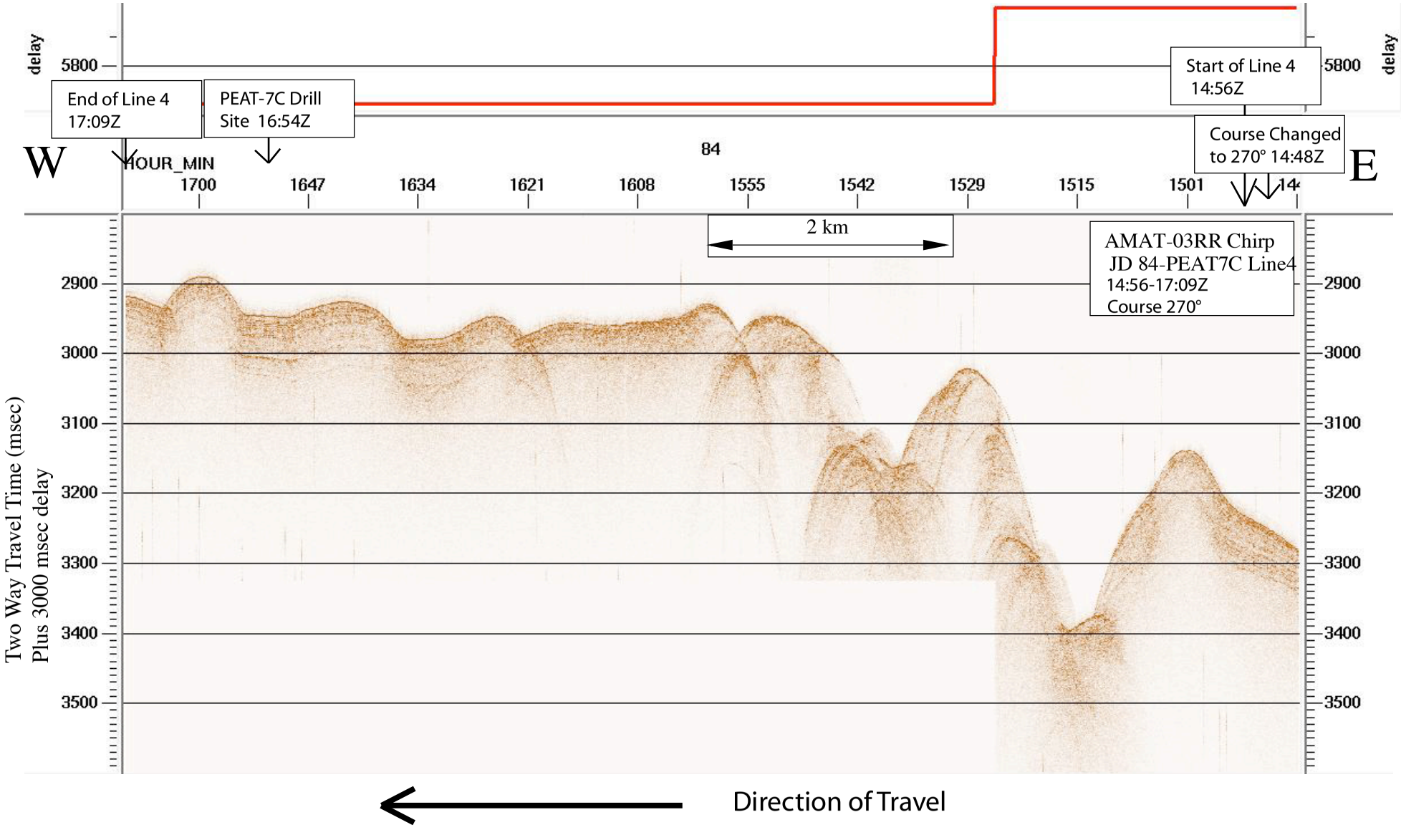
FigPEAT7C-11

# PEAT-7C survey Line 10 (48ch streamer, stacked & migrated)



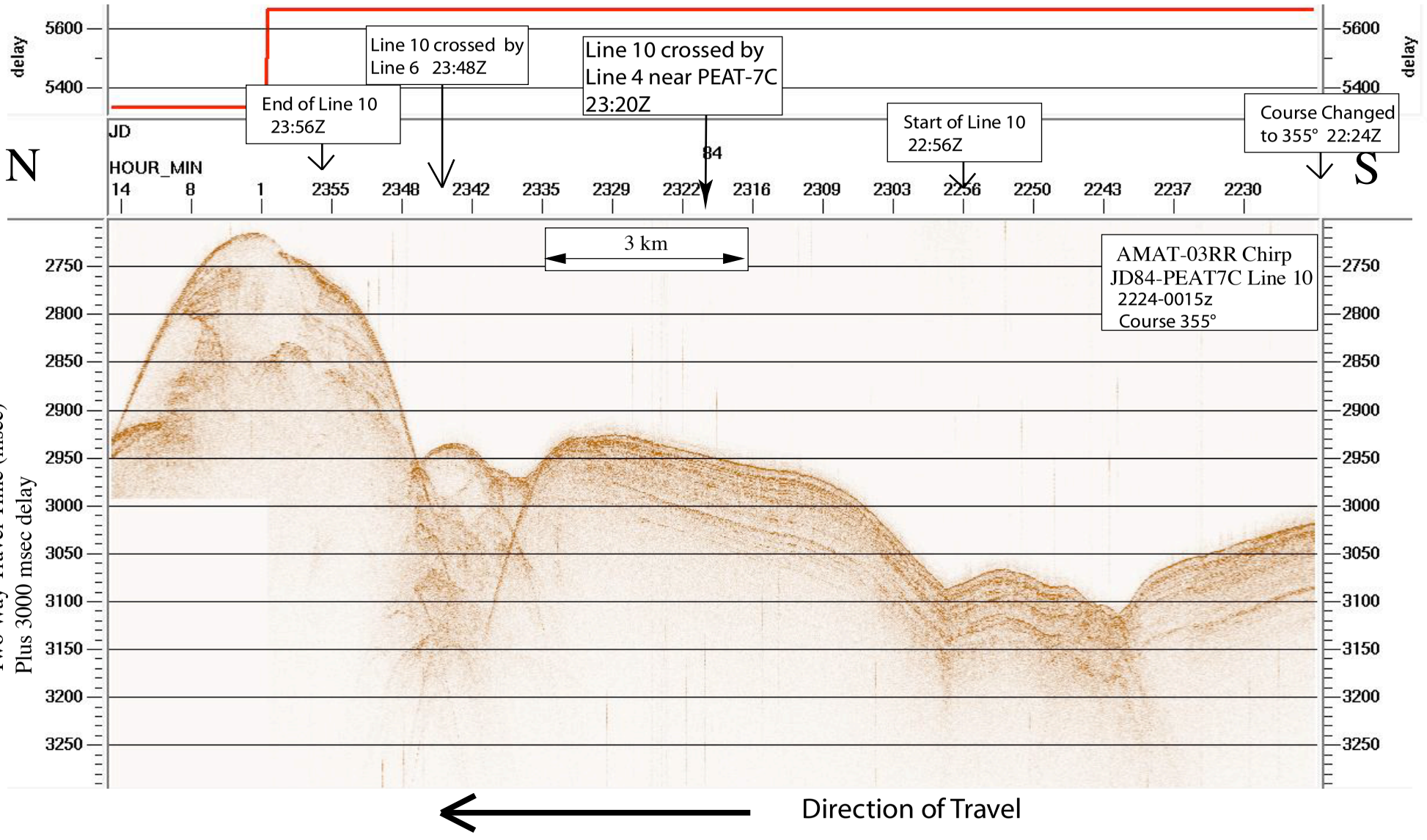
FigPEAT7C-12

# PEAT-7C survey Line 4 (CHIRP subbottom profiler)



FigPEAT7C-13

# PEAT-7C survey Line 10 (CHIRP subbottom profiler)



# SITE PEAT-8C (eastern equatorial Pacific)
# 02° 36.361'N, 117° 59.420'W

## *SITE OBJECTIVES*

PEAT-8C is proposed for drilling to focus on the paleoceanographic events following a mid-Miocene maximum in deposition (van Andel et al., 1975). In addition, large changes in the glaciation state and frequency have recently been described in the middle Miocene (Holbourn et al., 2005; Abels et al., 2005), in the interval following ca. 14 Ma. There is a wide latitude range of $CaCO_3$ deposition during the earliest Neogene, with a relatively sharp transition to a narrower $CaCO_3$ belt after 20 Ma (Lyle, 2003). $CaCO_3$ mass accumulation rates in the central equatorial Pacific recovered from the 18-19 Ma 'famine', and in the period between 14 and 16 Ma reached a second maximum in carbonate deposition, which is also evident in the seismic stratigraphy of the equatorial sediment bulge (Knappenberger, 2000, Mitchell et al., 2003). We designed PEAT-8C to recover an equatorial record at the early-mid Miocene sedimentation maximum on 18 Ma old crust.

Following SSEP recommendations we have positioned the Miocene sites somewhat to the south of the estimated paleo-equatorial position at their target ages in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the equator), to allow for some error in positions (evidence suggests a southward bias of the equatorial sediment mound relative to the hotspot frame of reference; Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermal sediments. In order to plan the site survey location we used the digital age-grid of sea-floor age from Müller et al., 1997, heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991, 1994) and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985), and the paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

## *GENERAL DESCRIPTION*

PEAT-8C is situated about 1° to the north of Galapagos Fracture Zone, on abyssal hill topography. Based on stage pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, and magnetic maps (Cande et al., 1989) we determined PEAT-8C to be located on ca. 18 Ma old basement . During the AMAT-03 site survey we collected magnetic anomaly data that can be correlated to those collated by Barckhausen et al. (2005) and confirm the anomaly location. Water depth in the general vicinity is about 4.2 km. The closest previous drilling location north of the Galapagos Fracture Zone for which basement age estimates are available comprises DSDP Site 79 (basement age approximately coincident with the Oligocene–Miocene boundary at 23.0 Ma; J. Backman, pers. comm.). No age information was obtainable from DSDP Site 571, and DSDP Site 572 is projected south of the fracture zone.

## *AMAT-03 Survey*

PEAT-8C was surveyed in March 2006 with Simrad EM120 swathmap bathymetry, Knudsen 320B digitally-recorded chirp subbottom profiling and 150 c.i. GI gun seismic reflection profiling (45 c.i. generator chamber, 105 c.i. injector) aboard the R/V Roger Revelle. PEAT-8C was recorded with a 4 channel streamer. The site was also piston cored, and a 10.9 m core was recovered.

PEAT-8C is in a region of abyssal hills, with highs to 3900 m and basins to 4400 m, close to the centre along a 350° trending and deepening valley. A seamount (3.7km water depth) with surrounding moat was found ca. 10km to the NNW of the site, facing downslope of the valley. The proposed site in ~4301m water depth is surrounded by a half-circle of ca. 4100m deep elevated hills towards the south-east. The fabric of the hills matches the magnetic anomaly fabric, and trends NNE-SSW (Figure PEAT8C-2). Sediment thickness at the site ranges from ca. 400 msec at the top of the abyssal hills to a maximum of a little more than 550 msec. At the proposed Site PEAT-8C (shotpoint 36015 on seismic line PEAT8C-sl-1, Figures PEAT8C-7,8,11) it is about 557 msec. Surface sediments consist of a carbonate-rich clay, ranging to nannofossil ooze with cyclical (m scale) carbonate content at depth. Smaller numbers of siliceous microfossils were found in the sediment as well.

## *LITHOLOGIC DESCRIPTION*

Nearest sediment core: RR0603-03JC
02° 33.4801'N, 117° 07.629'W, 4200m (uncorr.) 10.87m sediment from AMAT-03.

The trigger core RR0603-03TC recovered the sediment-water interface, with approximately 15cm of dark brown clay overlying a succession of bioturbated and mottled light brown and grey nannofossil ooze. Both the trigger core and piston core were scanned with the Oregon State University GeoTek multisensor track (MST) van, measuring GRA density, P-wave velocity, electrical resistivity, and magnetic susceptibility (FigPEAT8C-5). These data show cyclic variations in the carbonate proxies on a depth scale of 0.5-1.5m. Microfossil assemblages include calcareous nannoplankton, radiolaria and diatoms. Shipboard analysis (J. Backman & Ted Moore) of smear slides identified a series of bio- and cyclostratigraphic age markers (FigPEAT8C-6). These data suggest average sedimentation rates of around 8 to 13 m/Myr in the Pleistocene. The cyclic nature of the carbonate content downcore lends itself for comparison with previously astronomically age-calibrated paleoclimatic proxy data from cores taken in the vicinity (e.g., ODP Site 849). This comparison of cycles, interpreted to be typical glacial-interglacial cycles, suggest that the sedimentation rate in the uppermost part of the sediment column reaches approximately 12 m/Myr.

## *SEISMIC INTERPRETATION*

Primary Site (PEAT-8C):
**AMAT-03-PEAT8C Line 1**, 2006 JD080 17:41:53UTC, SP 36015.
Nearest crossing (1.24 km):
**crossing of PEAT8C Line 6**, 2006 JD080 23:48:13UTC, SP 38212

Crustal age: 18 Ma
Ship location @ SP36015: 2° 36.395'N, 117° 59.429'W
PEAT-8C Location (SP-2): 2° 36.361'N, 117° 59.420'W
Site water depth: 4301m (5.773 sec TWTT)
Basement depth: 4746m (6.330 sec TWTT)
Sediment thickness: 446m (0.557 sec TWTT)
Proposed Drilling Depth: to basement (estimated 446m) + tag basement
Used velocity model: from ODP Site 849:

| Interval | Interval velocity |
|---|---|
| 0-100msec | 1504.4 m/s |
| 100-200msec | 1542.3 m/s |
| 200-300msec | 1633.7 m/s |
| 300-544msec | 1700.8 m/s |

PEAT-8C was chosen near the intersection of Lines 1 and 6 from the AMAT-03 survey (Figures PEAT8C-3,4). The sediment here is of typical thickness but was moved away from the line crossing primarily because of a small fault right at the cross imaged in Line 6 and because the basement reflector was well-developed at the new location. The PEAT-8C location has a relatively flat basement structure that was well-imaged by seismic reflection. Sediment thickness was estimated using interval velocities from ODP Site 849 wireline logging. Site 849 has lithologies similar to PEAT-8C. The subbottom profiler sections (Figures PEAT8C-11,12) image about 50m of layered sediments in the upper sediment column.

## *GEOLOGIC HAZARDS*

There are no known geologic hazards: pelagic sediments over oceanic basalts. Significantly younger sites (ODP Site 849) have encountered chert near basement.

## *OTHER HAZARDS*

There are no manmade hazards in the vicinity.

## *SEISMIC DATA AVAILABLE from AMAT-03*

PEAT-8C Line 1
PEAT-8C Line 2
PEAT-8C Line 3
PEAT-8C Line 4
PEAT-8C Line 5
PEAT-8C Line 6

## *FIGURES*

Fig PEAT8C-1: Location map for Pacific Equatorial Age Transect. Proposed drill site of PEAT-8C is marked.

Fig PEAT8C-2: Swathmap bathymetry for the PEAT-8C region, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-03JC are marked.

Fig PEAT8C-3: Location of seismic lines in PEAT-8C region vs. shotpoints, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-03JC are marked.

Fig PEAT8C-4: Location of seismic lines in PEAT-8C region vs. survey time, from the AMAT-03 site survey. Proposed drill site and location of piston-core RR0603-03JC are marked.

Fig PEAT8C-5: MST physical properties data for RR0603-03JC.

Fig PEAT8C-6: Shipboard biostratigraphy for RR0603-03JC

Fig PEAT8C-7: Seismic profile PEAT-8C Line 1 across PEAT-8C, from AMAT-03, vs. survey time. Proposed drill site is marked.

Fig PEAT8C-8: Seismic profile PEAT-8C Line 1 across PEAT-8C, from AMAT-03, vs. shotpoint. Proposed drill site is marked.

Fig PEAT8C-9: Crossline seismic profile PEAT-8C Line 6 from AMAT-03, vs. survey time. Site was moved away from the cross with Line 1 because of the small fault nearby.

Fig PEAT8C-10: Crossline seismic profile PEAT-8C Line 6 from AMAT-03, vs. shotpoint. Site was moved away from the cross with Line 1 because of the small fault nearby.

Fig PEAT8C-11: Chirp subbottom profile from Line 1 across PEAT-8C, from AMAT-03. Proposed drill site is marked.

Fig PEAT8C-12: Chirp subbottom profile from Line 6 across PEAT-8C, from AMAT-03. Proposed drill site is marked.

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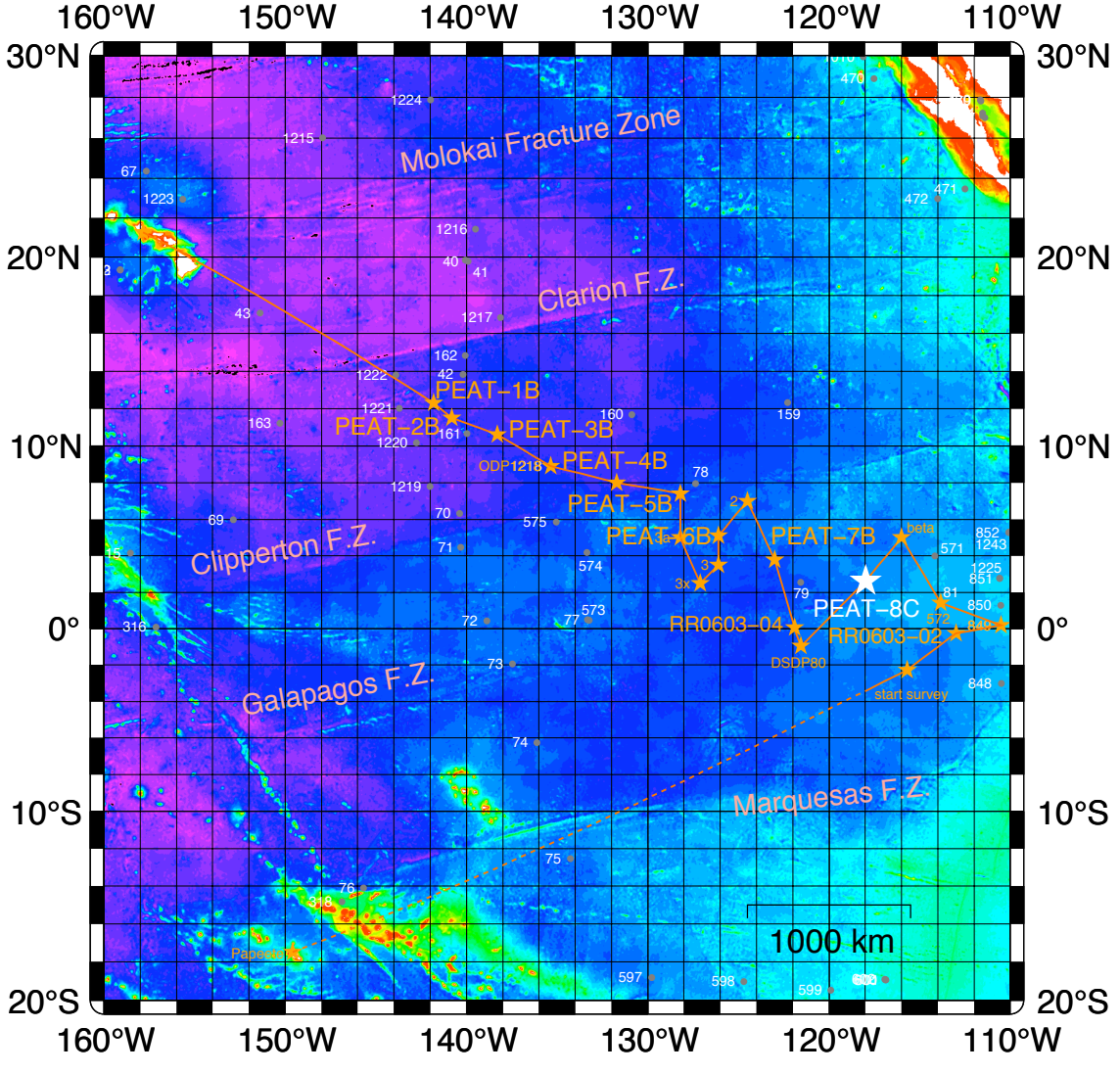
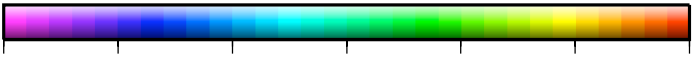
Sager, W.W., and M.S. Pringle, Mid-Cretaceous to Early Tertiary apparent polar wander path of the Pacific plate, J. Geophys. Res., 93, 11753-11771, 1988.

FigPEAT8C-1

# AMAT–03 PEAT-8C Overview

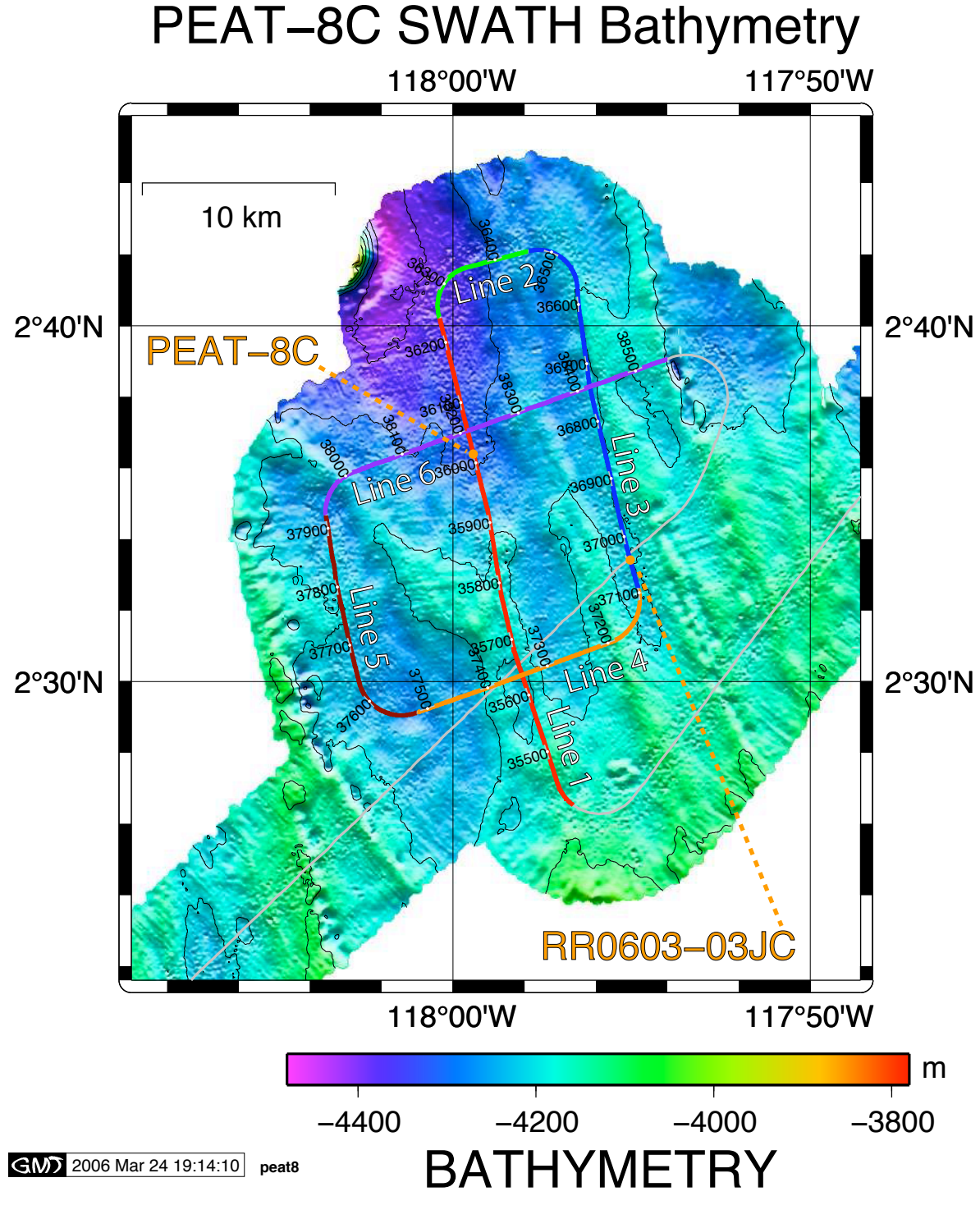



BATHYMETRY

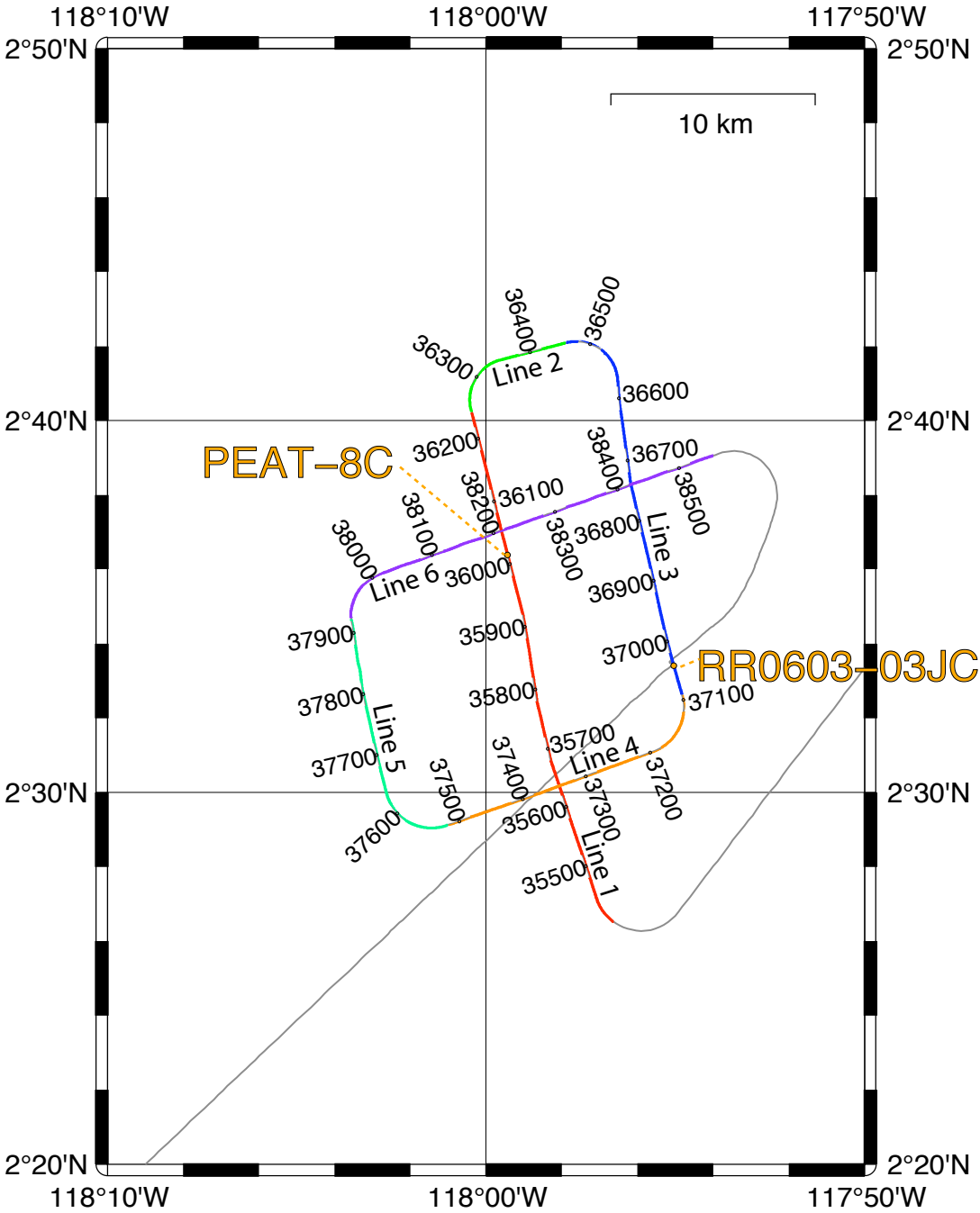
GMT 2006 Mar 24 18:33:10

FigPEAT8C-2


PEAT–8C SWATH Bathymetry
118°00'W
117°50'W
2°40'N
2°30'N
10 km
PEAT–8C
Line 2
Line 6
Line 3
Line 5
Line 4
Line 1
RR0603–03JC
m
–4400
–4200
–4000
–3800
BATHYMETRY
2006 Mar 24 19:14:10
peat8

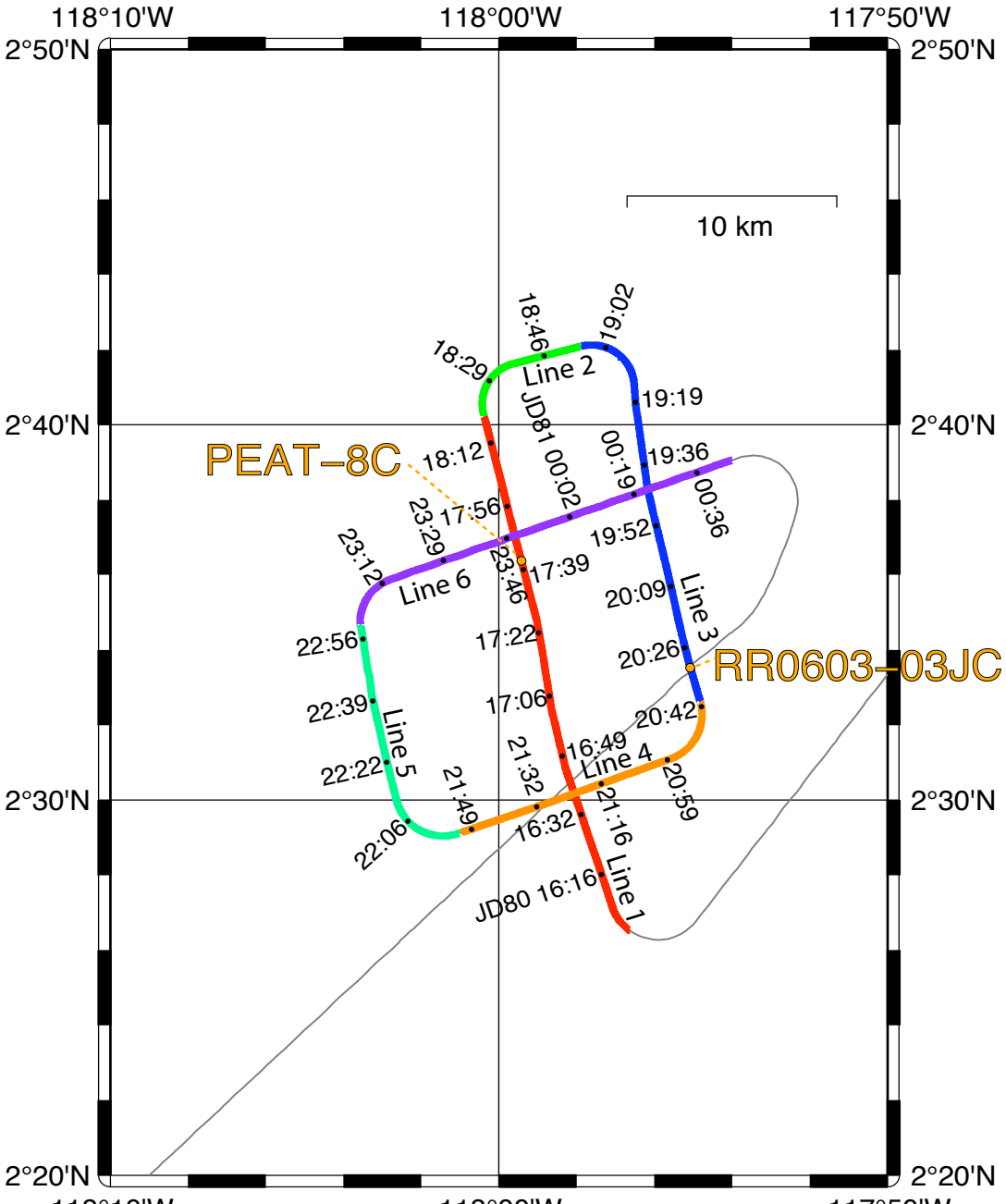
FigPEAT8C-3

# PEAT–8C Seismic Survey shotpoints

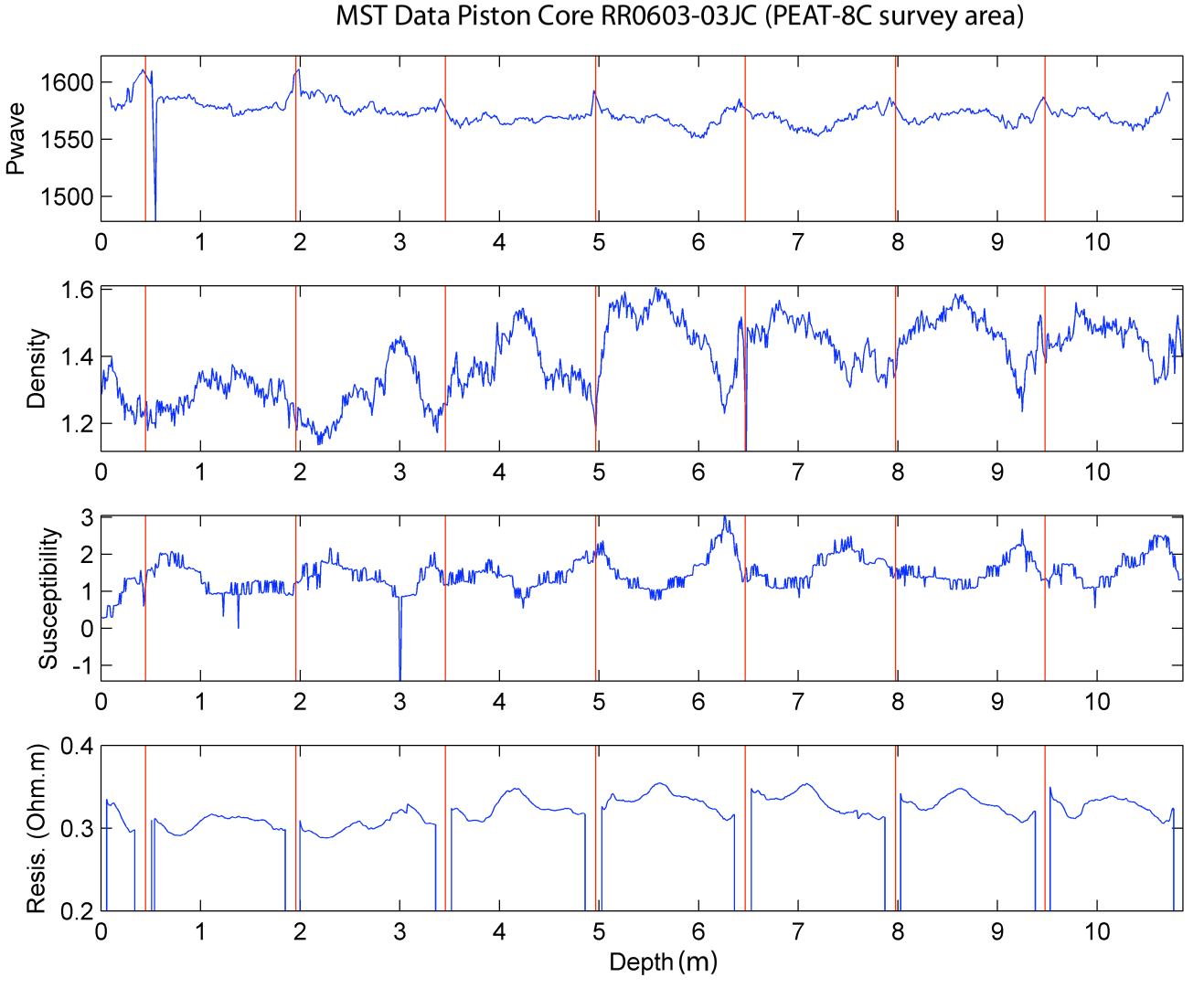


FigPEAT8C-4

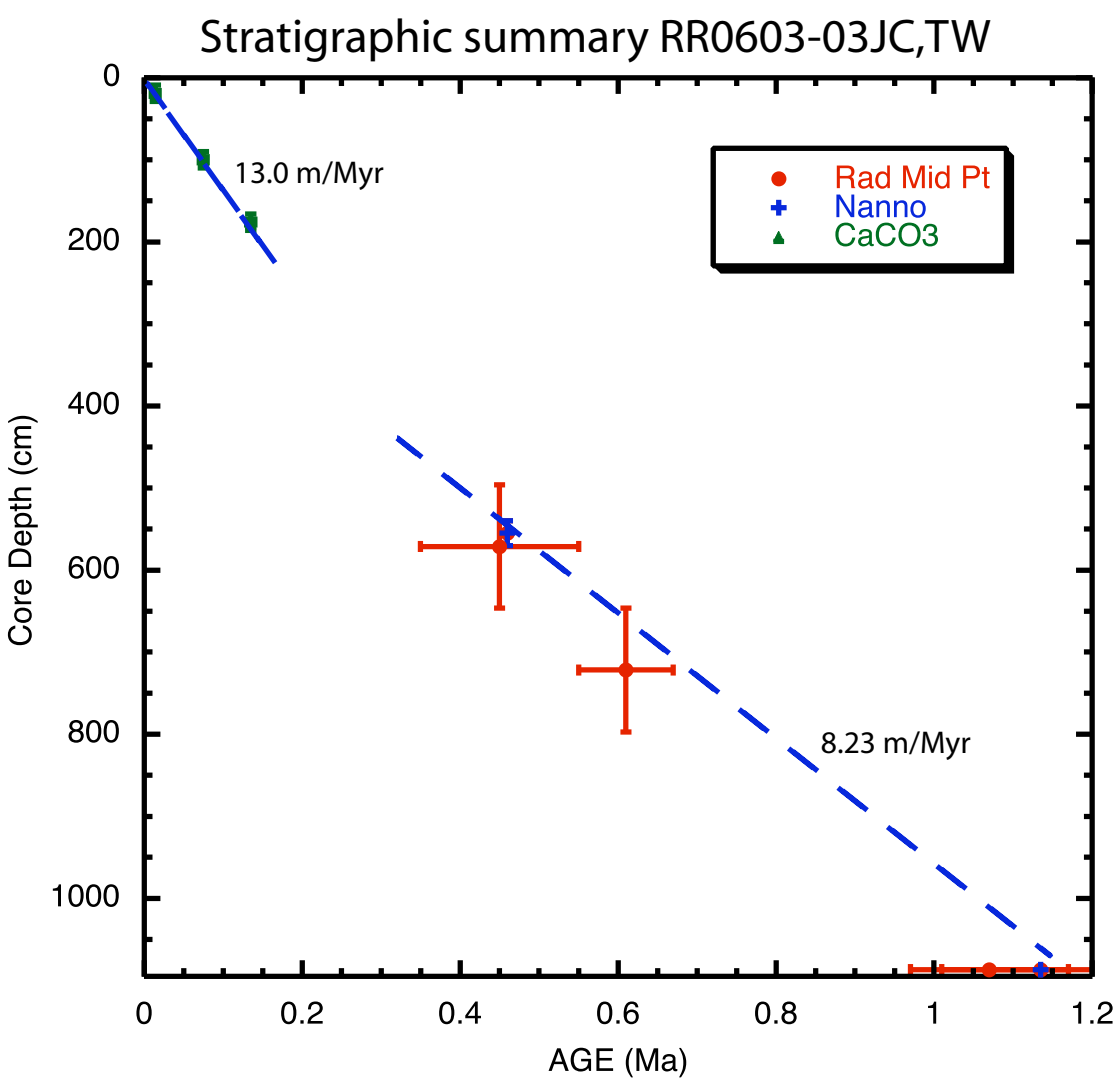
# PEAT–8C Seismic Survey shotpoints



FigPEAT8C-5

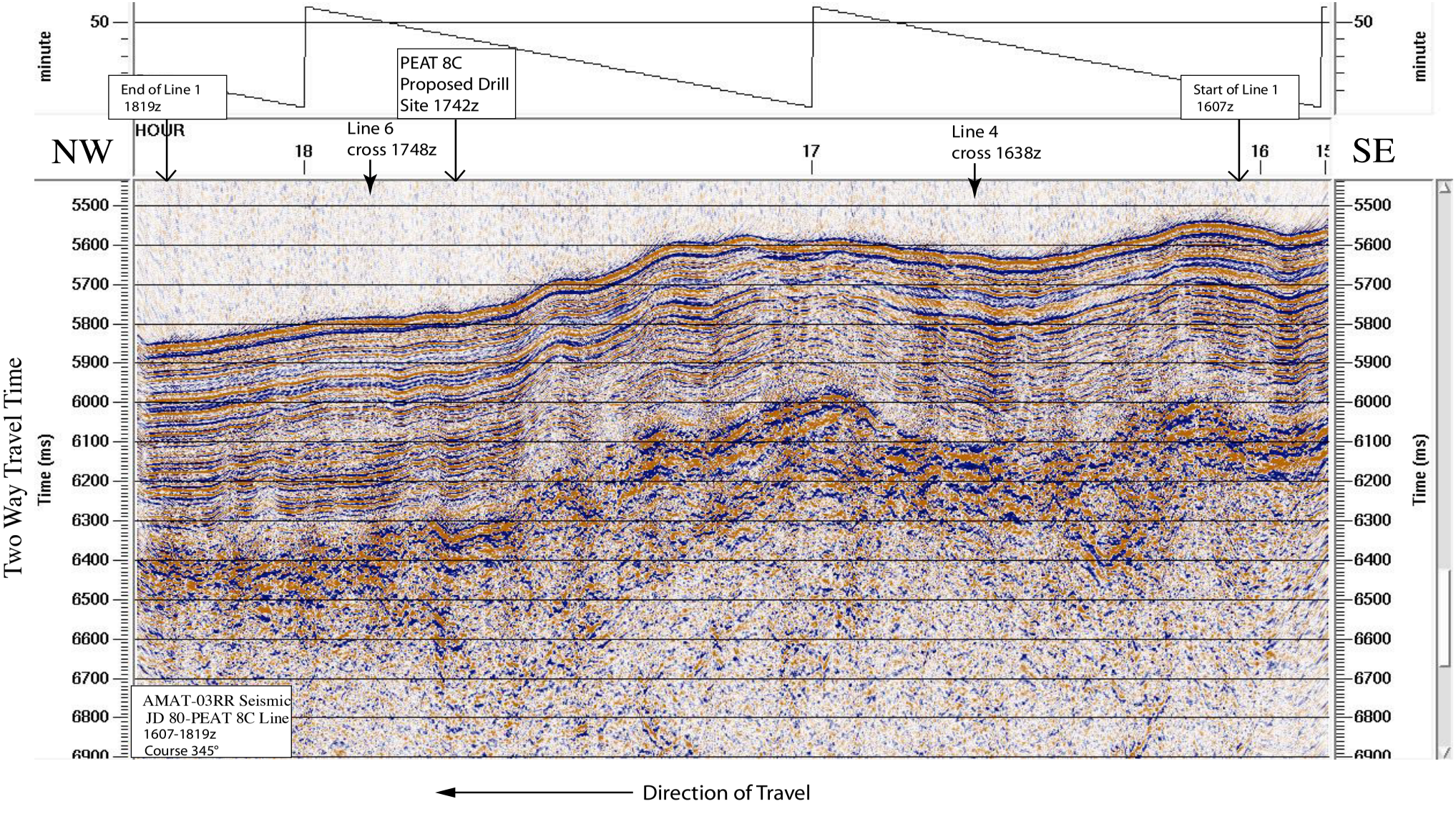

MST Data Piston Core RR0603-03JC (PEAT-8C survey area)
Pwave
1600
1550
1500
Density
1.6
1.4
1.2
Susceptibility
3
2
1
0
-1
Resis. (Ohm.m)
0.4
0.3
0.2
0
1
2
3
4
5
6
7
8
9
10
Depth (m)

FigPEAT8C-6


Stratigraphic summary RR0603-03JC,TW
Rad Mid Pt
Nanno
CaCO3
13.0 m/Myr
8.23 m/Myr
Core Depth (cm)
0
200
400
600
800
1000
0
0.2
0.4
0.6
0.8
1
1.2
AGE (Ma)

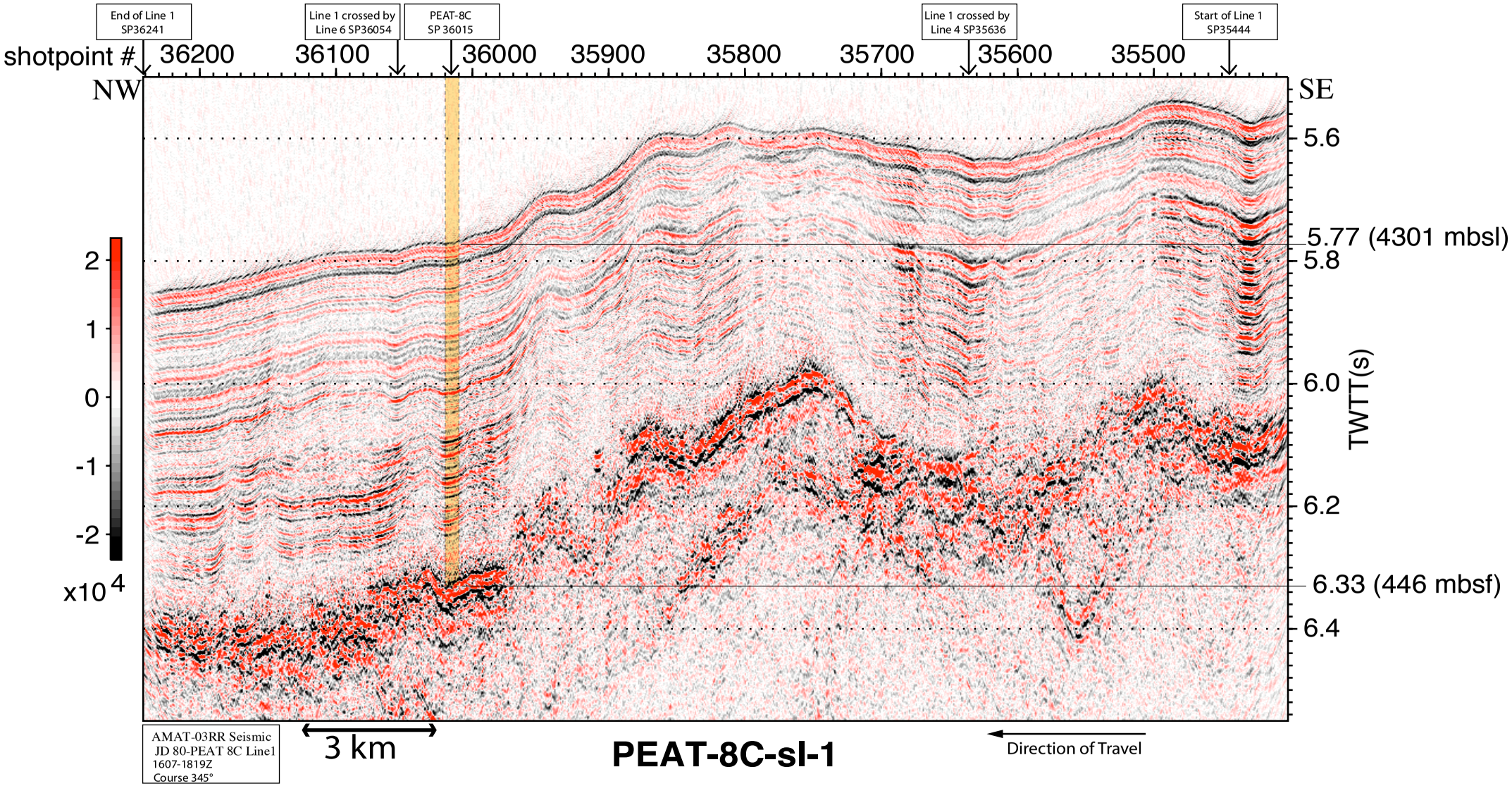
FigPEAT8C-7

# PEAT-8C survey Line 1



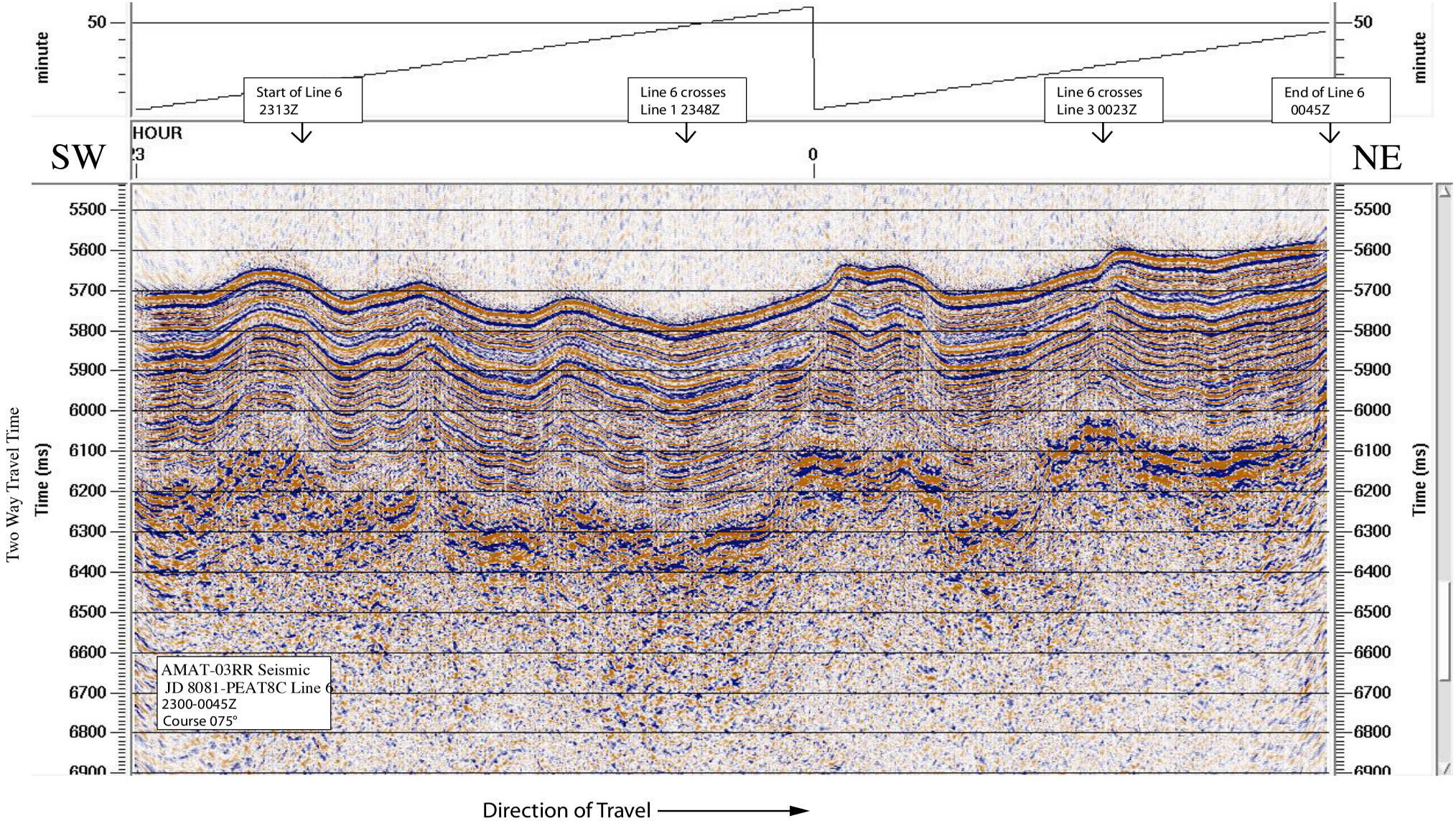
FigPEAT8C-8

# PEAT-8C survey Line 1 (4ch streamer, stacked & migrated)



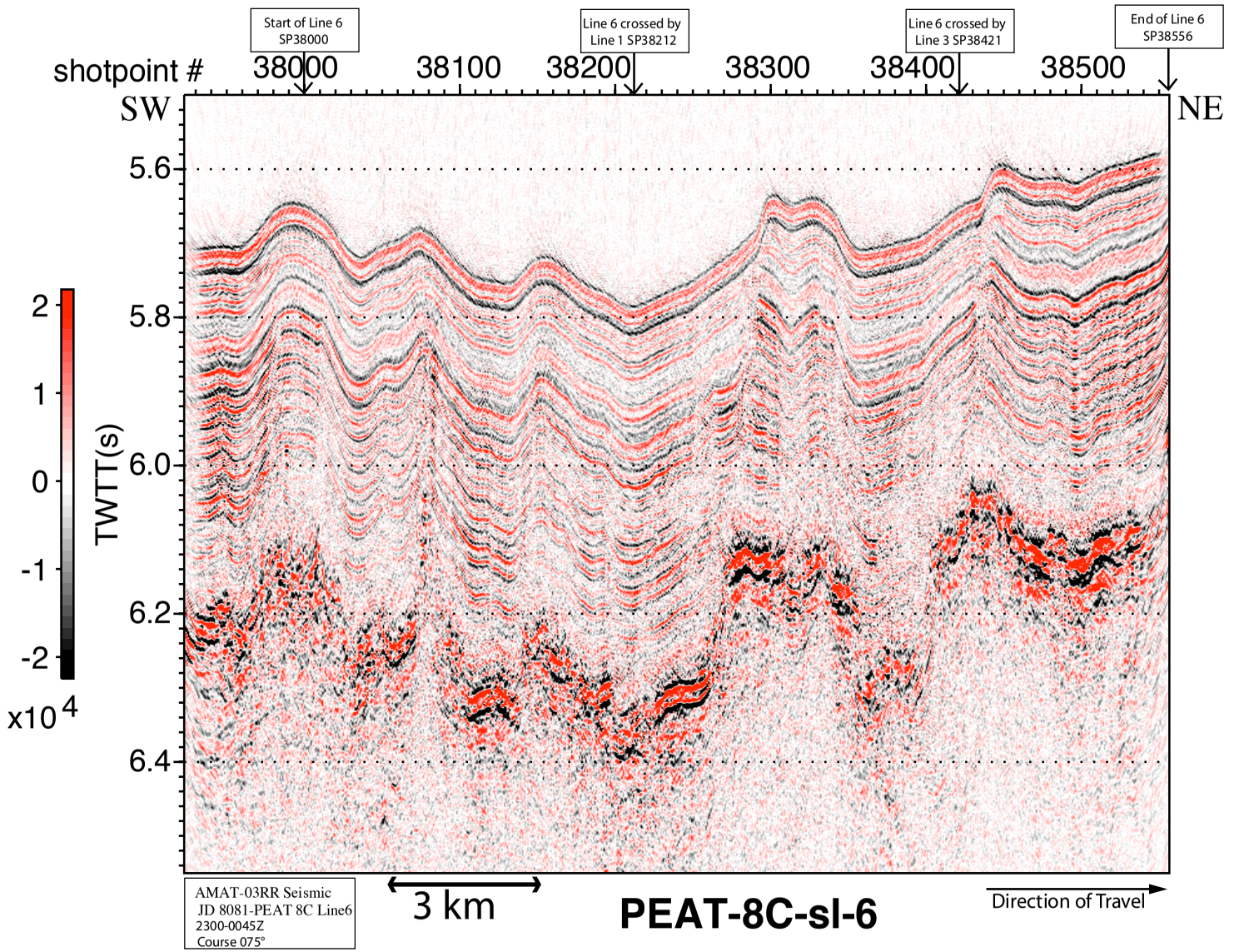
FigPEAT8C-9

# PEAT-8C survey Line 6



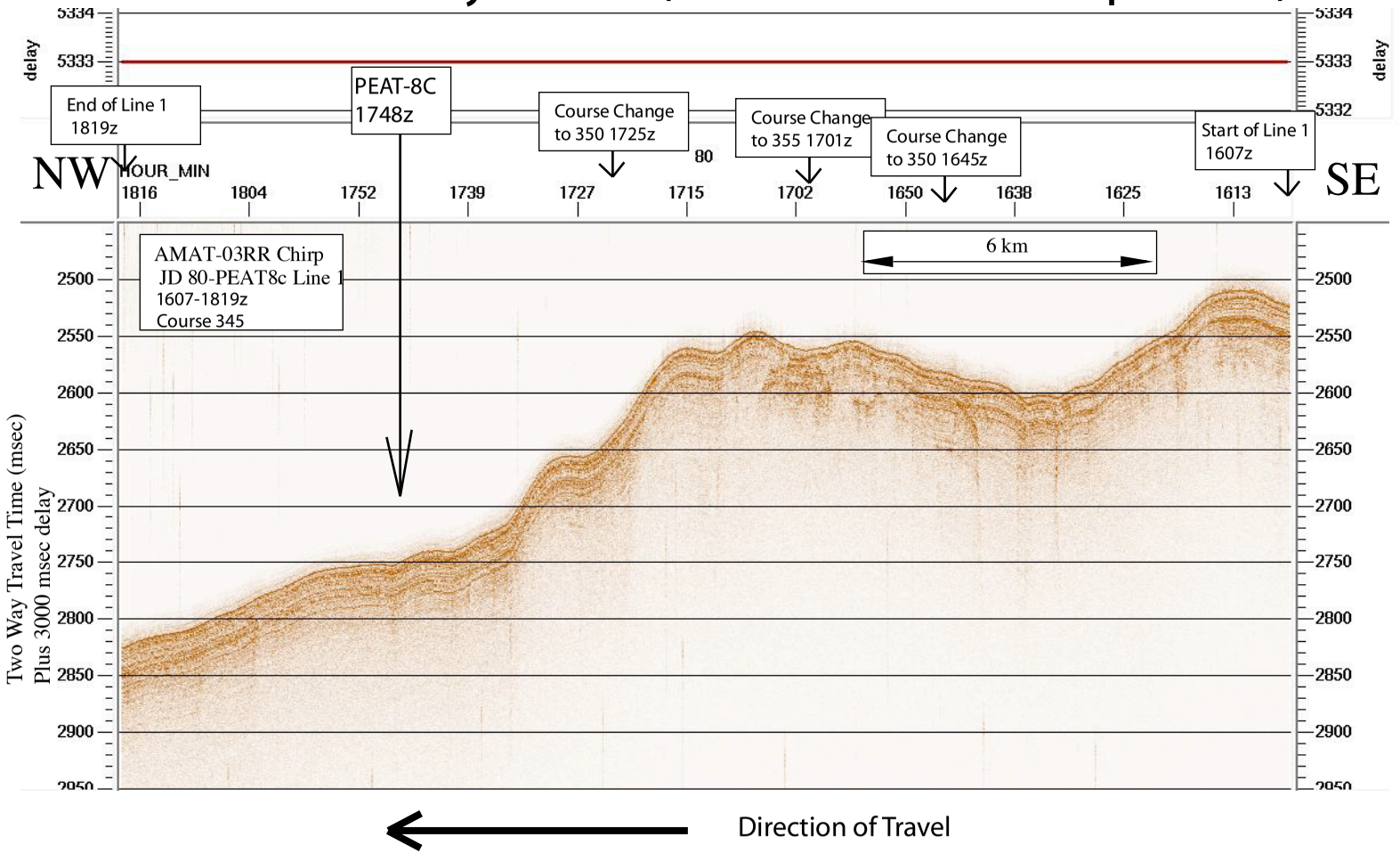
FigPEAT8C-10

# PEAT-8C survey Line 6 (4ch streamer, stacked & migrated)



FigPEAT8C-11

# PEAT-8C survey Line 1 (CHIRP subbottom profiler)



FigPEAT8C-12

# PEAT-8C survey Line 6

