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Assessment of sand content of cores from the Scotian Shelf as a proxy record of Holocene storminess

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This report summarises studies directed to the assessment of Holocene storminess on the Scotian Shelf, using the occurrence of sands in dated basin margin cores. It is a contribution to the Global Change program of the Geological Survey of Canada. The study was carried out as a Cooperative Education work-term project under the supervision of David J.W. Piper.

1 INTRODUCTION

1.1 Geological Setting and Background

The Scotian shelf off the coast of Nova Scotia has an irregular topography characterized by glaciated banks and mud-floored basins (King and Fader, 1986). Water depth on the shelf is generally less than 100m deep. Emerald Basin lies in the central part of the shelf and is the deepest basin (291m) (Fig. 1). Sediments found at the southern edge of the basin consist of silty muds with fine sandy laminae, and fine grained sands. Core samples taken in the area (Fig. 1) have been correlated using percentage sand, X-radiographs, and weed pollen distribution, and show several distinct periods when more sand was being deposited at the basin edge (Kontopoulos and Piper, 1982) (Fig. 2). Storms may generate shelf currents that have the potential to sweep sand off the seabed south of Emerald Basin. Kontopoulos and Piper (1982) interpreted the sand peaks to indicate evidence of storm induced waves and currents which redeposited these coarser grained sediments during intervals of hundreds of years. The study of such post-glacial Holocene sediments may give a proxy-climatic record of changes in oceanic conditions over the past ~10ka.

1.2 Purpose and Approach

Subsequent sampling of the Emerald Basin sediments was done with the aim of further describing the record of storminess on the central Scotian Shelf. Two gravity cores (93-026-008,009) and one piston core (93-026-007) were taken near the location of the 1982 cores (Fig. 1). The southern edge of Emerald Basin is an ideal setting for cores used in this type of study. Proximity of the core area to the shelf edge allows for a record of sand supply generated by storm waves and currents. At the same time the water depth is sufficient to prevent erosion of sediment by the storm waves. The sand is transported across the shelf and down into the outer margins of the basin, whereas towards the centre of the basin only muds would are deposited (Kontopoulos and Piper).

Similar methods using X-radiographs and sand percentage determinations are used to help correlate these new cores to those previously studied by Kontopoulos and Piper. This report describes the methodology used to analyze the cores and presents data which may give further evidence to support the theory of deposition of sand and coarse material due to storm induced waves and currents which occur periodically on the shelf. Further study was carried out on two cores taken from the Upper Scotian Slope area to see if storm graded sediment deposition can be correlated over a larger area.

2 MATERIALS

The main focus of this study is the core samples taken from the 93-026 cruise of the research vessel CSS Parizeau. The two gravity cores, 008 and 009, are 214cm and 213cm in length respectively. They consist of LaHave Clay, reddish brown in colour with minor reddish lenses in some areas. Silty mud with silty lenses or silty laminae (1-5mm) is the prominent lithology. Piston core 007 is 639cm in length with a trigger weight core (TWC) of 96cm. The TWC and upper portion (~110cm) of the piston core is LaHave Clay which grades into the greenish-grey Emerald Silt. Cores 008 and 009 were collected one nautical mile on either side north and south of the piston core (Fig. 1).

<u>Core Data</u>:

Core No.	Latitude Longitude	Water Depth(m)	Location
Hudson 87003			
007	43°20.70'N 60°12.90'W	920	Logan Canyon
Hudson 90015			
018	42°48.62'N 62°49.69'W	536	Albatross area
Parizeau 93026			
007TWC	43°24.85'N 63°19.93'W	190	Emerald Basin
007	43°24.85'N 63°19.93'W	190	Emerald Basin
008	43°23.99'N 63°19.90'W	192	Emerald Basin
009	43°25.99'N 63°19.94'W	194	Emerald Basin

The two other cores studied are 87-003-007 and 90-015-018. Core 87-003-007 is from near Logan Canyon, described as structureless silty mud and grey mud. Core 90-015-018 was taken from the Albatross area and consists of silty sand with traces of lamination.

The 3.5 kHz acoustic record from the 93-026 cruise and Huntec deep-tow seismic records from cruise 79-011 indicate subsurface geology of the core sampling areas (Fig. 4). Note that the site of core 007 is located about 0.5 km from the trackline of the Huntec profiles.

3 PROCEDURES AND METHODS

3.1 Multi-Sensor Track

Prior to splitting and description, the 93-026 cores were analyzed by the Multi-Sensor Track (MST), which measured P-wave amplitudes, velocity (m/sec), relative gamma counts, and magnetic susceptibility (1 sec and 10 sec counts). Each set of geophysical measurements was plotted against depth for each of the 92-026 cores (Fig. 3). All data were plotted, even though poor results for P-wave amplitudes occurred where core and liner were not in contact, and at the top and bottom ends of a core section.

3.2 Description and X-radiographs

Each of the 93-026 cores was X-rayed and video taped using the lab and equipment provided by AGC Curation. Evidence of major bedding, laminations, and clasts were recorded. Whole shells and/or fragments were also noted for possible later dating. Minor disturbance of parts of the cores during removal from the sea floor may account for some "apparent bedding" seen in the X-rays. Cores were split using the standard AGC method (Mudie et al., 1984) with a working and archive half, and described noting again major changes in lithology including bedding, clasts and shells. Colour was described using the Munsell Colour Chart as well a Colormet machine which yielded a L, a B, and an A value which represent the range in colour from black to white, red to green, and blue to yellow respectively. These three values were plotted individually against core depth (Fig. 3). Some technical problems, such as failure of the flash and poor calibration of the machine account for poor values in the Colormet data in certain areas of the cores for example core 008 at ~115 cm.

3.3 Subsampling

All three 93-026 cores were subsampled for bulk density at ~20cm intervals using a sampler of known volume. The wet and dry weight of the samples were recorded and calculated to give the bulk density of each sample. A salinity sample was taken at the each end of each core section by removing a small amount of sediment. These were centrifuged and the liquid tested for salinity using a refractometer.

Percentage sand determinations were made by removing small continuous channel samples subdivided at 1cm intervals down the length of core 008. Core 009 was sampled down to 178cm. The samples were weighed, dried (at 60° C), and then reweighed. A sonic bath was used to disaggregate each sample which was then sieved through a 63um sieve to retain only the sand which was then dried and reweighed. Using the sonic bath for disaggregation of the samples worked consistently well with only a few showing more than 1%-2% mud lumps. Most samples required several separations and sievings. Those with more clay generally took the longest time. No further analysis of sand size was made. Using a binocular microscope, % sand, % mud, and % forams and shells were estimated for the total sample. From this the weight% sand for each sample was calculated. Any granules or pebbles were also noted. Cores and 90-015-018 and 87-003-007 were subsampled for sand at 2cm and 50cm intervals respectively.

4 RESULTS AND CORRELATION OF DATA SETS

4.1 Stratigraphy and Correlation of Cores

In examining the downcore variations in gamma counts, magnetic susceptibility, and colormet L values, it is unclear as to how the TWC and piston core of 007 correlate. No obvious overlap is seen between the two. In the piston core there is an abrupt change in bulk density from 1.59 to 1.81 going downcore from 2.08m to 2.40m. This may correspond to the reflector (X) seen at 5mbsf in the 3.5 kHz profile (Fig. 4). If this assumption is correct the bottom of the core is located in the Emerald Silt facies A at about 9mbsf, and does not reach reflector (Y), interpreted as the top of the Scotian Shelf Drift. This implies that the top ~2m of the piston core is missing. The C-14 dates obtained are consistent with this interpretation but do not require this interpretation if the sedimentation rate decreases in the late Holocene. No evidence is found to indicate any changes in sedimentation rates.

The 3.5 kHz record (Fig. 4) at core site 009 shows ~4m to the first prominent reflector, whereas at core site 007 it is ~6m. This implies a lower sedimentation rate in core 009. Interpreted lithological correlations are made from core 007 at 82cm to core 009 at 178cm on the basis of soft reddish clay blebs seen in both. Abundant shell fragments at 54cm in core 007 can be correlated to a horizon similarly abundant in shell fragments at 150cm in 009. Assuming that the top 2m of 007 piston core is missing, then the lithological boundary between the LaHave Clay and Emerald Silt is at 282cm, making the relative thickness between the two cores consistent with the 3.5 kHz data. The 3.5 kHz data for core site 008 shows the first prominent 3.5 kHz reflector at about 5.5m. This suggests that the lithologic markers used to correlate core 007 and 009 are just below the base of the core making it difficult to tie all three together.

Using gamma count peaks as a further method of correlation, the peak (a) (Fig. 5) at 0.4m (= 2.4mbsf) in 007 and at 0.75m in 009 may be equivalent to that at 1.55m in 008. No C-14 dates are available from core 008. Shell ages from 007 and 009 appear to show a consistent downcore increase in age except for the sample at 95 cm in 009 (Fig. 6). This is a fragment and may be reworked.

4.2 Gamma-Ray Counts Versus Sand Correlation

Gamma rays are useful because they record the amount of U and K which is in the sedimentary material. Generally these elements are concentrated in the finer grained clays of the sediments. This infers that for coarser grained materials the relative gamma counts should be low. Scatter plots of the relative gamma counts plotted against sand content for core 008 and 009 (Fig. 7 and 8) show essentially no correlation. At the most there is slight tendency for higher gamma at lower sand. Certainly, the relative gamma count data are not useful as a proxy for sand, as was originally hoped.

4.3 Downcore Variation in Sand Content

Using the assumed correlation of cores 008 and 009 on the basis of the 3.5 kHz profiles and peak (a) in the gamma counts, it is possible to correlate eight major peaks and troughs in the percent sand (Fig. 9). There is no independent method of verifying this correlation. Both cores show a decrease in sand in their upper section above peak I (above 10 cm in 008 and 5 cm in 009). Sand percentage ranges from 7-15%. Intervals IV, V, and VI in both cores also show low sand content comparable to the surface values. The highest peaks occur at I, III, and VII in core 008 with 19%, 17%, and 21% sand respectively, and peak II and VII in core 009 with 18% and 19% sand. Generally sand abundance is persistently higher than surface values down to 125cm in core 008 and 110cm in 009. Sand then becomes low (less than 10%) until 140cm in 008 and 123cm in 009. In core 008 sand then stays moderate to high until the bottom of the core with a peak occurring at 207cm. Core 009 shows a wide variation in sand abundance from 123cm to 178cm with a sharp peak at 165cm followed by very low percentages down to the end of the core.

Peaks in foraminifer abundance in core 008 and 009 appear to correlate to the same intervals in these cores as defined by the sand abundance (Fig. 9). The occurrence of high percentages of foraminifers may be related to high productivity or periods of low sedimentation rates.

5 CORES FROM THE CONTINENTAL SLOPE

5.1 Albatross Slope

Core 90-015-018 from the Albatross slope (see p. 4) was analyzed for sand content from 0-140cm at 2cm intervals (Fig 10). Overall sand abundance was very high compared to the Emerald Basin cores typically from 40-60%. There is a sharp drop in sand at 52cm just below 7.2 ka C-14 date and there are two other intervals of low sand at 70-80cm and 129-132cm. The major peaks occur at approximately 25cm, 78cm, and 118cm.

5.2 Logan Canyon

Both the TWC and piston core for 87-003-007 were analyzed at 50cm intervals for sand content down to 400cm (Fig 11). Generally percent sand is low (less than 10%) with a peak at the top of the piston core and also increasing from 300-350cm at about 10 ka. The trigger weight core shows consistently low sand (7-15%).

6 DISCUSSION

In assessing the overall results from this study it appears that sand abundance can be used in a general sense as an indicator of past storminess. There are systematic variations observed in the 93-026 Emerald Basin cores from 0-7 ka. The probable age of core 009, based on the extrapolation of C-14 age, is shown in figure 9. Generally sand abundance is higher than surface values back to about 4 ka. From 4-4.5 ka sand percentage is low, and then becomes very high from 5-7 ka. Finally it becomes low again just above 7 ka. It should again be noted that the ages assume a constant sedimentation rate and reliable dates. As well, the upper 20cm of core 009? correlates well with core 4 from Kontopoulos and Piper, but because these previous cores are short (<65cm) there are no unambiguous correlations below 20cm.

It is harder to interpret the peaks and troughs seen in the continental slope cores and a past storminess record on the continental slope is less obvious and harder to define. No correlation between cores 90-015-018 and 87-003-007 is obvious, possibly due to the widely spaced data in 87-03-007, although both show distinct periods of higher and lower sand deposition. As well, no clear correlation is made between the Emerald Basin cores and the continental slope cores.

7 CONCLUSIONS

1. The methods for measuring sand abundance used in this study worked consistently well especially when samples were taken at small (1cm or 2cm) intervals. Peaks and troughs are representative of higher and lower periods of sand deposition. Gamma-ray counts did not give accurate indication of sand abundance and were only of limited use in correlating between the individual cores.

2. It is possible to correlate between individual cores using the sand abundance, but correlations are limited by the C-14 dates. More C-14 dates, especially in core 008 and 009 would aid in better correlations.

3. A record of past storminess on the continental shelf and slope can be interpreted for the past ~7 ka, with storms depositing more than average amounts of sand from 1-4 ka and particularly 5-7 ka. Individual peaks in sand abundance represent major storms with recurrence intervals of several hundred years.

Recommendations:

Further dates for core 009 and also any in 008 would aid in more accurately correlating the Emerald Basin cores, as well as doing sand percentage determinations down core 007 in order to compare the sand peaks and troughs with those in cores 008 and 009. Core 87-003-007 could be further analyzed for sand abundance at smaller intervals (1 or 2cm).

REFERENCES

King, L.H. and Fader, G.B. 1986 *Wisconsinan glaciation of the continental shelf, southeastern Atlantic Canada*. Geological Survey of Canada, Bulletin 363, 72p.

Kontopoulos N. and Piper D.J.W. 1982 *Storm-graded sand at 200 m water depth, Scotian Shelf, eastern Canada*. Geo-marine Letters, v. 2, p. 77-81.

Mudie, P.J., Piper, D.J.W., Rideout, K., Robertson, K.R., Schafer, C.T., Vilks, G. and Hardy, I.A. 1984. Standard methods for collecting, describing and sampling Quaternary sediments as Atlantic Geoscience Centre. G.S.C. Open File 1044.

TABLE 1. RADIOCARBON DATES USED IN THIS STUDY

Slope of Emerald Basin

Core	Depth	Material	Age*	Lab #
93026-007TWC	74	*Astarte crenata* valve	2740±60	TO-4389
93026-007	150	*Yoldia hyperborea* valves	8240±70	TO-4386
93026-007	305	*Macoma moesta* valve frags	13520±70	TO-4387
93026-007	570	*Portlandia arctia* valve	17590±120	TO-4388
93026-009	158	*Astarte crenata* valves	6530±120	TO-4390

Continental Slope off Sable Island (Logan Canyon)

Core	Depth	Material	Age*	Lab #
87003-007	342	pelecypod fragment	9940±300	TO-2386
87003-007	440	foraminifers	10360±250	TO-2385

Continental Slope near Albatross well

Core	Depth	Material	Age*	Lab #
90015-018	48	carbonate fragments	7210±80	TO-4484
90015-018	90	*Lunatia heros*	9200±80	TO-2390
90015-018	137	*Nuculana* sp valves	10260±90	TO-4483

* age with reservoir correction

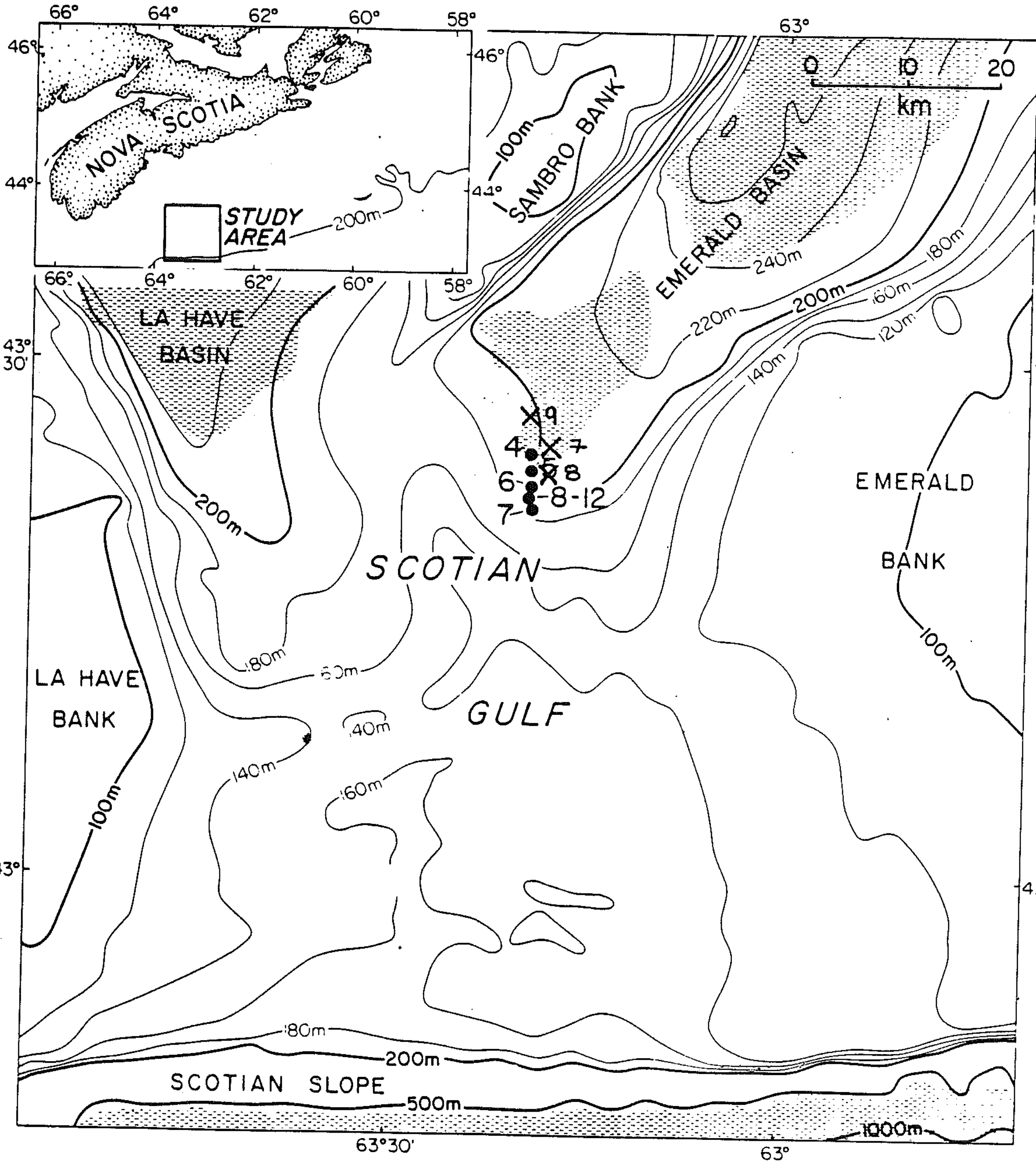


Figure 1. Map of Emerald Basin showing location of cores used in this study (X), and those of Kontopoulos and Piper (1982) (●).

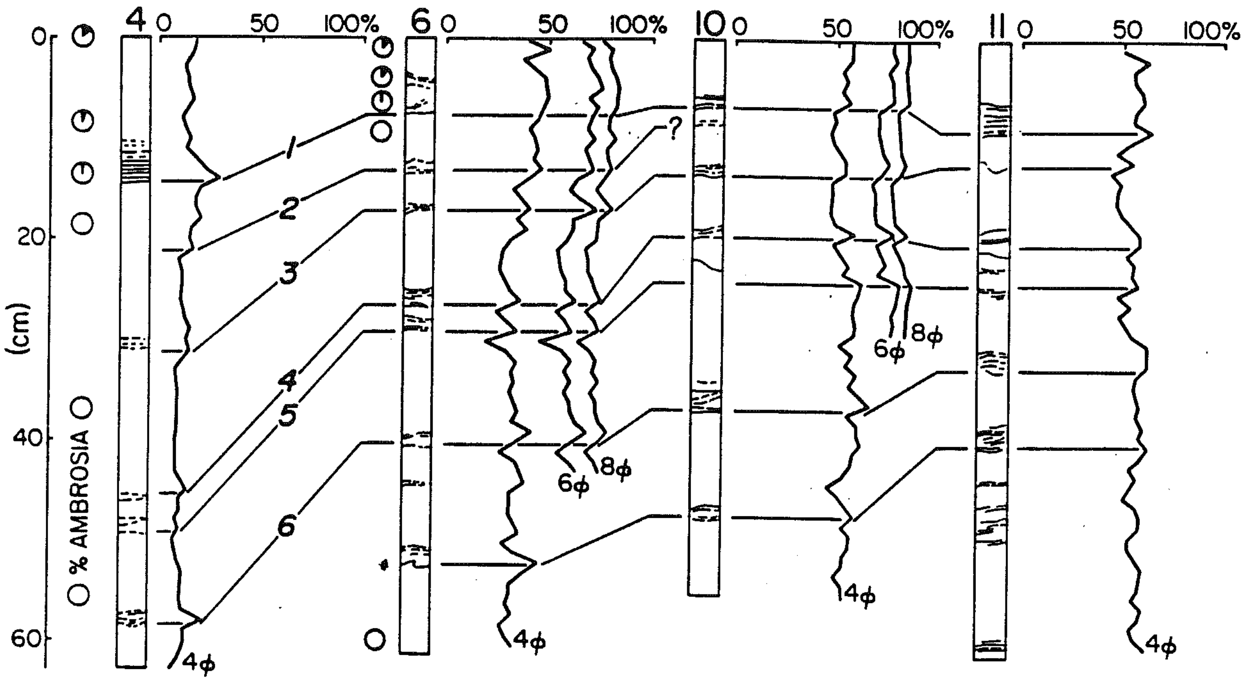
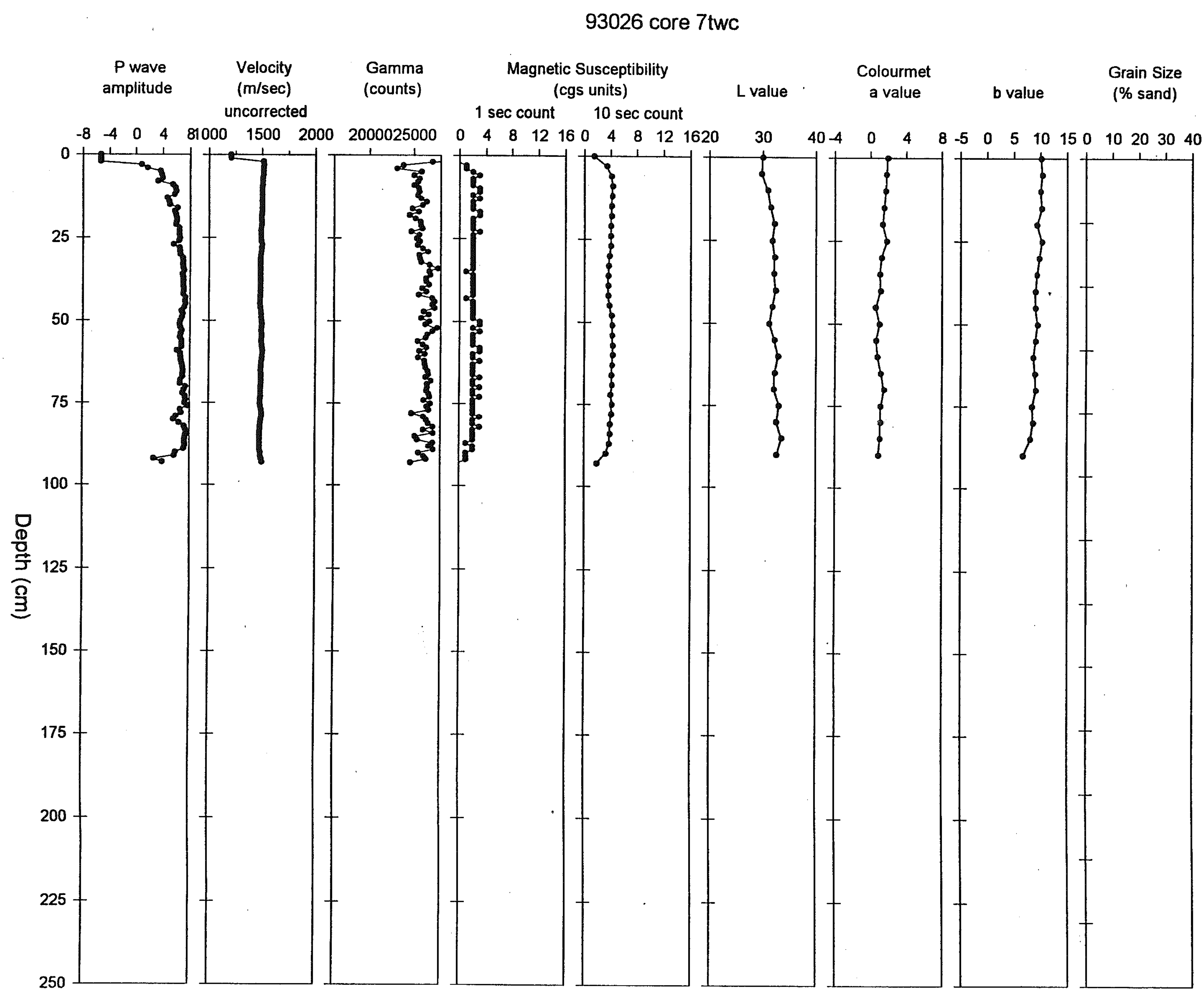


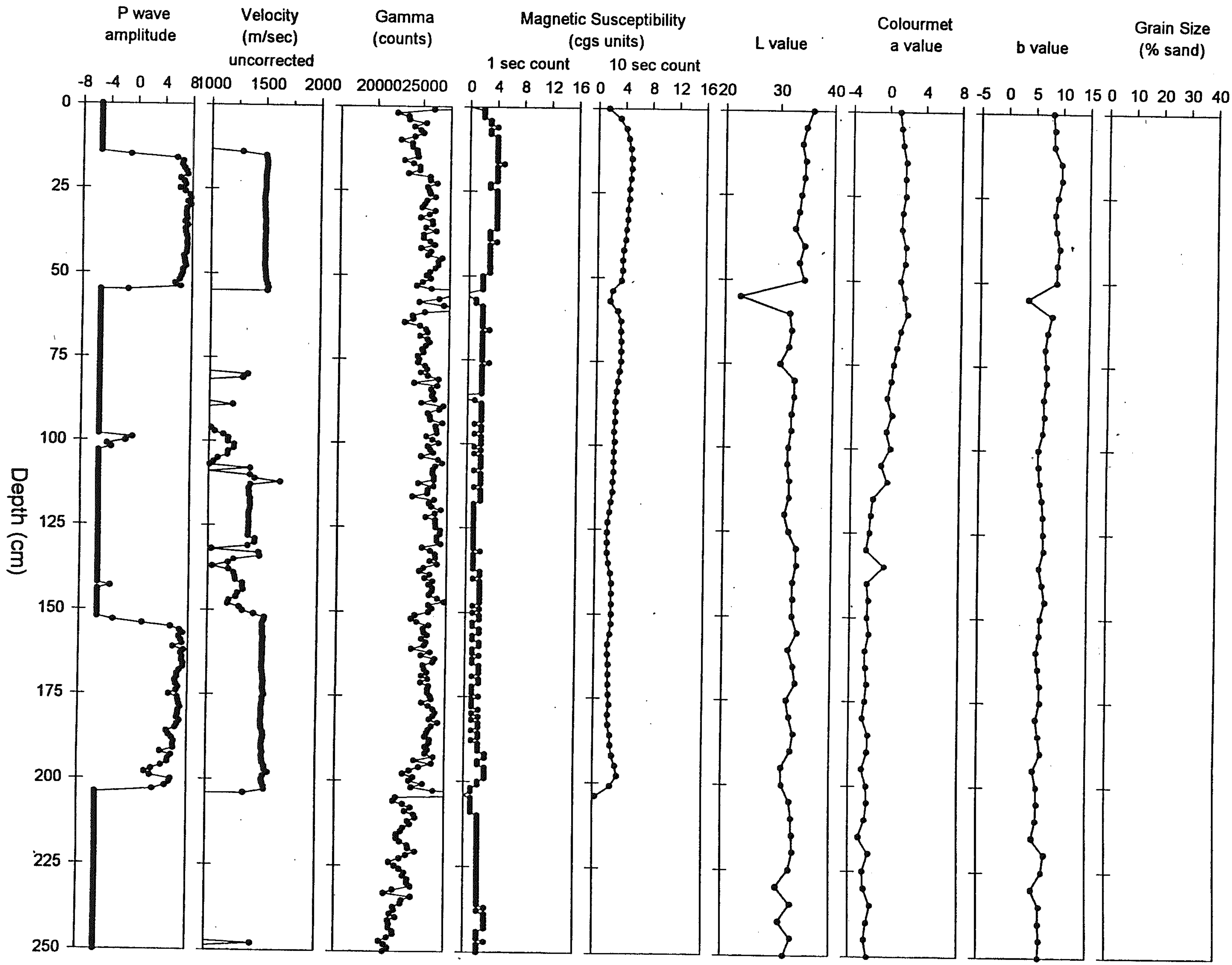
Figure 2. Changes in sand abundance and core correlations, from Kontopoulos and Piper (1982).

Figure 3. (following pages)

Down-core variations in P wave amplitude, velocity, gamma counts, magnetic susceptibility, colormet values, and grain size for cores 007TCW, 007, 008, 009; downcore variation in foraminifera in sand fraction for cores 008 and 009.

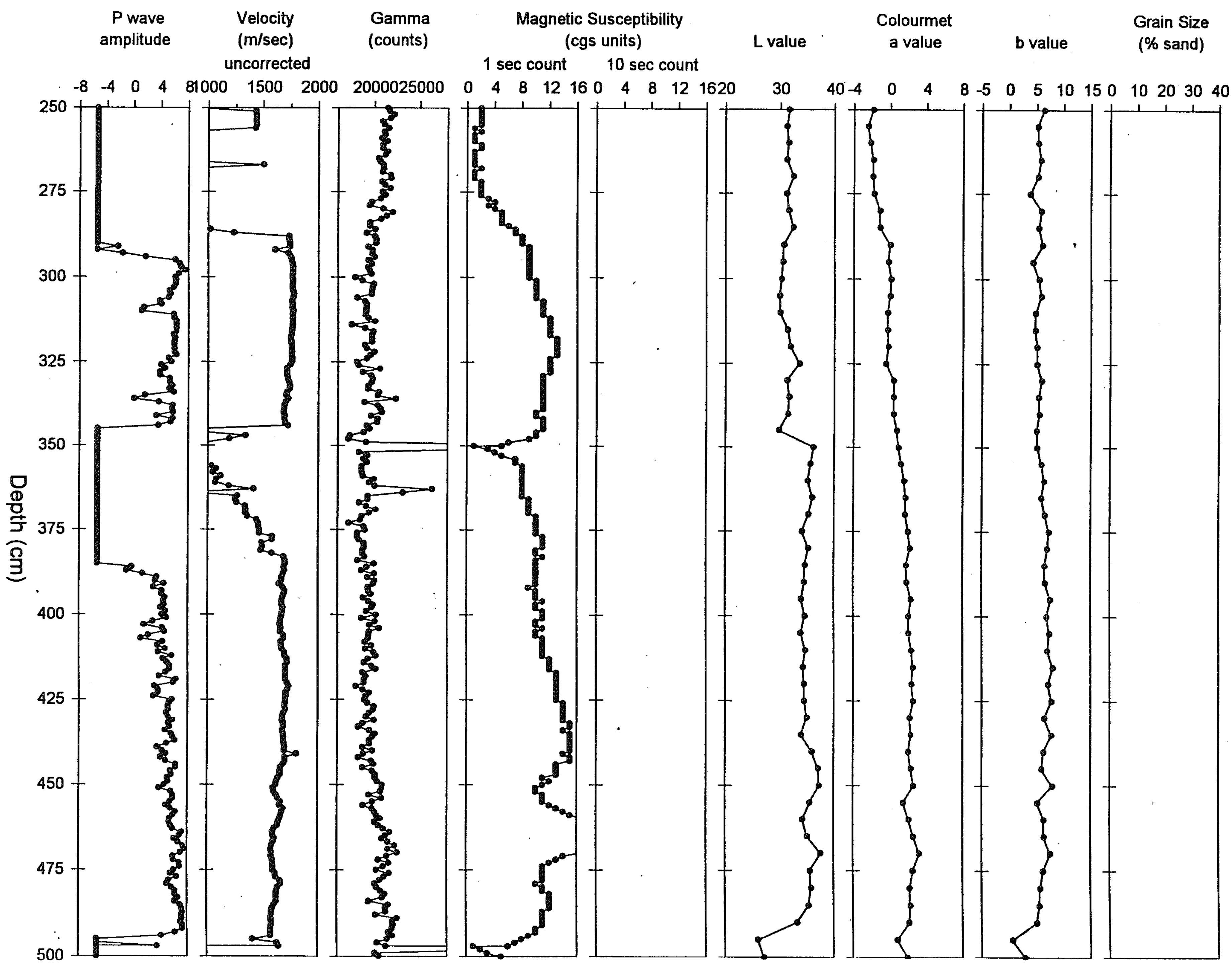

93026 core 7twc
P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

93026 core 7



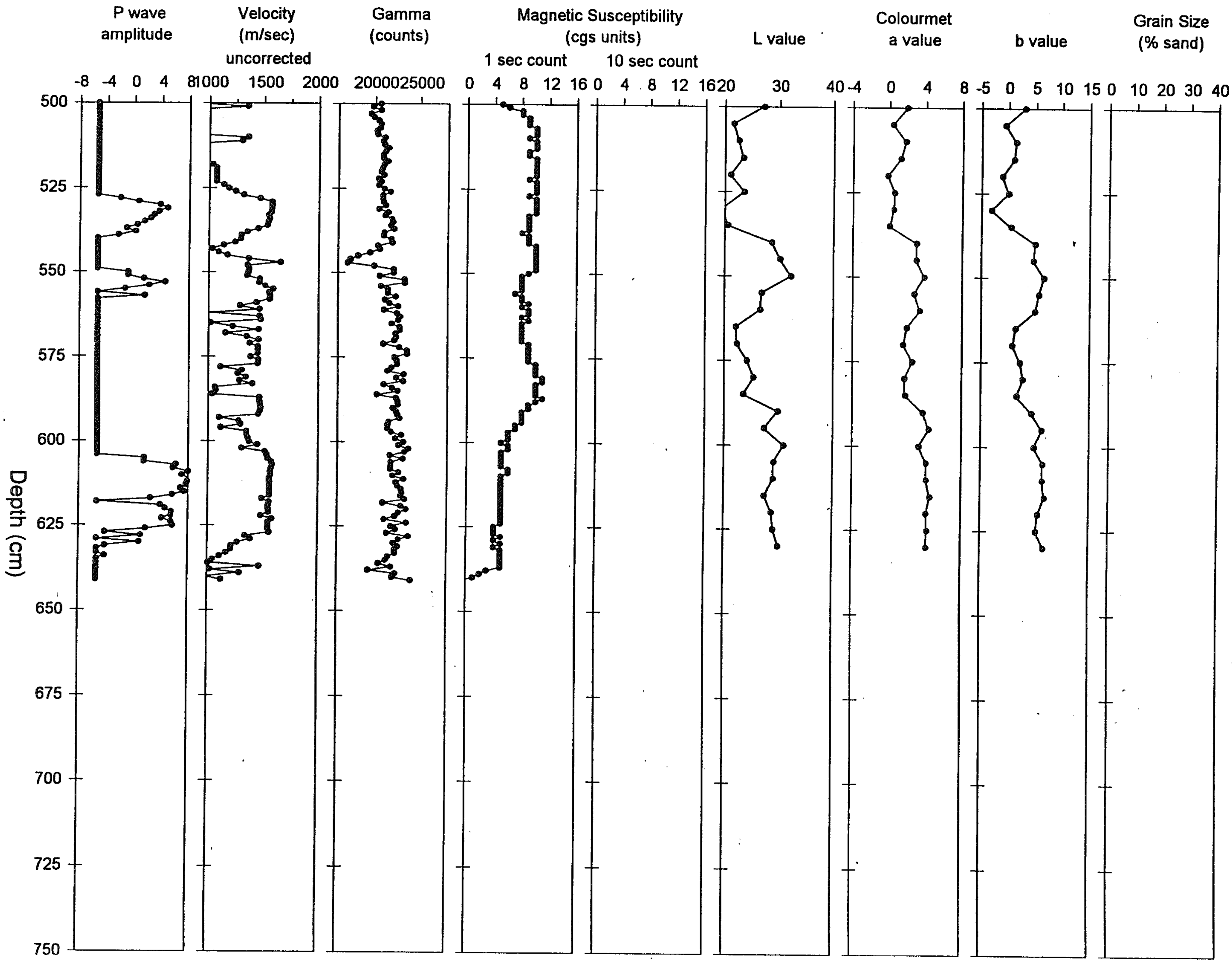
P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

93026 core 7

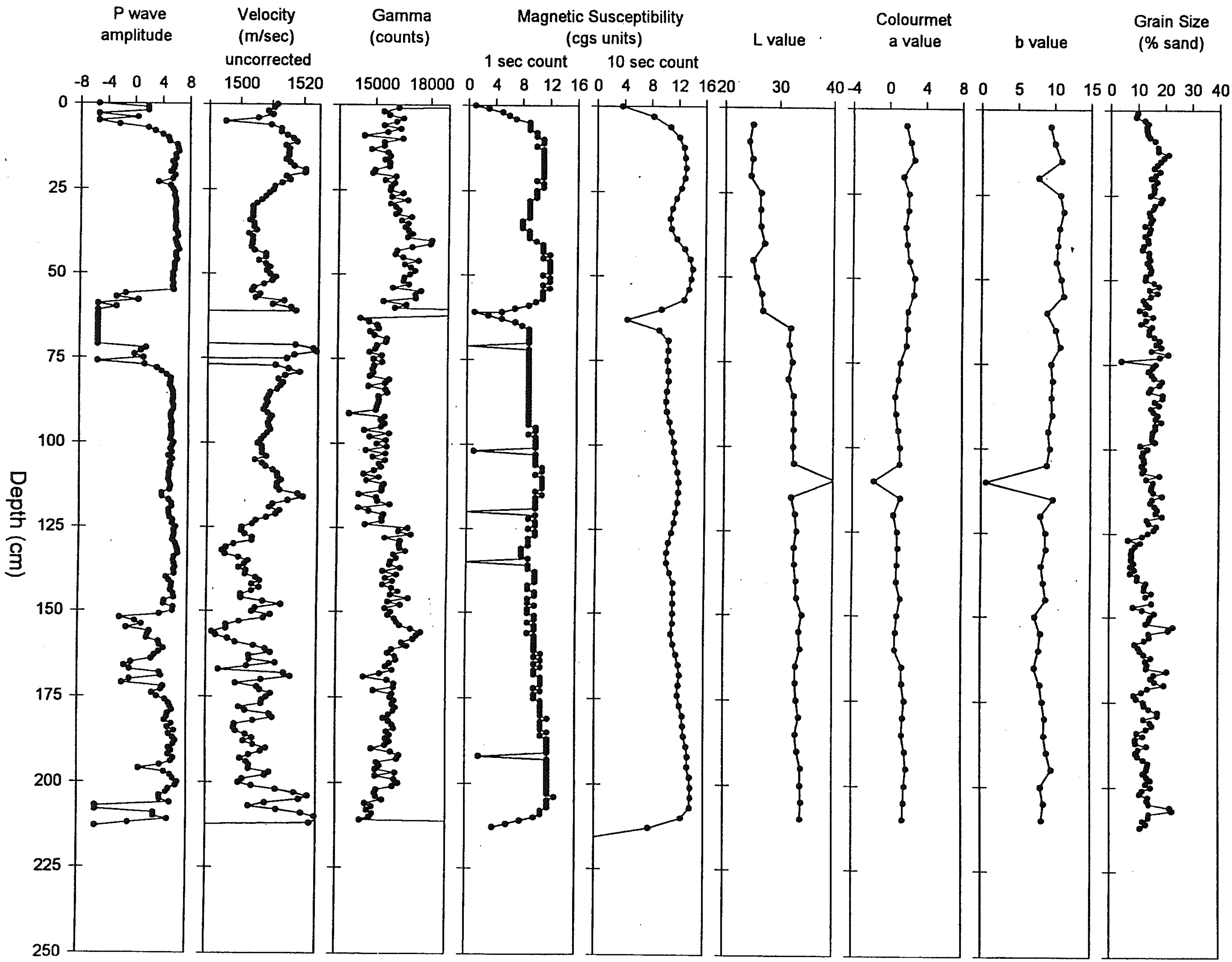


P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

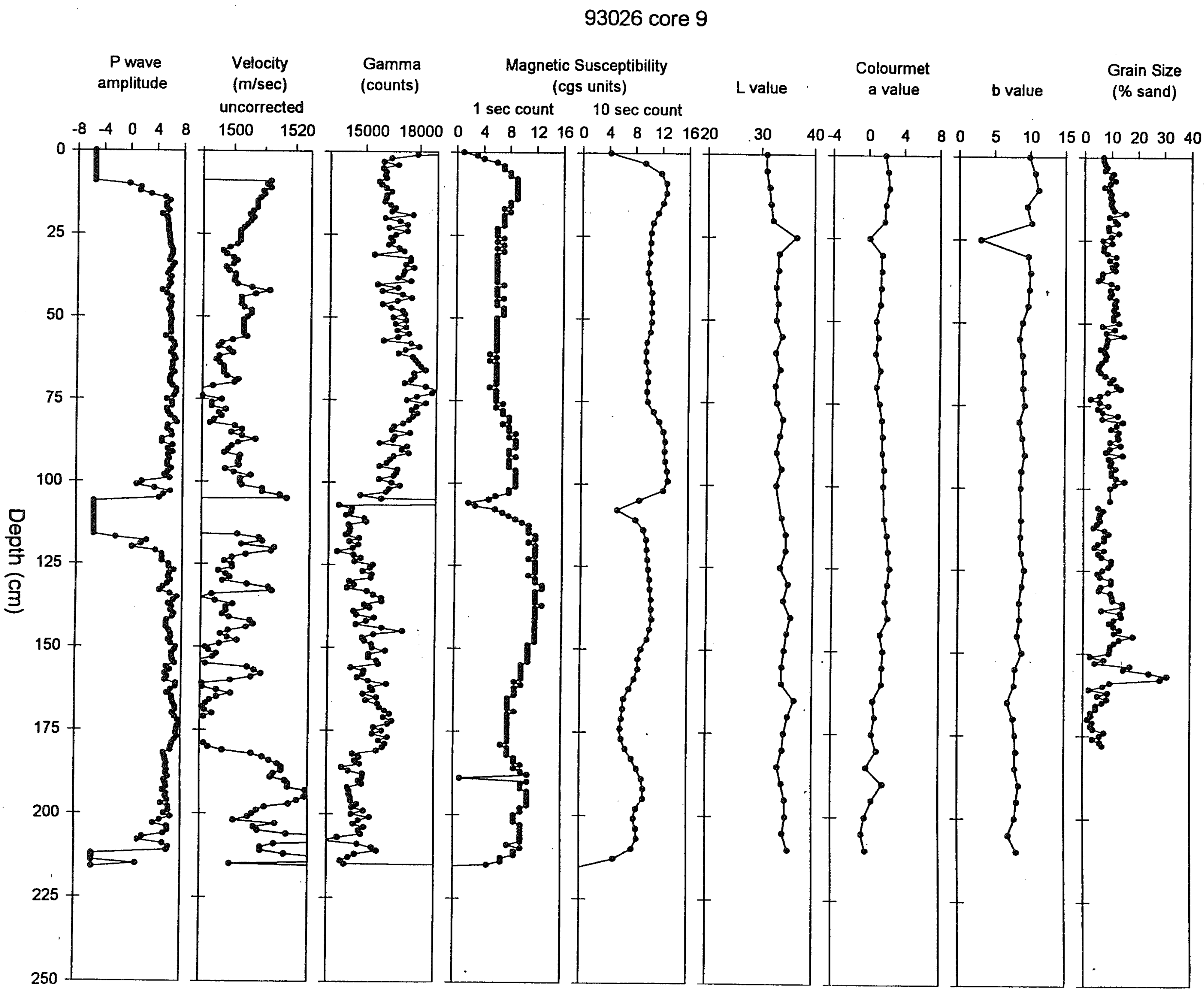
93026 core 7


P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

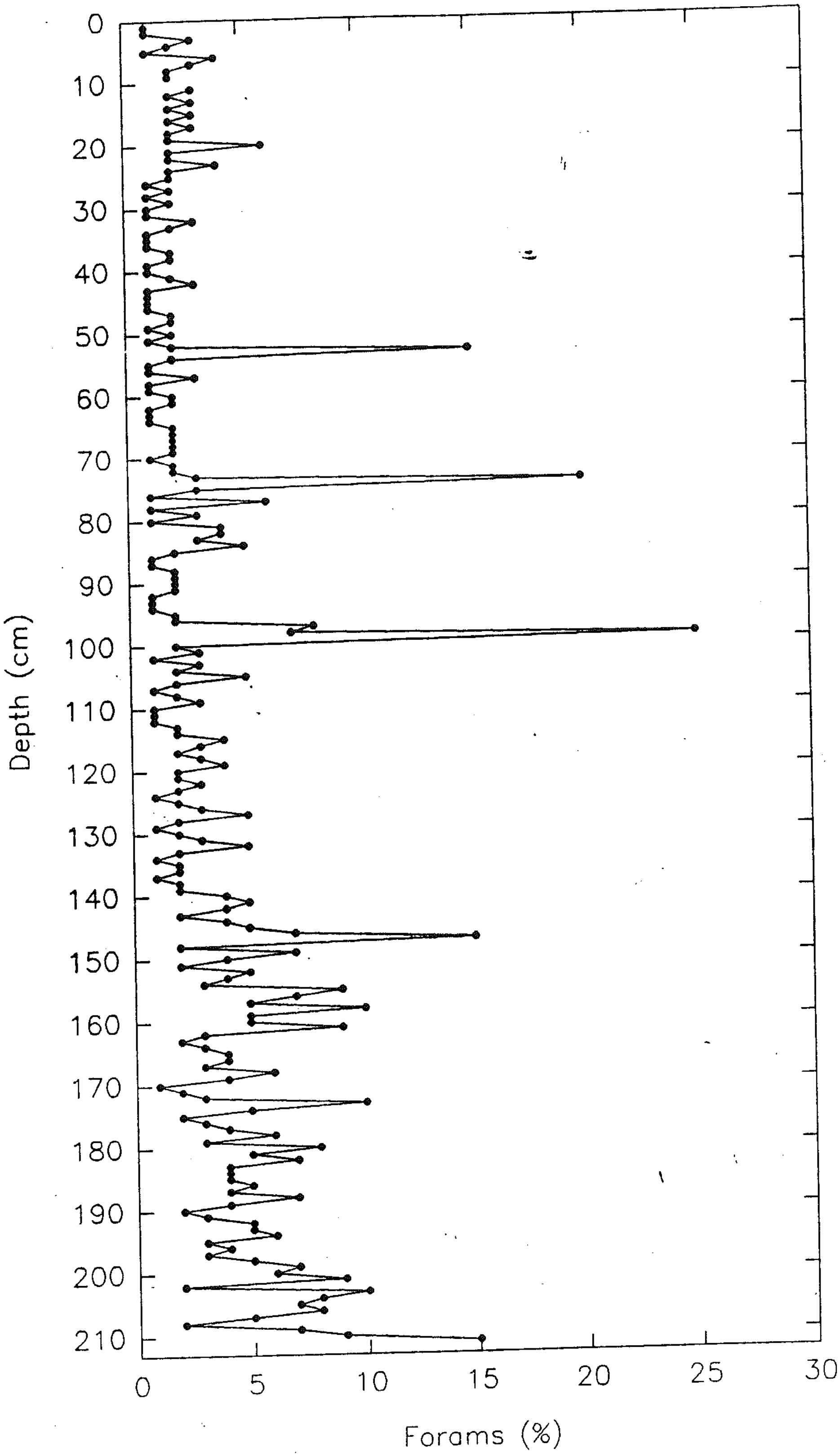
93026 core 8



P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

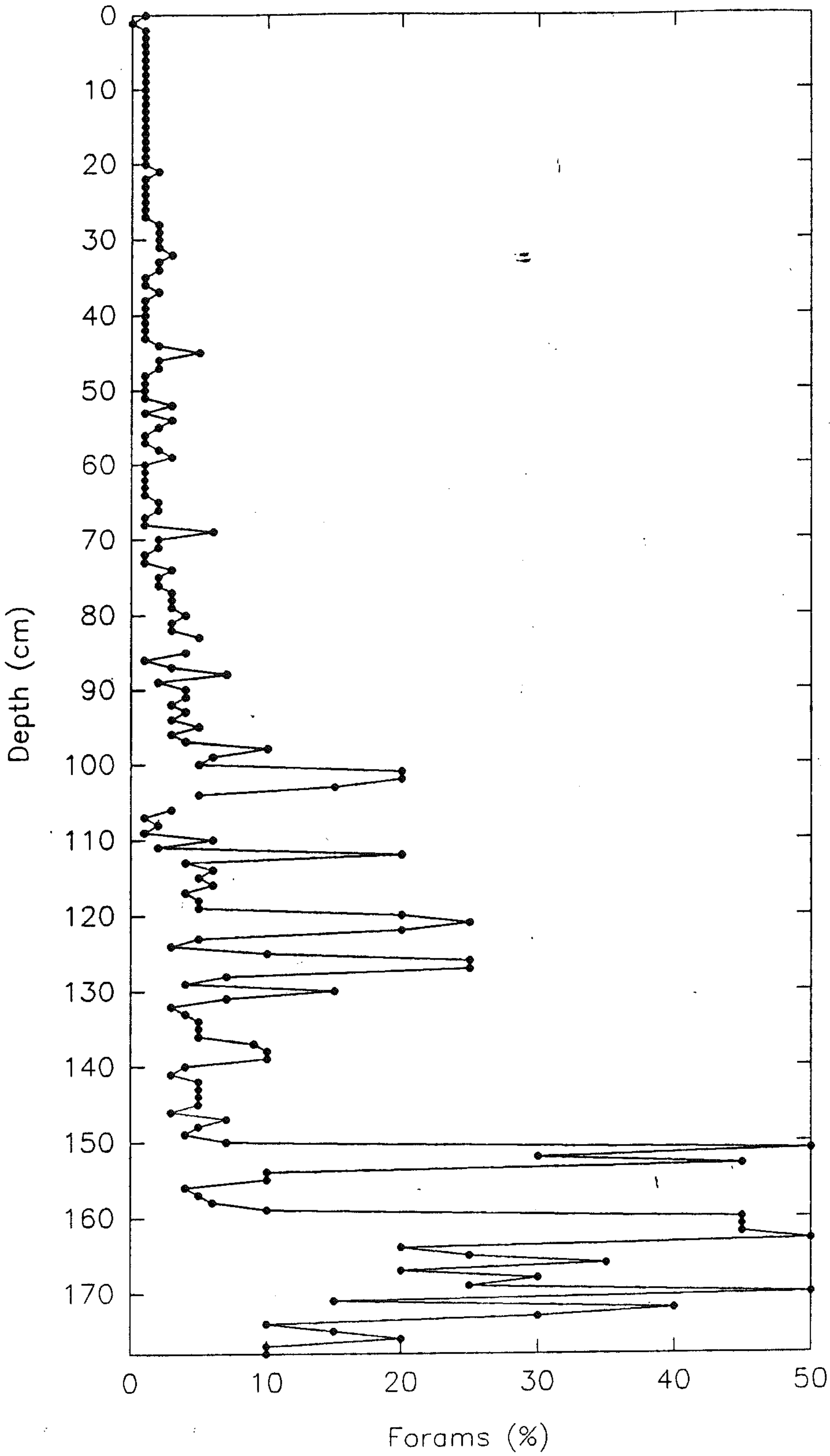

93026 core 9
P wave amplitude
Velocity (m/sec) uncorrected
Gamma (counts)
Magnetic Susceptibility (cgs units)
1 sec count
10 sec count
L value
Colourmet a value
b value
Grain Size (% sand)
Depth (cm)

93026008



Depth (cm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
0
5
10
15
20
25
30
Forams (%)

93026009


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Depth (cm)
0
10
20
30
40
50
Forams (%)

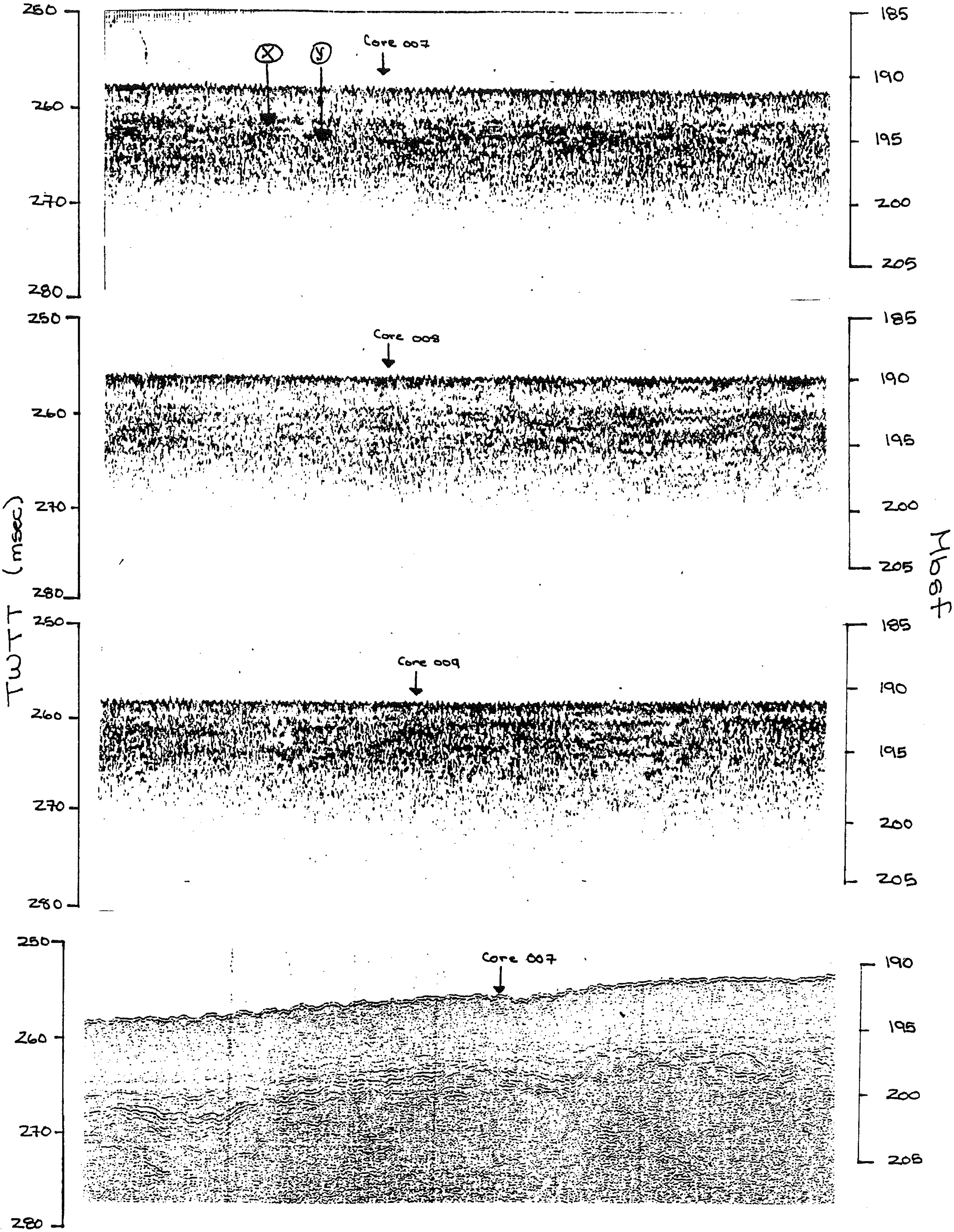


Figure 4. 3.5 kHz and Huntec DTS profiles at core sites showing locations of cores and marker horizons X and Y. (3.5 kHz from cruise 93-026; Huntec DTS from 79-001 day 158 2300hrs.)

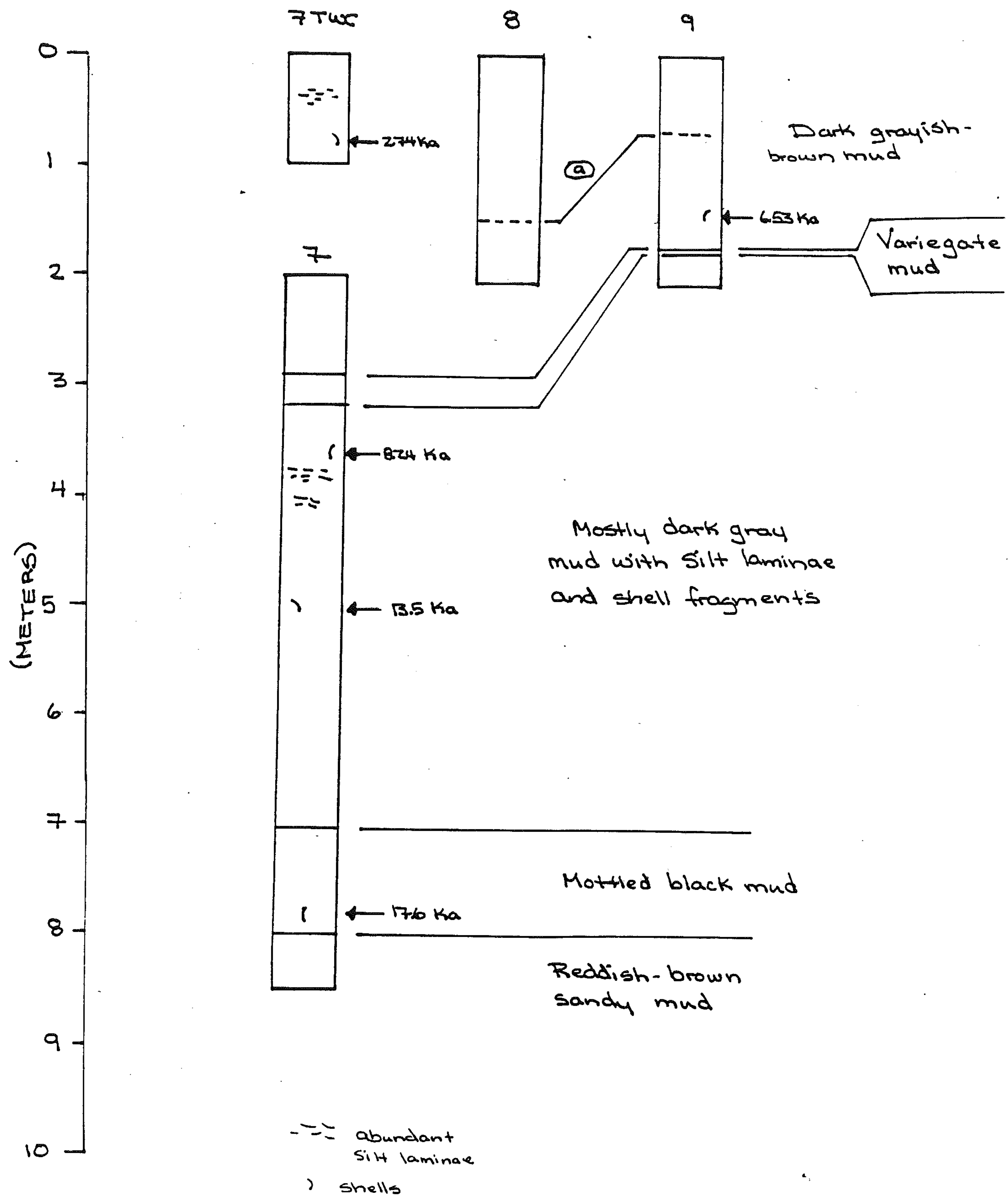


Figure 5. Summary of core lithologies, showing location of radiocarbon dates and interpolated core correlations. (ⓐ is a correlatable peak in gamma counts)

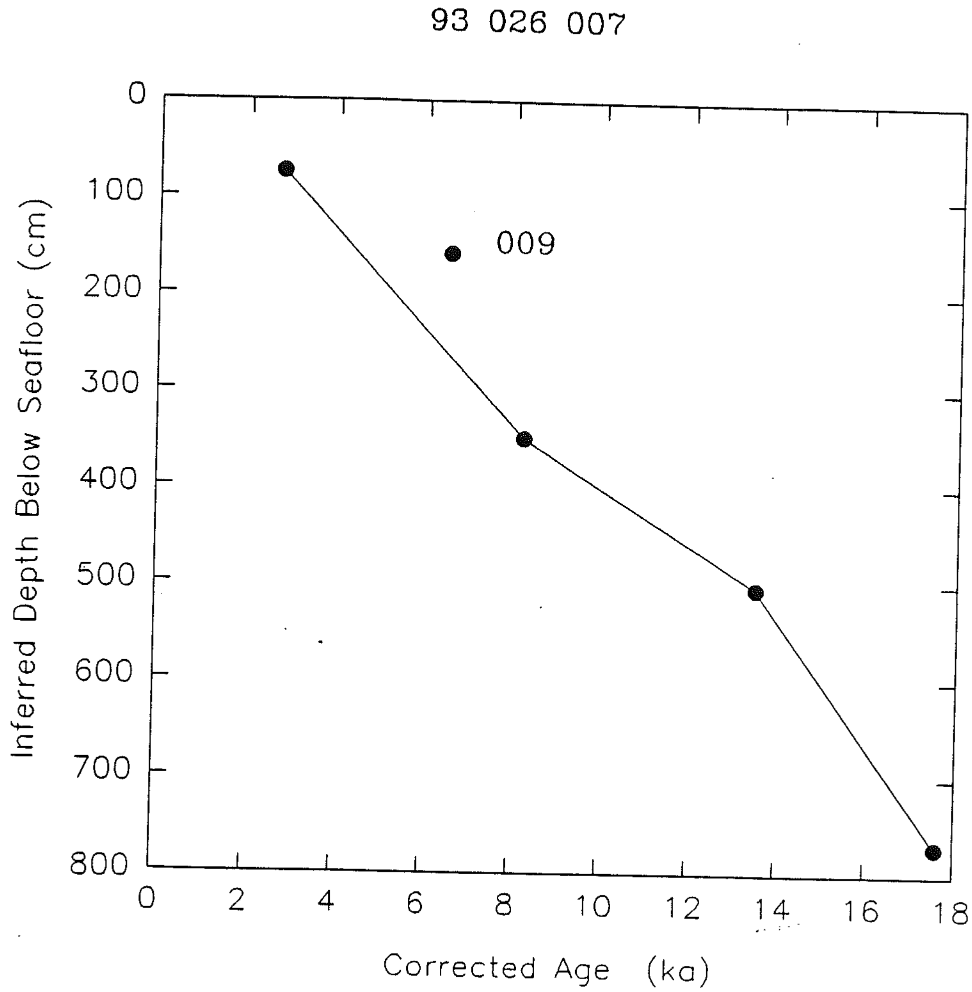


Figure 6. Plot of C-14 age (corrected for reservoir effect) against corrected depth for cores 007 and 009.

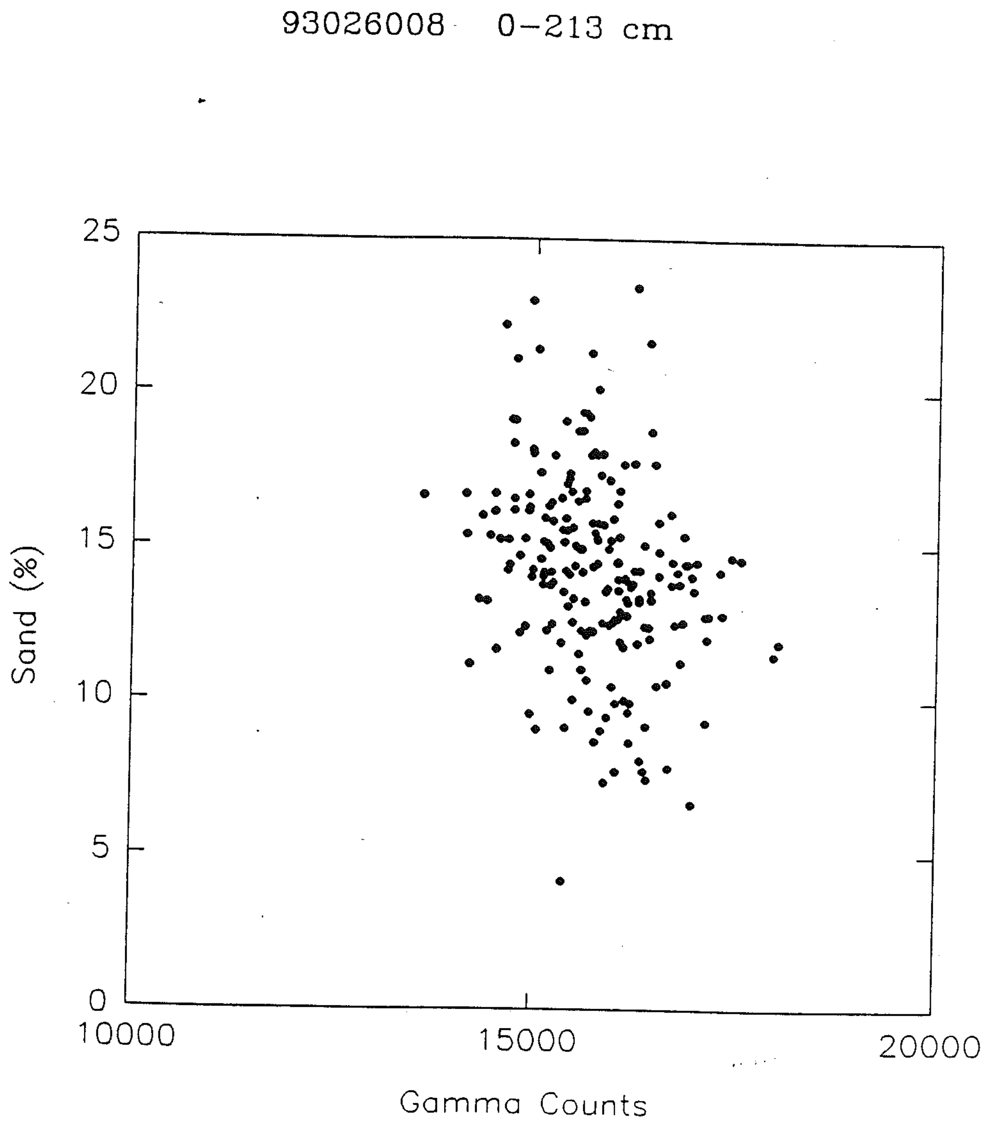


Figure 7. Scatter plot of gamma verses sand content for core 008.

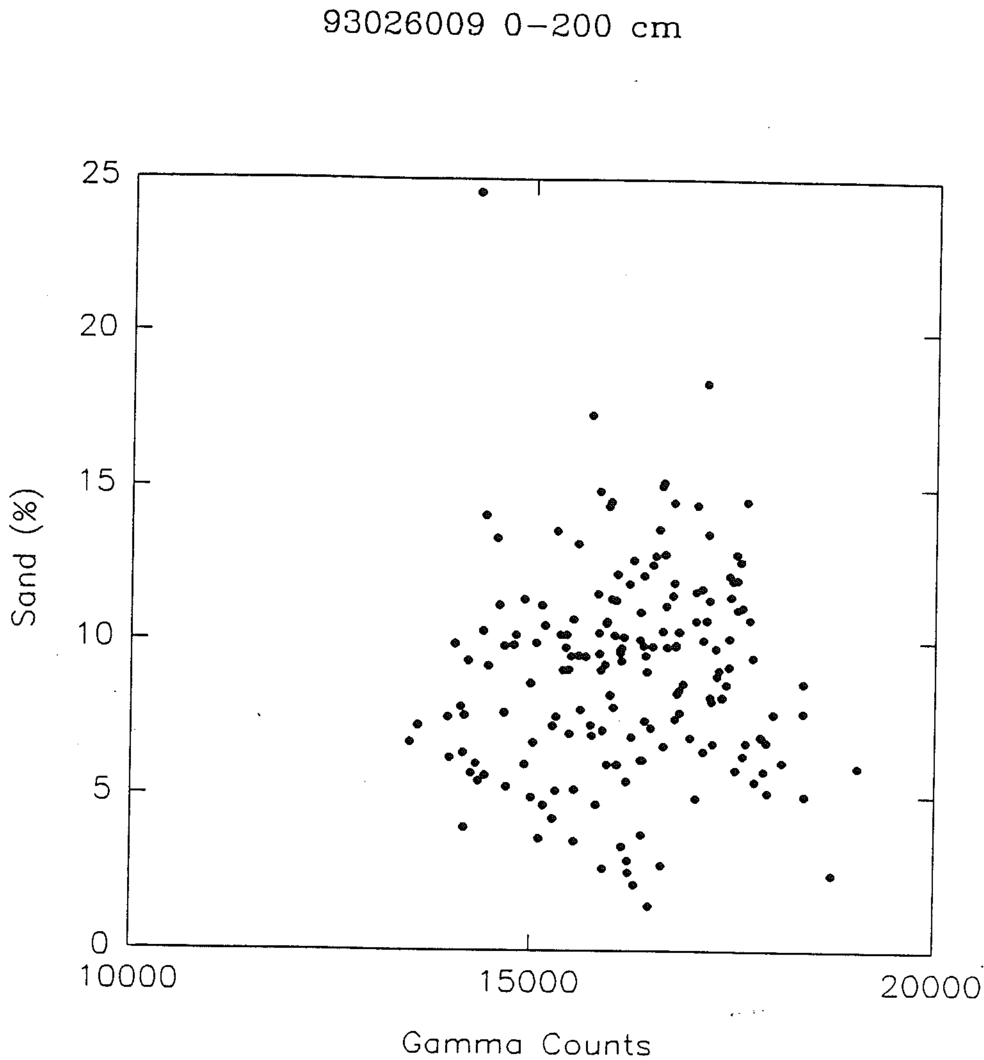


Figure 8. Scatter plot of gamma verses sand content for core 009.

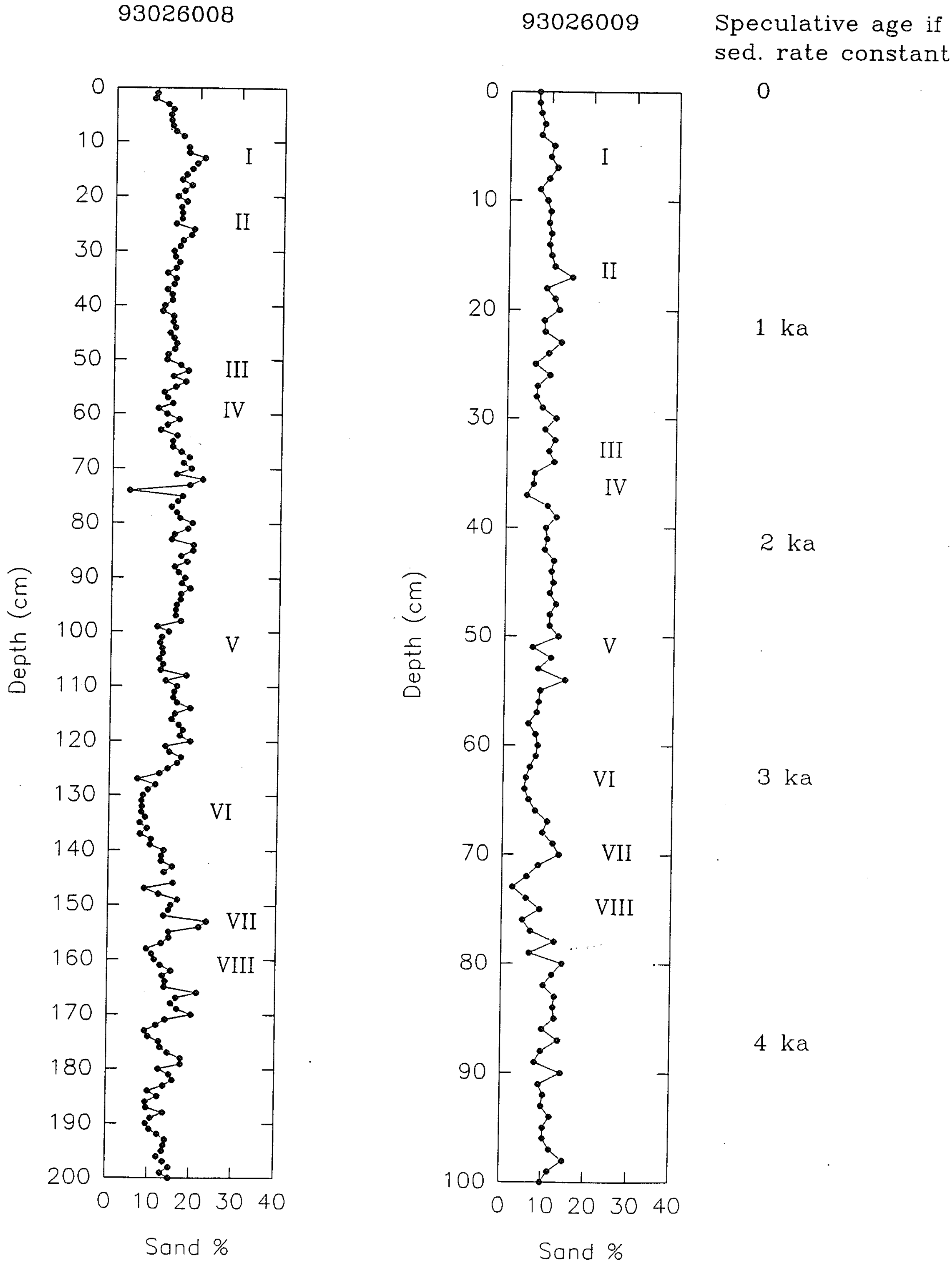


Figure 9. Downcore plot of % sand for the upper parts of cores 008 and 009, at different scales to show inferred correlation. Ages are speculative and interpolated from C-14 dates in cores 007 and 009 assuming constant sedimentation rate.

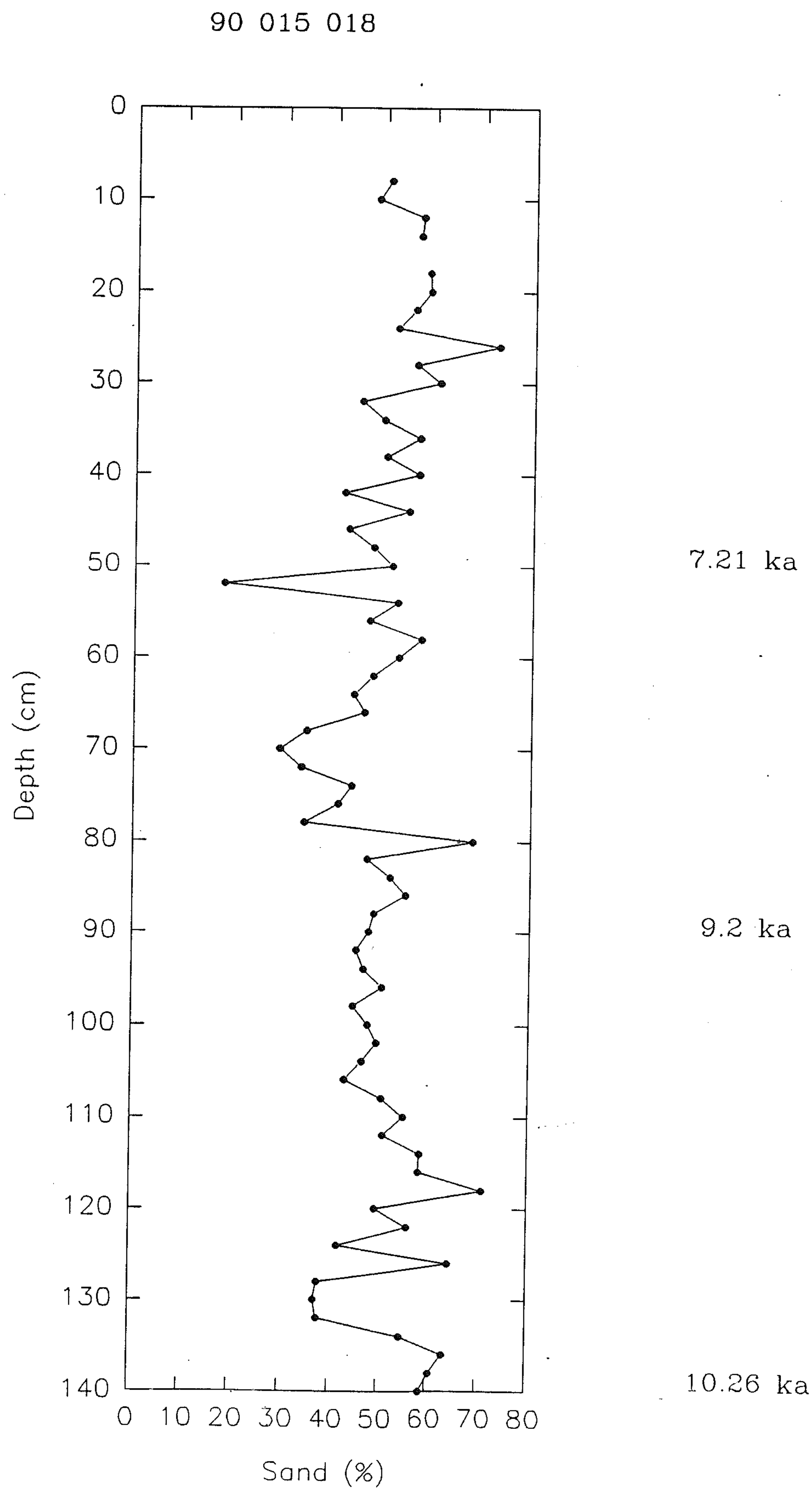


Figure 10. Downcore plot of % sand for core 90015018 from the Albatross slope showing radiocarbon dates.

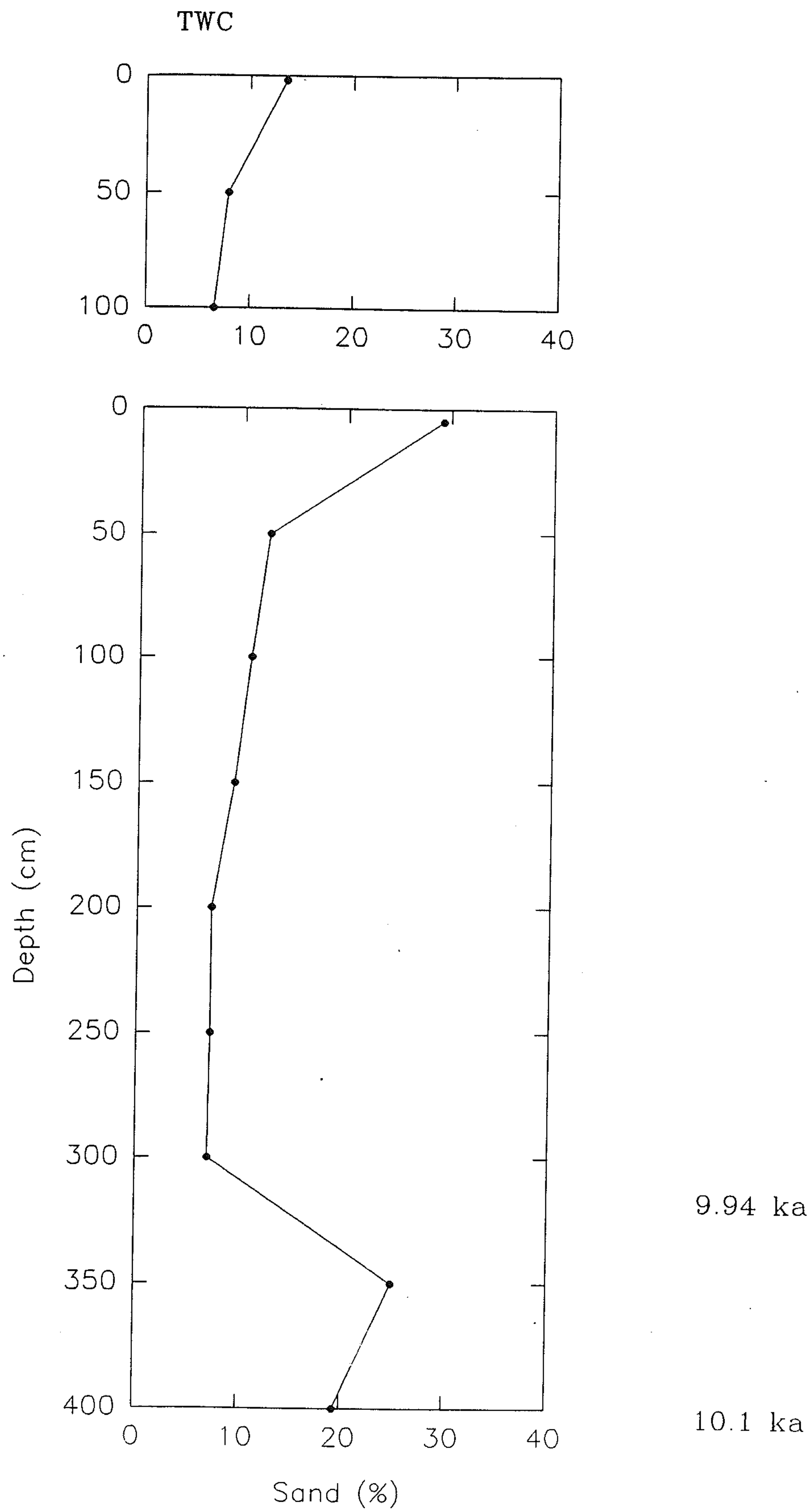


Figure 11. Downcore plot of % sand for core 87003007 from the Logan Canyon slope showing radiocarbon dates.

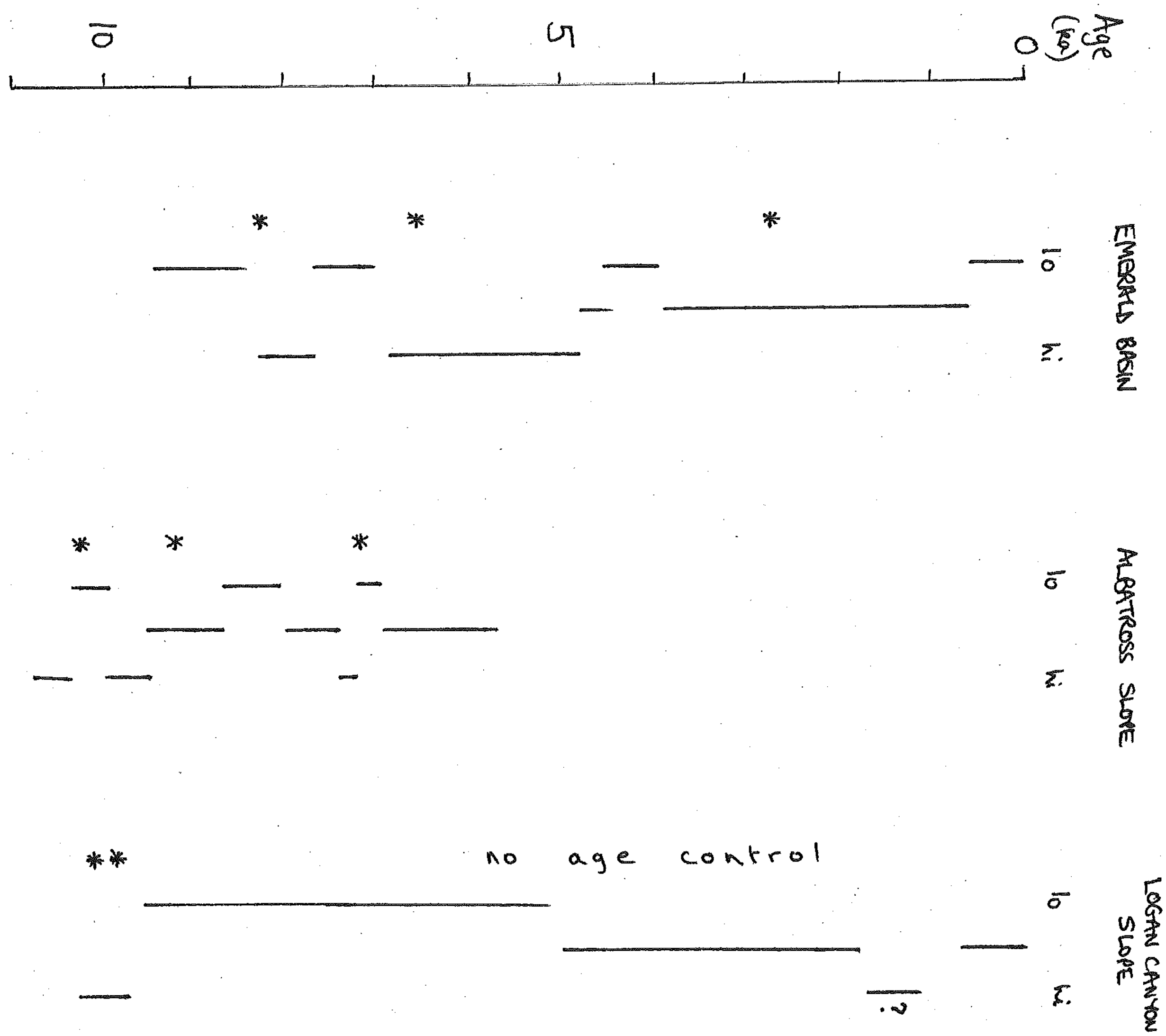


Figure 11. Plot of sand-rich and sand-poor intervals in cores against interpolated age.