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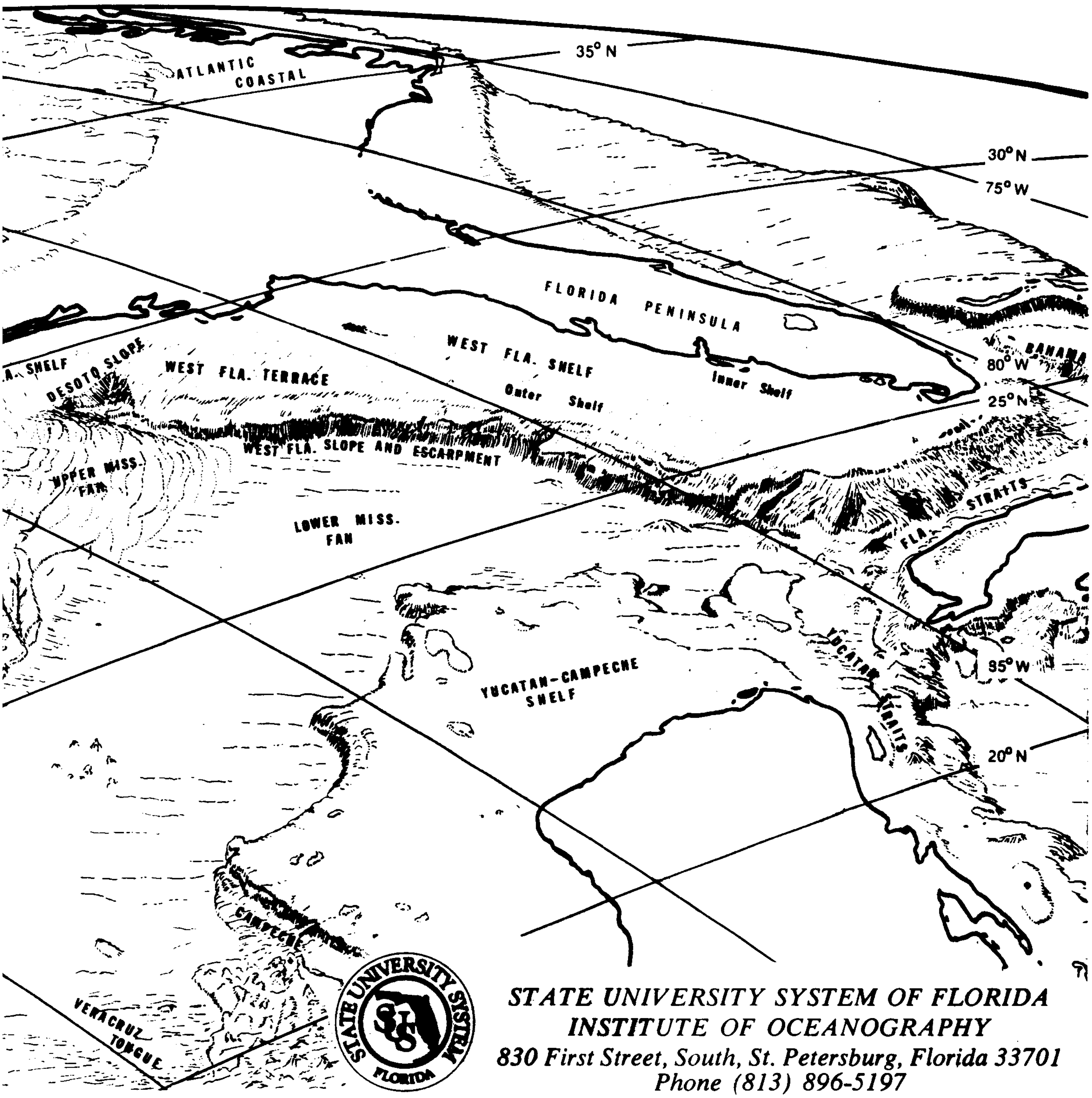

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MICROMOLLUSCS

REPORT TO THE BUREAU OF LAND MANAGEMENT ON SMALL MOLLUSCS COLLECTED IN THE MAFLA AREA DURING 1975-76

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The continuation of the MAFLA project in 1975-76 gave project workers a change to compare results with work done in 1974. This is not to say that we can compare on a straight line station to station basis, for only nineteen stations were carried over from 1974. The number of stations was reduced, but the new stations included new territory, more shallow water stations, and several much deeper stations. A number of species were added to the species list, almost all from the deepest stations.

Another new dimension for 1975-76 was three sampling periods instead of one. This meant that a seasonal study could be made of living populations. This did not work too well for micromolluscs as the subsamples were too small to obtain many live specimens. The top two centimeters of a single box core would have been a better sample, but this would have meant taking yet another box core at each station.

Two samples from each station and from each cruise were carefully examined under the microscope, and all live collected micromolluscs removed and stored in alcohol. The number of live specimens was less than it appeared at first. This was because some thick shelled burrowing bivalves had to be opened to ascertain whether or not they had been alive at time of collection. Crassinella lunulata was the most common species that had to be examined in this manner. A few specimens belonged to species that attain a size of more than seven millimeters when adult. They are included here for the sake of completeness.

The sampling tube used had an inside diameter of 5.5 cm, or an area of 23.76 cm^2. Molluscs tend to be patchy in distribution, as many species are gregarious. Hence the number of live collected specimens varied from zero to 37. The total number of live collected specimens was 317. No live material was taken at seven of the stations (six deep water stations and station number 2637). Of the 262 samples, 53 did not have live material. The total area sampled was 2 cm x 131 cm x 23.76 cm = 6225.12 cm^2.

When the number of specimens is divided into the area, we get a figure of one live micromollusc for each 19.64 cm^2, or, an average of 509.16/m^2. This is a surprising figure for an average on the continental shelf. If the survey had been made in shallow water off the Florida peninsula, the result would have been considerably higher. Twenty of the first 27 stations were made in depths of less than 50 m. There were 259 live collected specimens, and an average of 973.7/m^2. However, the low productivity area to the west of Cape San Blas, Florida, cannot be ignored. There is a total of 30 shallow stations less than 50 m deep, with an average of 709.7/m^2. The 15 offshore stations with depths up to 186.5 m have an average of 126.26/m^2.

From the above it can be seen that most of the stations were made in comparatively shallow water. At these depths, benthic browsing gastropods of the families Caecidae, Vitrinellidae, Rissoidae, etc., are able to live in some abundance. There is also more food available for bivalves.

There are dramatic changes in population density from shallow to deep stations, but there are also changes from area to area. The 27 stations southeast of Cape San Blas have 279 specimens, while the 18 stations west of Cape San Blas have only 38 live collected specimens. The low number in the western area appears to be due to two reasons, the great amount of fine sediment off the Mississippi coast, and low productivity off the Alabama, west Florida coast.

The three sample periods also showed a difference. Sample periods one and two were almost identical with 70 and 71 specimens. Sample period three, however, had 176 specimens, or 2 1/2 times as many as each of the earlier periods. Caution must be observed in trying to interpret these results, however. More than half (53%) of sample period three specimens came from just three samples. One K sample had 37 specimens, while the corresponding A sample had none.

Some species common in the dead fauna were not taken alive. Several live collected specimens belonged to species not found in the dead fauna. In the case of Solemya occidentalis, there were five live collected, but only one dead specimen. This species, however, has an almost uncalcified shell, and it does not last long after the death of the animal. This is an unusual case, and nearly all of the small molluscs end up in the dead fauna which becomes part of the bottom sediment. The few live specimens collected reflect the amount of food available minus the effect of predation.

The dead fauna, by contrast was quite abundant. A single sample from each of the Cruise I stations was dried and the micromolluscan fauna picked out under the microscope. A total of 18,115 specimens were identified (a few to genus only), and 6,328 were not identified. All of these specimens, 24,443 in all, were physically handled and examined by the Principal Investigator. The unidentified material includes specimens that may not be Mollusca, the probable young of large species, and representatives of taxonomically difficult groups.

The same three classes of Mollusca made up nearly all of the specimens.

This time, however, five Polyplacophora (chitons) were found in the live collected material. A few chiton valves have been observed in the dead fauna, but naturally no effort was made to identify them. The dead fauna was entirely Bivalvia, Gastropoda or Scaphopoda.

Much of this fauna showed the effects of heavy predation. The specimens of one gastropod in particular, Finella dubia, were usually broken or crushed. Bivalves were more likely to be bored although some had been broken. Sea stars and some fish eat molluscs without crushing them; it is impossible to calculate how many of the dead fauna may have been consumed by these animals. One of the most voracious sea stars is Luidia clathrata, and a fish that preys largely on Mollusca is the batfish, Ogcocephalus. Fretter (1956) obtained small molluscs from Astropecten irregularis, while Wells and Wells (1961) published a long list of small molluscs from Astropecten articulatus stomachs.

The associated invertebrate fauna was very similar to that found in 1974, especially bryozoans and ostracods. The micro-coral, Guynia annulata, was found again with the same type of growth habit. Brachiopods were more abundant as a number of the micro-brachiopod, Platidia clepsydra Cooper, 1973, were present in several stations, especially 2106, 2212, and 2645.

The station data sheets all have the amount of sediment in the sample. This was measured after being sieved through a 250 μ screen and later oven dried. When most of the material is very fine, the result is a small sample, when the material is coarse, there is a large sample. The smallest amount retained by the screen was two milliliters at station 2637. The largest sample was 159 ml at station 2318. At this station, a very rare small clam, Crassinella dupliniana, became dominant. It was not common at any other locality.

Of the other bivalves, Parvilucina multilineata was the most abundant. It was the dominant micromollusc at five stations, and was present at 26. Of the 1747 specimens, 1732 were found at 2101 through 2423 (except zero at the four deepest stations). Only 15 specimens were found from 2424 through 2645.

Gouldia cerina was the second most abundant bivalve with a total of 1218 specimens from 35 localities. This clam ranked third in 1974, somewhat behind Crassinella lunulata. G. cerina was the dominant micromollusc at only one locality, but was a common species at a large number of stations.

Vesicomya pilula was third in rank due to large numbers at the deep water stations 2212, 2313, 2427, 2535, and 2536. This species was dominant at five stations, and had a total of 1155 from 14 localities. It was noticed in 1974 that V. pilula, usually a rather deep dwelling species, was in comparatively shallow water off the Mississippi-Alabama coast. This was also true of the 1975 collections. It is thought that light may be the important factor in this distribution, as the visibility of bottom water is much lower than to the southeast.

Crassinella lunulata ranked fourth in abundance with 972 specimens from 39 stations. There may be a problem, however, as the deeper water specimens are a little different from those of shallow water stations. If, however, it is all one species, then C. lunulata was found at 39 stations, more than any other bivalve. This is also one of the best protected of the small clams since the shell becomes fairly thick at a very early age.

Varicorbula operculata ranked fifth with a total of 681 specimens. This is a shallow water species not found at the deepest stations, and is rare at depths of more than 50 m. Optimum depth range is about 18 to 36 m. The vast majority of specimens came from stations 2207-2210 and from 2421-2424.

Chione grus was at 27 stations, but usually in small numbers. However, there were 131 at station 2422 and 184 at 2423. There was a total of 134 specimens at the other 25 stations The species was virtually absent from the deepest stations.

Nuculana concentrica was concentrated in the turbid area off Mississippi-Alabama. There were 192 specimens from seven stations (2637-2643). There was no overlap with Nuculana acuta, the other shallow water member of the genus. This had been noticed in the 1974 material, but the names were transposed in the 1974 final report. N. acuta was found at 15 stations from 2101 to 2536. While present in shallow water, it seemed to prefer the deeper stations.

Several bivalves, Bathyarca sp., Nucula crenulata, Nuculana aspecta, and N. carpenteri, were found only at the deep water stations. Bathyarca was eighth in abundance for bivalves with 186 specimens at five localities. Its most shallow station was 2106 at 161.5 m. The other three species were not numerous.

One of the most unusual distributions was that of Crassinella dupliniana. There were 113 specimens taken, but 104 of these were found at one locality, station 2318. This was also the station with the largest amount of material (159 ml) retained by the sieve. C. dupliniana apparently prefers a coarse sand with little fine material. In this, it occupies a habitat similar to the shallow water clam, Cuna dalli.

The most restricted distribution was that of Pythinella cuneata. Forty-five specimens were found at one locality, 2639. It was present at stations five through ten in 1974. Station 2639 is the same as station nine. None of the other five stations were sampled in 1975, hence 2639 was the only 1975 station in the area where P. cuneata was found previously.

Dimya tigrina Bayer, 1971, was identified too late to be involved on the data sheets. It is different in that it is the only small bivalve from the collections that is cemented to the substrate like an oyster. Previously, it has been known from only one locality off the coast of Columbia, some 2600 km to the southeast. In MAFLA material, it was at 2644 and 2645.

The gastropods were slightly more numerous than the bivalves (9111 to 8967). As in 1974, the herbivores were far more numerous than carnivores, and predominated in areas where the water was clear. Transect 2637-2645 had few gastropods.

Finella dubia was the most abundant gastropod with 2332 specimens. It ranked fourth in 1974, but broken specimens were also counted in 1975. F. dubia is apparently subject to heavy predation by small crustaceans, and is eaten after the shell is crushed. More than half of the specimens counted were broken. F. dubia was found at all except deep stations over 107 m, and the two Mississippi stations (2637 and 2638).

Caecum pulchellum ranked next with 2265 specimens. This needs further study as there may be more than one species involved. Distribution was similar to that of Finella dubia, but, strangely, there were none at stations 2318, 2419, and 2420. This area was not sampled in 1974, so we have no comparative material.

Meioceras cubitatum (listed as Caecum cubitatum in 1974) ranked third in abundance with 1324 specimens. It was almost always found with Caecum pulchellum although the ratio varied considerably. There is no species problem as the other two Gulf Meioceras are distinct, and are rarely found in the offshore area with M. cubitatum.

Caecum bipartitum ranks fourth in abundance with 634 specimens. This is a shallow water species almost entirely confined to the area south and east of Cape San Blas. Some specimens were quite distinct, but others were very difficult to separate from C. pulchellum. In general, the two species were found together, but one would be scarce where the other was abundant, and vice versa. C. bipartitum appears to be a good species living in warm calcium carbonate environments in the Gulf of Mexico.

The fifth most abundant species was the small rissoid, Alvania auberiana, with 514 specimens. This is the same rank that it had in 1974. Its look-alike, termed A. cf. auberiana, was once again present in small numbers, and, as in 1974, only in depths of 66 m or more. A. auberiana, however, was common in a depth range of 18.3 to 50.3 m. Only one specimen was found in depths over 107.3 m. And, like the other gastropods discussed so far, it was rather rare in transect 2637-2645.

Caecum imbricatum is another small browsing snail. There were 313 specimens at 33 stations. It too prefers the shallow shelf, and is not found at the deepest stations.

Natica pusilla is next in rank with a total of 253 specimens at 27 stations. It is the most abundant small carnivore of the shallow shelf, and its deepest occurrence is 68 m. Its range of habitats is enormous since all it needs is sand and a supply of bivalves to feed on. It was most abundant in the area between St. Petersburg and Cape San Blas. On the other hand, it was the only identified gastropod found at station 2637.

Other fairly common species include Cyclostremiscus cubanus, a browser living in the same general area as Caecum pulchellum, but much more rare off Mississippi-Alabama. A small Skenea, about 0.9 mm, and apparently undescribed, is also a browser. Its distribution is very similar to that of Cyclostremiscus cubanus. Acteocina candei and Volvulella persimilis are burrowing carnivores that presumably feed on Foraminifera. They are both shallow water species with a wide range in the study area. We apparently only touched the upper part of the range of a similar species, Cylichna verrilli, for only two specimens were collected at very deep water stations. A small deep water browser, Alvania precipitata, was found only at the deeper stations of 68 m or more.

The two microscaphopods found in 1974, Cadulus iota and C. mayori, were found again in the same general area off northwest Florida-Alabama. C. iota was taken at eleven stations, C. mayori at only two.

SUMMARY

Live collected micromolluscs were not abundant in the subsamples due to the small surface area of the cores. Enough material was collected, however, to make some basic assumptions.

1. Small molluscs are relatively abundant in shallow water (<50 m) in the northeastern Gulf of Mexico (about 700/m^2).

2. Small molluscs are uncommon on the deeper shelf (50 to 186 m) in this area (about 125/m^2).
3. The continental shelf from Cape San Blas, Florida, to the Chandeleur Islands is an area of low productivity for molluscs.
4. Live bivalves are more abundant than live gastropods.
5. Browsing gastropods are rare in depths of more than 50 m.
6. Browsing gastropods are extremely rare in areas with much fine sediment.
7. Two most important factors influencing abundance and distribution of small molluscs are sediment type and depth of water.

Two species, Parvilucina multilineata and Varicorbula operculata, small clams, were present as considerable numbers of very young specimens in the January-February cruise samples. It is believed that winter spawning may be a mechanism to avoid heavy predation on the young. At any rate, these are two very successful bivalves, and rank first and fifth in the dead fauna for bivalves. They were 44% of the live fauna.

As in 1974, it was noted that there were abundant signs of predation. Many small molluscs never reach maturity, and are either crushed or drilled or swallowed whole while still quite young. The burrowing bivalves seem to be attacked mainly by burrowing gastropods, but molluscs which remain out in the open, such as Finella dubia, a small gastropod, are usually crushed and broken, and were probably preyed upon by small crustacea.

The dead fauna was examined from samples taken during the first cruise. There were 18,115 identified specimens. About 6000 more, some of them doubtfully molluscs, were not identified. Gastropods and bivalves were almost equal in numbers, mostly filter feeding bivalves and browsing gastropods. As in the 1974 samples, gastropods were somewhat more numerous in the area south and east of Cape San Blas, while bivalves were the more numerous off the Mississippi-Alabama coast.

The 1974 stations only went to a depth of 85 m. The 1975 stations included eight with depths greater than this, the deepest being 186.5 m. This brought in some depth controlled species not encountered in 1974, and radically changed the rank of the small clam, *Vesicomya pilula*. It was found only at the deeper stations in depths more than 66 m except off the Mississippi-Alabama coast at 2639 in 32 m. Several species, such as *Nuculana aspecta*, *Bathyarca* sp., and *Cylichna verrilli*, are strictly shelf edge and deeper species.

The 1975 samples confirm the observations made in 1974. Browsing gastropods and filter feeding bivalves compete in nearly equal numbers off the west coast of Florida. The west Florida shelf appears to be a zone of lower productivity, while the area between the Chandeleurs and the Mississippi barrier islands supports mainly bivalves, but few gastropods. The reason for this is that turbid waters make benthic browsing nearly impossible.

REFERENCES

Fretter, V., 1956, The anatomy of the prosbranch *Circulus striatus* (Philippi) and a review of its systematic position, Porc. Zool. Soc. Lond., 126 (3):369-381.

Moore, D. R., 1975, The micromollusca of the MAFLA project. Report to the Bureau of Land Management, January, 1975:1-32, 2 figs.

Wells, H. W., M. J. Wells, and I. E. Gray, 1961, Food of the sea star *Astropecten articulatus*. Biol. Bull., 120:265-271.

Micromollusc

Species List

MAFLA--1975-76

1. Nucula proxima Say, 1822
2. Nucula crenulata A. Adams, 1856
3. Nuculana acuta (Conrad, 1831)
4. Nuculana concentrica (Say, 1824)
5. Nuculana aspecta (Dall, 1927)
6. Nuculana carpenteri (Dall, 1881)
7. Solemya occidentalis Deshayes, 1857
8. Limopsis sulcata Verrill and Bush, 1898
9. Glycymeris pectinata (Gmelin, 1791)
10. Cratis antillensis (Dall, 1881)
11. Arcopsis adamsi (Dall, 1886)
12. Bathyarca sp.
13. Crenella divaricata (d'Orbigny, 1845)
14. Dacrydium vitreum (Hölboll, 1842)
15. Musculus lateralis (Say, 1822)
16. Cyclopecten nanus Verrill and Bush, 1897
17. Cyclopecten simplex Verrill, 1897
18. Dimya tigrina Bayer, 1971
19. Limea bronniana Dall, 1886
20. Crassinella lunulata (Conrad, 1834)
21. Crassinella dupliniana (Dall, 1903)
22. Glans dominguensis (d'Orbigny, 1845
23. Pleuromeris armilla (Dall 1902)
24. Carditopsis smithi (Dall, 1896)

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25. Astarte nana Dall, 1886
26. Pteromeris perplana (Conrad, 1841)
27. Cuna dalli Vanatta, 1904
28. Pythinella cuneata (Verrill and Bush, 1898)
29. Vesicomya pilula (Dall, 1881)
30. Montacuta triquetra Verrill and Bush, 1898
31. Lucina nassula (Conrad, 1846)
32. Linga amiantus (Dall, 1901)
33. Parvilucina multilineata (Tuomey and Holmes, 1857)
34. Parvilucina blanda (Dall and Simpson, 1901)
35. Divaricella quadrisulcata (d'Obrigny,1842)
36. Thyasira trisinuata d'Orbigny, 1842
37. Diplodonta sp.
38. Nemocardium peramabile (Dall, 1881)
39. Laevicardium mortoni (Conrad 1830)
40. Ervilia concentrica (Holmes, 1860)
41. Tellina versicolor DeKay, 1843
42. Tellina sp.
43. Abra aequalis (Say, 1822)
44. Abra lioica (Dall, 1881)
45. Semele bellastriata (Conrad, 1837)
46. Semele nuculoides (Conrad, 1841)
47. Semele purpurascens (Gmelin, 1791)
48. Gouldia cerina (C.B. Adams, 1845
49. Chione grus (Holmes, 1858)
50. Pitar morrhuanus (Linsley, 1848)
51. Pitar simpsoni (Dall, 1895)

MAFLA--1975-76, Species List, page 3

52. Dosinia discus (Reeve, 1850)
53. Cyclinella tenuis (Recluz, 1852)
54. Parastarte triquetra (Conrad, 1846)
55. Hiatella arctica (Linne, 1767)
56. Corbula swiftiana C.B. Adams, 1852
57. Varicorbula operculata (Philippi, 1848)
58. Bushia elegans (Dall, 1886)
59. Verticordia ornata (d'Orbigny, 1842)
60. Verticordia fischeriana Dall, 1881
61. Cardiomya ornatissima (D'Orbigny, 1842)
62. Cardiomya perrostrata (Dall, 1881)
63. Myonera lamellifera (Dall, 1881)
64. Scissurella proxima Dall, 1927
65. Diodora sp.
66. Arene tricarinata (Stearns, 1872)
67. Skenea sp.
68. Didianema pauli Pilsbry and McGinty, 1945
69. Tricolia thalassicola Robertson, 1958
70. Alvania auberiana (d'Orbigny, 1842)
71. Alvania cf. auberiana
72. Alvania precipitata (Dall, 1889)
73. Zebina browniana (d'Orbigny, 1842)
74. Parviturboides interruptus (C.B. Adams, 1850)
75. Solariorbis shimeri (Clapp, 1914)
76. Anticlimax pilsbryi (McGinty, 1945)
77. Cyclostremiscus cubanus (Pilsbry and Aguayo, 1933)
78. Cyclostremiscus jeannae (Pilsbry and McGinty, 1945)

MAFLA--1975-76, Species List, page 4

79. Teinostoma incertum Pilsbry and McGinty, 1945

80. Teinostoma parvicallum Pilsbry and McGinty, 1945

81. Macromphalina palmalitoris Pilsbry and McGinty, 1950

82. Aorotrema pontogenes Schwengel and McGinty, 1942

83. Caecum pulchellum Stimpson, 1851

84. Caecum bipartitum Folin, 1870

85. Caecum imbricatum Carpenter, 1858

86. Caecum floridanum Stimpson, 1851

87. Caecum plicatum Carpenter, 1858

88. Caecum clava Folin, 1867

89. Caecum ryssotitum Folin, 1867

90. Caecum heladum Olsson and Harbinson, 1953

91. Brochina sp.

92. Meioceras cubitatum Folin, 1868

93. Meioceras nitidum (Stimpson, 1851)

94. Meioceras cornucopiae Carpenter, 1858

95. Finella dubia (d'Orbigny, 1842)

96. Diastoma varium Pfeiffer, 1840

97. Cerithiopsis crystallinum Dall, 1881

98. Seila adamsi (H.C. Lea, 1845)

99. Aclis sp.

100. Calyptraea centralis (Conrad, 1841)

101. Eulima sp.

102. Strombiformis bilineatus Alder, 1848

103. Natica pusilla Say, 1822

104. Olivella pusilla (Marrat, 1871)

105. Marginella sp.

106. Marginella lavalleeana d'Orbigny, 1842
107. Granulina ovuliformis (d'Orbigny, 1841)
108. Terebra protexta (Conrad, 1845)
109. Odostomia didyma Verrill and Bush, 1900
110. Turbonilla sp.
111. Odostomia dianthophila Wells and Wells, 1961
112. Odostomia sp.
113. Cyclostremella humilis Bush, 1897
114. Acteon punctostiratus (C.B. Adams, 1840)
115. Ringicula semistriata d'Orbigny, 1842
116. Acteocina candei (d'Orbigny, 1842)
117. Acteocina canaliculata (Say, 1822)
118. Cylichna verrilli Dall, 1889
119. Pyrunculus caelatus (Bush, 1885)
120. Retusa sulcata (d'Orbigny, 1842)
121. Volvulella persimilis (Morch, 1875)
122. Cadulus iota Henderson, 1920
123. Cadulus mayori Henderson, 1920
124. Chaetopleura apiculata (Say, 1830)

LIVE/DEAD RATIO, "K Samples"

STATION	SPECIES	I	II	III
2101	Calyptrea centralis	1/1	-	-
2102	Tellina versicolor	-	1/4	-
2103	Crassinella lunulata	1/111	-	-
	Parvilucina multilineata	-	1/76	1/76
	Varicorbula operculata	-	-	1/9
	Finella dubia	-	-	1/238
2104	-	-	-	-
2105	-	-	-	-
2106	-	-	-	-
2207	Varicorbula operculata	-	-	1/34
	Caecum imbricatum	-	1/38	-
2208	Parvilucina multilineata	-	2/235	-
	Caecum bipartitum	-	2/169	-
2209	Parvilucina multilineata	1/403	-	2/403
	Caecum bipartitum	1/18	-	-
	Finella dubia	1/134	-	-
2210	Parvilucina multilineata	-	-	1/104
	Varicorbula operculata	-	-	17/60
	Caecum bipartitum	-	-	1/90
	Meioceras cubitatum	-	-	2/155
2211	-	-	-	-
2212	-	-	-	-
2313	-	-	-	-
2314	Parvilucina multilineata	-	-	1/1
	Tellina versicolor	-	-	1/1
2315	Parvilucina multilineata	-	3/682	-
2316	Parvilucina multilineata	-	1/26	-
	Meioceras cubitatum	-	1/34	-
	Finella dubia	-	1/142	-
	Volvulella persimilis	-	1/8	-

STATION	SPECIES	I	II	III
2317	Crassinella lunulata	-	1/20	-
	Parvilucina multilineata	5/84	-	1/12
	Tellina versicolor	-	-	1/12
	Varicorbula operculata	1/4	-	1/54
	Acteocina candei	-	-	1/4
2318	Parvilucina multilineata	-	-	1/7
	Caecum imbricatum	-	2/25	-
	Meioceras cubitatum	-	-	1/1
	Brochina antillarum	-	1/3	-
2419	Tellina versicolor	-	-	1/6
	Diplodonta sp.	-	-	1/2
2420	-	-	-	-
2421	Crenella divaricata	-	-	1/2
	Crassinella lunulata	-	1/4	-
	Tellina versicolor	-	-	1/4
	Varicorbula operculata	-	-	1/63
	Caecum bipartitum	-	-	2/57
	Caecum imbricatum	-	1/8	1/8
2422	Crassinella lunulata	1/13	-	-
	Varicorbula operculata	1/87	-	-
2423	Cyclostremiscus cubanus	1/7	-	-
2424	Tellina versicolor	-	-	1/6
	Caecum bipartitum	1/6	-	-
2425	Crassinella lunulata	-	1/12	-
2426	Nuculana acuta	-	1/22	-
	Pyrunculus caelatus	-	1/2	-
2427	-	-	-	-
2528	-	-	-	-
2529	Brochina sp.	4/3	-	-
2530	Brochina sp.	-	-	1/1
2531	-	-	-	-
2532	-	-	-	-
2533	-	-	-	-
2534	-	-	-	-
2535	-	-	-	-
2536	-	-	-	-

STATION	SPECIES	I	II	III
2637	-	-	-	-
2638	Nucula proxima	-	-	1/8
	Nuculana concentrica	-	-	2/39
2639	-	-	-	-
2640	Tellina versicolor	-	1/12	-
2641	-	-	-	-
2642	-	-	-	-
2643	Nuculana concentrica	1/9	-	-
2644	-	-	-	-
2645	-	-	-	-

LIVE/DEAD RATIO, "A Samples"

STATION	SPECIES	I	II	III
2101	Tellina versicolor	1/9	-	-
	Semele bellastriata	1/0	-	-
	Solemya occidentalis	-	1/0	-
	Acteocina candei	-	-	1/2
	Chitons	-	2/0	-
2102	Tellina versicolor	-	1/4	-
2103	Parvilucina multilineata	-	1/76	1/38
	Tellina vèrsicolor	-	1/28	-
	Acteocina candei	-	1/4	-
	Abra aequalis	1/5	-	-
2104	Semele bellastriata	-	1/0	-
2105	-	-	-	-
2106	Parvilucina blanda	-	1/0	-
	Myonera lamellifera	1/0	-	-
	Scissurella proxima	-	1/0	-
2207	Solemya occidentalis	1/0	-	-
	Tellina versicolor	-	-	1/6
2208	Lucina nassula	1/8	-	-
	Parvilucina multilineata	-	-	1/235
	Caecum bipartitum	-	-	2/169
	Glottidea pyramidata (brachiopod)	-	1/0	-
2209	Nucula proxima	-	-	1/0
	Parvilucina multilineata	-	1/403	-
	Acteocina candei	-	-	1/6
2210	Crassinella lunulata	-	1/43	-
	Parvilucina multilineata	-	1/104	1/208
	Varicorbula operculata	-	-	1/15
	Caecum bipartitum	-	-	1/90
	Meioeras cubitatum	-	-	1/155
	Finella dubia	-	1/210	-
	Retusa sulcata	-	1/6	-
	immature Turridae	-	1/0	0
	Aclis sp.	-	-	1/0
2211	immature pectinid	1/0	-	-
	Pleuromeris armilla	-	-	1/0

STATION	SPECIES	I	II	III
2212	-	-	-	-
2313	Nucula crenulata	-	-	2/1
2314	Parvilucina multilineata	-	-	2/1
	Natica pusilla	-	-	1/0
2315	Tellina versicolor	-	1/9	-
	Marginella sp.	-	-	1/2
2316	Lucina nassula	1/0	-	-
	Parvilucina multilineata	3/26	-	-
	Tellina versicolor	1/4	-	-
	Varicorbula operculata	1/8	-	1/8
2317	Parvilucina multilineata	1/21	1/7	-
	Strombiformis bilineatus	-	1/0	-
2318	Meioceras cubitatum	-	1/1	-
	Turbonilla sp.	-	1/0	-
	venerid clam	-	1/0	-
2419	very small clam	1/-	-	-
2420	Abra sp.	-	-	1/-
2421	Parvilucina multilineata	2/19	-	-
	Varicorbula operculata			32/63
	Caecum bipartitum	2/57	-	-
	clam	-	-	1/-
	Marginella lavalleeana	-	1/0	-
2422	Nucula proxima	1/14	-	-
	clam	-	-	1/-
	Macromphalina palmalitoris	-	1/0	-
2423	Nucula proxima	1/18	-	-
2424	Bushia elegans	-	-	1/0
	Solemya occidentalis	-	1/0	-
	Semele bellastriata	-	-	1/0
2425	-	-	-	-
2426	Cadulus iota	-	-	2/13
	Nuculana aspecta	1/10	1/20	-
	Cylichna verrilli	1/10	-	-

STATION	SPECIES	I	II	III
2427	-	-	-	-
2528	Crassinella lunulata	1/9	-	-
2529	Varicorbula operculata	-	-	1/9
2530	Varicorbula operculata	-	-	1/0
2531	Varicorbula operculata	-	-	1/1
	Brochina antillarum	-	-	1/1
	Semele purpurascens	-	-	1/0
2532	-	-	-	-
2533	-	-	-	-
2534	Pitar morrhuanus	1/0	-	-
2535	-	-	-	-
2536	-	-	-	-
2637	-	-	-	-
2638	-	-	-	-
2639	Nuculana concentrica	1/112	-	-
2640	Brochina antillarum	-	-	1/0
2641	Tellina versicolor	-	-	1/10
2642	-	-	-	-
2643	Tellina versicolor	-	1/2	-
2644	-	-	-	-
2645	-	-	-	-

11-03-76

DEAD FAUNA
MAFLA
MICROMOLLUSCS

SUBSTRATE
(desc. based on major constituents as reported by Wanless)

Station #	(m) depth	(ml) Sample Size	(ident'd) total # specimens	(specimens/ml) density	(# of spp) diversity	(% remaining in pareth.) #dominant spp	Substrate Grain Size	Substrate Compos.
2101	11	55	135	2.45	23	6(24.7)	f	qtz,$CaCO_3$
2102	17.4	77	111	1.44	26	4(48.7)	f	$CaCO_3$,qtz
2103	36.6	126	1522	12.07	38	6(45.4)	m	qtz,$CaCO_3$
2104	53.3	97	1115	11.49	33	6(20.5)	m	$CaCO_3$
2105	89.6	103	144	1.39	27	5(39.8)	c	$CaCO_3$
2106	161.5	65	120	1.84	24	8(29.3)	f	$CaCO_3$
2207	18.3	33	555	16.81	36	5(28.5)	f	qtz,$CaCO_3$
2208	34.1	19	919	48.36	30	6(17.1)	slt	$CaCO_3$
2209	29.3	36	1025	28.47	28	5(18.1)	slt	$CaCO_3$
2210	36.6	54	972	18.00	27	6(19.2)	no data	
2211	42.1	130	905	6.96	34	6(20.9)	csd	$CaCO_3$
2212	186.5	39	375	9.61	20	3(24.4)	slt	$CaCO_3$
2313	164.6	42	388	9.23	19	3(25.6)	slt	$CaCO_3$
2314	42.7	04	16	4.00	12	12(0%)	no data	
2315	36.6	43	2698 1349x2	62.74	32	4(21.5)	no data	
2316	37.2	84	616	7.33	28	5(31.8)	fsd	Qtz,$CaCO_3$
2317	29.3 27.4	75	1224 306x4	16.32	27	5(26.8)	vfsd	$CaCO_3$
2318	18.9	159	304	1.91	28	4(33.2)	msd	$CaCO_3$,qtz

Station #	depth	Sample Size	specimens	density	diversity	#dominant spp	Grain Size	Compos.
2419	9.8	93	124	1.33	17	3(36.3)	fsd	$CaCO_3$,qtz
2420	14.6	83	64	0.77	17	5(46.7)	f to msd	Qtz,$CaCO_3$
2421	19.2	36	244	6.77	24	4(26.2)	vf to fsd	Qtz,$CaCO_3$
2422	24.1	99	922	9.31	34	6(26.8)	msd	Qtz,$CaCO_3$
2423	29.6	122	1565	12.82	48	5(37.4)	c-vcsd	Qtz,$CaCO_3$
2424	28.3	119	252 126x2	2.11	20	4(29.3)	msd	$CaCO_3$,qtz
2425	36.6	98	172 86x2	1.75	26	7(39.5)	m-csd	$CaCO_3$,qtz
2426	86.3	101	288 144x2	2.85	21	9(16.1)	msd	Qtz,$CaCO_3$
2427	172.2	21	291	13.85	15	2(14.2)	slt	$CaCO_3$
2528	37.2	23	612 153x4	4.97	23	6(20.6)	c-vscd	Qtz, $CaCO_3$
2529	37.5	88	286	3.25	30	5(33.8)	vcsd	$CaCO_3$
2530	40.2	91	166	1.82	22	5(27.3)	csd	qtz,$CaCO_3$
2531	44.5	98	269	2.74	23	4(19.1)	c-vcsd	$CaCO_3$
2532	50.3	117	1116 558x2	9.53	37	5(31.4)	msd	qtz,$CaCO_3$
2533	66.4	110	326 163x2	2.96	26	5(24.8)	csd	$CaCO_3$
2534	72.5	81	145	1.79	27	5(40.3)	vcsd	$CaCO_3$
2535	115.8	13	260	20.0	21	2(18.6)	slt	$CaCO_3$
2536	180.4	11	346	31.45	11	1(12.5)	slt	$CaCO_3$
2637	21.3	2	41	20.5	9	3(19.7)	slt	$CaCO_3$,qtz
2638	25.6	5	53	10.6	6	3(5.7)	slt	Qtz,$CaCO_3$

Station #	depth	Sample Size	specimens	density	diversity	#dominant spp	Grain Size	Compos.
2639	32.0	47	834 417x2	17.74	25	6(25.6)	vf fsd	$CaCO_3$,qtz
2640	35.7	119	130	1.09	22	7(18.1)	msd	$CaCO_3$,qtz
2641	35.1	95	62	0.65	19	7(29.4)	fsd	$CaCO_3$,qtz
2642	36.0	133	41	0.30	15	5(29.6)	fsd	$CaCO_3$,qtz
2643	68.0	92	202	2.19	36	5(39.9)	m-csd	Qtz,$CaCO_3$
2644	70.7	99	147	1.48	23	6(31.5)	csd	$CaCO_3$
2645	107.3	104	233	2.24	31	8(33.9)	vcsd	$CaCO_3$

slt-4-64
vfsd-64-125
fsd-125-250
msd-250-500
csd-500-1000
vcsd -/mm-2mm

DOMINANT SPECIES OF MICROMOLLUSCS, DEAD FAUNA

Sample #	Species	% of sample
2101	Caecum bipartitum	5.9
	Finella dubia	5.9
	Natica pusilla	5.9
	Ervillia concentrica	6.6
	Tellina versicolor	6.6
	Parvilucina multilineata	44.4
	other identified	24.7
2102	Ervilia concentrica	5.4
	Natica pusilla	10.8
	Parvilucina multilineata	13.5
	Finella dubia	21.6
	other identified	48.7
2103	Parvilucina multilineata	4.9
	Crassinella lunulata	7.2
	Caecum pulchellum	7.4
	Meioceras cubitatum	9.2
	Gouldia cerina	10.3
	Finella dubia	15.6
	other identified	45.4
2104	Gouldia cerina	7.2
	Alvania auberiana	7.4
	Crassinella lunulata	10.4
	Finella dubia	14.8
	Meioceras cubitatum	18.1
	Caecum pulchellum	21.6
	other identified	20.5
2105	Arcopsis adamsi	6.9
	Alvania precipitata	10.4
	Nuculana aspecta	11.1
	Caecum pulchellum	13.1
	Crassinella lunulata	18.7
	other identified	39.8
2106	Cyclopecten simplex	5.0
	Vesicomya pilula	5.0
	Abra lioica	5.8
	Astarte nana	7.5
	Crassinella lunulata	7.5
	Dacrydium vitreum	7.5
	Montacuta triquetra	8.3
	Bathyarca sp.	24.1
	other identified	29.3
2207	Varicorbula operculata	6.1
	Caecum imbricatum	6.8
	Caecum pulchellum	9.5
	Finella dubia	20.9
	Parvilucina multilineata	28.2
	other identified	28.5

Sample #	Species	% of sample
2208	Meioceras cubitatum	5.0
	Gouldia cerina	7.7
	Finella dubia	12.0
	Varicorbula operculata	14.4
	Caecum bipartitum	18.3
	Parvilucina multineata	25.5
	other identified	17.1
2209	Varicorbula operculata	8.6
	Caecum bipartitum	10.5
	Meioceras cubitatum	10.5
	Finella dubia	13.0
	Parvilucina multilineata	39.3
	other identified	18.1
2210	Varicorbula operculata	6.1
	Gouldia cerina	6.7
	Caecum bipartitum	9.2
	Meioceras cubitatum	15.9
	Parvilucina multilineata	21.3
	Finella dubia	21.6
	other identified	19.2
2211	Cyclostremiscus cubanus	5.1
	Finella dubia	5.3
	Alvania auberiana	6.4
	Crassinella lunulata	6.7
	Gouldia cerina	10.7
	Caecum pulchellum	44.9
	other identified	20.9
2212	Limopsis sulcata	14.6
	Bathyarca sp	20.2
	Vesicomya pilula	40.8
	other identified	24.4
2313	Cerithiopsis crystallinum	5.4
	Bathyarca sp.	14.4
	Vesicomya pilula	54.6
	other identified	25.6
2314	Crenella divaricata	6.3
	Crassinella lunulata	6.3
	Parvilucina multilineata	6.3
	Verticordia ornata	6.3
	Caecum pulchellum	6.3
	Finella dubia	6.3
	Zebina browniana	6.3
	Semele nuculoides	6.3
	Abra aequalis	6.3
	Tellina versicolor	12.5
	Caecum imbricatum	12.5
	Bittium varium	18.8
	other identified	0.0

Sample #	Species	% of sample
2315	Caecum bipartitum	5.4
	Meioceras cubitatum	19.9
	Parvilucina multilineata	25.3
	Finella dubia	27.9
	other identified	21.5
2316	Crassinella lunulata	5.2
	Gouldia cerina	7.1
	Meioceras cubitatum	11.0
	Caecum pulchellum	21.8
	Finella dubia	23.1
	other identified	31.8
2317	Parvilucina multilineata	6.9
	Gouldia cerina	8.2
	Meioceras cubita tum	18.6
	Caecum pulchellum	19.6
	Finella dubia	19.9
	other identified	26.8
2318	Caecum imbricatum	8.2
	Finella dubia	10.9
	Ervilia concentrica	13.5
	Crassinella dupliniana	34.2
	other identified	33.2
2419	Finella dubia	12.1
	Parvilucina multilineata	12.9
	Ervilia concentrica	38.7
	other identified	36.3
2420	Tellina versicolor	6.3
	Caecum bipartitum	6.3
	Finella dubia	6.3
	Ervillia concentrica	14.1
	Parvilucina multilineata	20.3
	other identified	46.7
2421	Parvilucina multilineata	7.8
	Finella dubia	16.8
	Caecum bipartitum	23.4
	Varicorbula operculata	25.8
	other identified	26.2
2422	Alvania auberiana	6.4
	Varicorbula operculata	9.0
	Gouldia cerina	9.1
	Finella dubia	12.6
	Chione grus	13.6
	Caecum pulchellum	22.5
	other identified	26.8

Sample #	Species	% of sample
2423	Gouldia cerina	5.1
	Alvania auberiana	9.4
	Chione grus	11.8
	Caecum pulchellum	16.7
	Finella dubia	19.6
	other identified	37.4
2424	Gouldia cerina	5.6
	Finella dubia	15.9
	Varicorbula operculata	21.4
	Meioceras cubitatum	27.8
	other identified	29.3
2425	Pteromeris perplana	5.8
	Crassinella lunulata	7.0
	Gouldia cerina	7.0
	Finella dubia	7.0
	Caecum imbricatum	10.5
	Caecum pulchellum	11.6
	Meioceras cubitatum	11.6
	other identified	39.5
	Montacuta triquetra	5.6
2426	Nuculana acuta	7.6
	Meioceras cubitatum	8.3
	Cadulus iota	9.0
	Limopsis sulcata	9.7
	Vesicoyma pilula	9.7
	Caecum pulchellum	9.7
	Crassinella lunulata	10.4
	Nuculana aspecta	13.9
	other identified	16.1
2427	Bathyarca sp.	6.8
	Vesicomya pilula	79.0
	otheridentified	14.2
2528	Gouldia cerina	5.2
	Chione grus	5.8
	Glans dominguensis	8.5
	Crassinella lunulata	11.7
	Finella dubia	14.3
	Caecum pulchellum	33.9
	other identified	20.6
2529	Caecum floridanum	5.2
	Finella dubia	5.2
	Gouldia cerina	6.2
	Crassinella lunulata	18.5
	Caecum pulchellum	31.1
	other identified	33.8

Sample #	Species	% of sample
2530	Caecum imbricatum	5.4
	Gouldia cerina	6.0
	Alvania auberiana	6.6
	Finella dubia	6.6
	Caecum pulchellum	48.1
	other identified	27.3
2531	Finella dubia	5.2
	Gouldia cerina	8.9
	Crassinella lunulata	10.0
	Caecum pulchellum	56.8
	other identified	19.1
2532	Alvania auberiana	6.6
	Meioceras cubitatum	8.0
	Gouldia cerina	12.0
	Limea bronniana	15.9
	Caecum pulchellum	26.1
	other identified	31.4
2533	Meioceras cubitatum	6.7
	Arcopsis adamsi	6.7
	Cyclostremiscus cubanus	7.3
	Crassinella lunulata	9.8
	Caecum pulchellum	44.7
	other identified	24.8
2534	Arcopsis adamsi	8.2
	Gouldia cerina	8.9
	Cratis antillensis	10.3
	Caecum pulchellum	14.4
	Crassinella lunulata	17.9
	other identified	40.3
2535	Nuculana acuta	23.4
	Vesicomya pilula	58.0
	other identified	18.6
2536	Vesicomya pilula	87.5
	other identified	12.5
2637	Natica pusilla	14.6
	Linga amiantus	17.0
	Nuculana concentrica	48.7
	other identified	19.7
2638	Linga amiantus	5.8
	Nucula proxima	15.0
	Nuculana concentrica	73.5
	other identified	5.7

Sample #	Species	% of sample
2639	Crassinella lunulata	6.0
	Nucula proxima	8.4
	Corbula swiftiana	9.6
	Pythinella cuneata	10.8
	Gouldia cerina	12.7
	Nuculana concentrica	26.9
	other identified	25.6
2640	Meioceras cubitatum	6.1
	Caecum pulchellum	7.6
	Caecum imbricatum	7.6
	Tellina versicolor	9.2
	Finella dubia	10.7
	Natica pusilla	10.7
	Gouldia cerina	20.0
	other identified	18.1
2641	Gouldia cerina	6.4
	Natica pusilla	6.4
	Nuculana concentrica	9.6
	Varicorbula operculata	9.6
	Caecum imbricatum	9.6
	Finella dubia	12.9
	Tellina versicolor	16.1
	other identified	29.4
2642	Gouldia cerina	7.3
	Meioceras cubitatum	9.7
	Natica pusilla	12.1
	Ervilia concentrica	12.1
	Tellina versicolor	29.2
	other identified	29.6
2643	Finella dubia	5.4
	Caecum pulchellum	6.4
	Crassinella lunulata	11.3
	Gouldia cerina	12.8
	Vesicomya pilula	24.2
	other identified	39.9
2644	Vesicomya pilula	6.1
	Arcopsis adamsi	6.8
	Gouldia cerina	6.8
	Finella dubia	6.8
	Crassinella lunulata	14.2
	Caecum pulchellum	27.8
	other identified	31.5

Sample #	Species	% of sample
2645	Cratis antillensis	5.1
	Vesicomya pilula	6.0
	Arcopsis adamsi	6.4
	Caecum plicatum	6.4
	Caecum pulchellum	6.8
	Alvania precipitata	7.2
	Gouldia cerina	10.7
	Crassinella lunulata	17.5
	other identified	33.9

DEAD FAUNA
MAFLA MICROMOLLUSCS
Species Distribution (geographically & bathymetrically)

Spp.	Localities		Depth	
1) Nucula proxima	2101r	2424r	11	28.3
	2102r	2426r	17.4	86.3
	2103c	2528r	36.6	115.8
	2210r	2535r	36.6	115.8
	2315r	2637c	36.6	21.3
	2317r	2638a	29.3	25.6
	2318r	2639a	18.9	32.0
	2420r	2640r	14.6	35.7
	2422r	2641r	24.1	35.1
	2423c	2542r	29.5	36
2) Nuculana acuta	2101r	2529r	11	37.5
	2104r	2532r	53.3	50.3
	2207r	2533r	18.3	66.4
	2212r	2535d	186.5	115.8
	2313c	2536r	164.6	180.4
	2421r		19.2	
	2423r		29.6	
	2423r		29.6	
	2424r		28.3	
	2426r		86.3	
	2427r		172.2	
3) Nuculana concentrica				
	2637d		21.3	
	2638d		25.6	
	2639d		32.0	
	2640c		35.1	
	2642r		36.0	
	2643c		68.0	
4) Nuculana carpenteri	2106r		161.5	
	2212r		186.5	
	2313c		164.6	
	2427c		172.2	
	2535c		115.8	
	2536c		180.4	
5) Limopsis sulcata	2106r	2643r	161.5	68.0
	(2212a)	(2644r)	186.5	70.7
	2313r	2645c	164.6	107.3
	2317r		29.3	
	2425r		36.6	
	2426a		86.3	
	(2427r)		172.2	
	2530r		40.2	
	2531r		44.5	
	2532r		50.3	
	2533r		66.4	
	2534d	72.5		
	2640r	35.7		

Species	Station				Depth			
6) Cratis antillensis		2105c			89.6			
		2106r			161.5			
		2644r			70.7			
		2645a			107.3			
7) Arcopsis adamsi	2104c	2529r			53.3	37.5		
	2105a	2531r			89.6	44.5		
	2106r	2532c			161.5	50.3		
	2211r	2533a/d			42.1	66.4		
	2422r	2543r			24.1	68.0		
		2644d				70.7		
	2528r	2645d			37.2	107.3		
8) Bathyarca sp	2106d				161.5			
	2212d				186.5			
	2313d				164.6			
	2427a/d				172.2			
	2536c				180.4			
9) Crenella divaricata	2102r	2211r	2423r	2643r	17.4	42.1	29.6	68.0
			2424r				28.3	
	2103c	2314r	2425r	2644r	36.6	42.7	36.6	70.7
	2014c	2315c	2529r		53.3	36.6	37.5	
	2207r	2316r	2531r		18.3	37.2	44.5	
	2208r	2317r	2532r		34.1	29.3/ 27.4	50.3	
	2209c	2318r	2533r		29.3	18.9	66.4	
	2210c	2421r	2534c		36.6	19.2	72.5	
10) Dacrydium vitreum	2106a				161.5			
	2212r				186.5			
	2534r				72.5			
	2643r				68.0			
	2645c				107.3			
11) Musculus lateralis	2103r	2317r	2424r		36.6	29.3/ 27.4	28.3	
	2104r	2318r			53.3	18.9		
	2207r	2419r			18.3	9.8		
	2208c	2420r			34.1	14.6		
	2209r	2421r			29.3	19.2		
	2210r	2422r			36.6	24.1		
	2315r	2423r			36.6	29.6		
12) Cyclopecten nanus	2104r	2529c	2641r		53.3	37.5	35.1	
	2208r	2531r	2642r		34.1	44.5	36.0	
	2209r	2532r	2643r		29.3	50.3	68.0	
	2315r	2533r			36.6	66.4		
	2424r	2534c			28.3	72.5		
	2425c	2639r			36.6	32.0		
	2528r	2640c			37.2	35.7		

Cyclopect ensimplex		2106a				161.5				
		2212r				186.5				
		2313c				164.6				
		2427r				172.2				
		2536r				180.4				
		2645r				107.3				
imea bronniana		2105c				89.6				
		2106c				161.5				
		2533r				66.4				
		2534r				72.5				
		2535r				115.8				
		2644r				70.7				
		2645c				107.3				
inella lunulata	2101r	2210c	2318c	2426d	2534d	11.0	36.6	18.9	86.3	72.5
	2103a/d	2211a	2419r	2427r	2639a	36.6	42.1	9.8	172.2	32.0
	2104d	2212c	2420c	2528a	2640c	53.3	186.5	14.6	37.2	35.7
	2105a/d	2313c	2421r	2529d	2641c	89.6	164.6	19.2	37.5	35.1
	2106a	2314a/d	2422r	2530c	2643d	161.5	42.7	24.1	40.2	68.0
	2207c	2315c	2423c	2531a	2644d	18.3	36.6	29.6	44.5	70.7
	2208r	2316a	2424r	2532d	2645d	34.1	37.2	28.3	50.3	107.3
	2209r	2317r	2425d	2533a		29.3	29.3/	36.6	66.4	
							27.4			
s dominguensis	2104r	2532r				53.3	50.3			
	2106r	2533c				161.5	66.4			
	2211r	2534c				42.1	72.5			
	2318r	2643r				18.9	68.0			
	2425r	2644c				36.6	70.7			
	2427r	2645r				172.2	107.3			
	2528a					37.2				
') Carditopsis smithi	2103r					36.6				
	2210r					36.6				
	2211r					42.1				
	2315r					36.6				
	2317r					29.3/				
						27.4				
3) Astarte nana	2105r					89.6				
	2106a					161.5				
	2426r					86.3				
	2530r					40.2				
	2531r					44.5				
	2532r					50.3				
	2534r					72.5				
	2535r					115.8				
	2645r					107.3				

19) Pteromeris perplana								
	2103r				36.6			
	2208r				34.1			
	2316r				37.2			
	2424r				28.3			
	2425a				36.6			
20) Pythinella cuneata	2639c				32.0			
21) Vesicomya pilula	2105r	2533r	2644a		89.6	166.4	70.7	
	2106a	2534c	2645a		161.5	72.5	107.3	
	2212d	2535d			186.5	115.8		
	2313d	2536d			164.6	180.4		
	2426d	2639c			86.3	32.0		
	2427d	2643d			172.2	68.0		
22) Montacuta triquetra								
	2104r	2532r	2643c		53.3	50.3	68.0	
	2105r	2533r	2655c		89.6	66.4	70.7	
	2106a	2534c	2645c		161.5	72.5	107.3	
	2426a	2535r			86.3	115.8		
23) Lucina nassula	2102r	2315r			11	36.6		
	2103r	2317r			36.6	29.3/ 27.4		
	2104r	2420r			53.3	14.6		
	2207r	2421r			18.3	19.2		
	2208r	2423r			34.1	29.6		
	2209r	2640r			29.3	35.7		
	2210r				36.6			
24) Linga amiantus	2102r	2639r			11	32.0		
	2211r				42.1			
	2315r				36.6			
	2318r				18.9			
	2419c				9.8			
	2422r				24.1			
	2637a				21.3			
	2638a				25.6			
25) Parvilucina multilineata								
	2102d	2314c	2422c	2640r	11	42.7	24.1	35.7
	2102d	2315d	2423c	2641r	17.4	36.6	29.6	35.1
			2424r				28.3	
	2103a	2316c	2425r		36.6	37.2	36.6	
	2104c	2317a	2426r		53.3	29.3/ 27.4	86.3	
	2207d	2318c	2528r		18.3	18.9	37.2	
	2208d	2419a	2532r		34.1	9.8	50.3	
	2209d	2420d	2637r		29.3	14.6	21.3	
	2210d	2421a	2639r		36.6	19.2	32.0	

26) Parvilucina blanda	2426r					86.3		
27) Thyasira trisinuata	2104r					53.3		
	2210r	2639c				36.6	32.0	
	2423r	2643r				29.6	68.0	
	2535r	2645r				115.8	107.3	
	2536r					180.4		
28) Nemocardim peramabile								
	2106c	2645r				161.5	107.3	
	2212r					186.5		
	2313c					164.6		
	2427r					172.2		
	2535r					115.8		
	2536r					180.4		
29) Tellina versicolor	2101a	2314a	2422r	2643r	11	42.7	24.1	68.0
	2102c	2315r	2423r		17.4	36.6	29.6	
	2103c	2316r	2424c		36.6	37.2	28.3	
	2104r	2317r	2532r		53.3	29.3/	50.3	
						27.4		
	2107r	2318r	2639c		18.3	18.9	32.0	
	2208r	2419c	2640a		34.1	9.8	35.7	
	2209r	2420a	2641d		29.3	14.6	35.1	
	2210r	2421r	2642d		36.6	19.2	36.0	
30) Abra lioica	2106a	2535c			161.5	115.8		
	2209r	2536c			29.3	180.4		
	2212c	2639r			186.5	32.0		
	2313c	2645r			164.6	107.3		
	2421r				19.2			
	2426r				86.3			
	2427r				172.2			

Gouldia cerina

.01c	2208a	2317a	2426c	2533c	2642a	11	34.1	29.3/ 27.4	86.3	66.4	36.0
.02r	2209c	2421r	2528a	2534a	2643a	17.4	29.3	19.2	37.2	72.5	68.0
.03d	2210a	2422a	2529a	2535r	2644a	36.6	36.6	24.1	37.5	115.8	70.7
.04a	2211a	2423a	2530a	2638r	2645d	53.3	42.1	29.6	46.2	25.6	107.3
.06r	2315c	2424a	2531a	2639d		161.5	36.6	28.3	44.5	32.0	
.07r	2316a	2425a	2532a	2640d		18.3	37.2	36.6	50.3	35.7	
				2641a						35.1	

Chione grus

101c	2208r	2315r	2421r	2529c	2641c	11	34.1	36.6	19.2	37.5	35.1
102r	2209r	2316r	2422a	2531r	2643r	17.4	29.3	37.2	24.1	44.5	68.0
103c	2210r	2317c	2423a	2532r		36.6	36.6	29.3/ 27.4	29.6	50.3	
104r	2211c	2419r	2426r	2639r		53.3	42.1	9.8	86.3	32.0	
107r	2212r	2420r	2528a	2640r		18.3	186.5	14.6	37.2	35.7	

Hiatella arctica

103r	2529r	36.6	37.5
208r	2532r	34.1	50.3
209r		29.3	
421r		19.2	
422r		24.1	
423r		29.6	
425r		36.6	

Corbula swiftiana

535c	115.8
637r	21.3
638r	25.6
639a	32.0
640r	35.7
641r	35.1
643r	68.0

Varicorbula operculata

102c	2315c	2423c	2640r	17.4	36.6	29.6	35.7	
103r	2316r	2424d	2641a	36.6	37.2	28.3	35.1	
104r	2317r	2425r	2642r	53.3	29.3/ 27.4	36.6	36.0	
207a	2318r	2426r	2643r		18.3	18.9	86.3	68.0
208a	2419r	2529c	2644r		34.1	9.8	37.5	70.7
209a	2420r	2531r		29.3	14.6	44.5		
210a	2421d	2533r		36.6	19.2	66.4		
211r	2422a	2639r		42.1	24.1	32.0		

36) Verticordia ornata

2104r	2313r	2426r	2645r	53.3	164.6	86.3	107.3
2106c	2314a	2427r		161.5	42.7	172.2	
2208r	2316r	2532r		34.1	37.2	50.3	
		2533r				66.4	
2209r	2422r	2535r		29.3	24.1	115.8	
2211r	2423r	2639r		42.1	29.6	32.0	
2212r	2425r	2643r		186.5	36.6	68.0	

37) Cardiomya ornatissima

38) Cardiomya perrostrata

2103r	36.6
2316r	37.2

39) Arene tricarinata

2103r	2422r	2645r	36.6	24.1	107.3
2105r	2423r		89.6	29.6	
2207r	2529r		18.3	37.5	
2208r	2530r		34.1	40.2	
2211r	2531r		37.2	50.3	
2419r	2644r		9.8	70.7	

40) Tricolia thalassicola

2104c	2532r	53.3	50.3
2105c	2645r	89.6	107.3
2211r		42.1	
2316r		37.2	
2530r		40.2	
2531r		44.5	

41) Alvania auberiana

2103c	2211a	2426r	2643r	36.6	42.1	86.3	68.0
2104a	2315r	2528c	2644	57.3	36.6	37.2	70.2
2105r	2316c	2529c	2645c	89.6	37.2	37.5	107.3
2106r	2317c	2530a		161.5	29.2/ 27.4	40.2	
2207c	2318r	2532a		18.3	18.9	50.3	
2208r	2422a	2533c		34.1	24.1	66.4	
2209r	2423a	2534c		29.3	29.6	72.5	
2210r	2425r	2640r		36.6	36.6	35.7	

42) Alvania cf auberiana

2105c	2645	89.6	107.3
2106r		161.5	
2212r		186.5	
2533r		66.4	
2534r		72.5	
2643r		68.0	
2644c		70.7	

43) Alvania precipitata

2105a	2643r	89.6	68.0
2106c	2644r	161.5	70.7
2212r	2645a	186.5	107.3
2313c		164.6	
2427r		172.2	
2534r		72.5	
2535r		115.8	
2536r		180.4	

) Cyclostremiscus cubanus

2103r	2211a	2530c	36.6	42.1	40.2
2104r	2316c	2532c	53.3	37.2	50.3
2105r	2317c	2533a	89.6	29.3/ 27.4	66.4
2207r	2422r	2534r	18.3	24.1	72.5
08r	2423r	2639r	34.1	29.6	32.0
09r	2528r	2640r	29.3	39.2	35.7
2210r	2529c		36.6	37.5	

45) Teinostoma incertum

2104r	2532r	53.3	50.3
2210r	2533r	36.6	66.4
2211c	2645r	42.1	102.3
2528c		37.2	
2529r		37.5	
530c		40.2	

Aorotrema pontogenes

11r	42.1
23r	29.6
425r	36.6
2443r	68.0

47) Caecum pulchellum

2101c	2211d	2424r	2533d	11	42.1	28.3	66.4
2102e	2314a	2425d	2534d	17.4	42.7	36.6	72.5
2103a	2315r	2426a	2637e	36.6	36.6	86.3	21.3
2104d	2316d	2528d	2640a	53.3	37.2	37.2	35.7
2105d	2317d	2529d	2641r	89.6	29.3/ 27.4	37.5	35.1
2207a	2421r	2530d	2643a	18.3	19.2	40.2	68.0
2208r	2422d	2531d	2644r	34.1	24.1	44.5	70.7
2210r	2423d	2532d	2645a	36.6	29.6	50.3	107.3

48) Caecum bipartitum

2101a	2317c	2531r	11	29.3/ 27.4	44.5
2102c	2318c	2640r	17.4	18.9	35.7
2103c	2319c	2641r	36.6	9.8	35.1
2207c	2420a		18.3	14.6	
2208d	2421d		34.1	19.2	
2209a	2422r		29.3	24.1	
2210a	2423r		36.6	29.6	
2315a	2424c		36.6	28.3	
2316r	2425r		37.2	36.6	

Species	Localities					Depths				
Caecum imbricatum	2101r	2314d	2423c	2639r		11	42.7	29.6	32.0	
	2102c	2315c	2424c	2640a		17.4	36.6	28.3	35.7	
	2103c	2316c	2425d	2641a		36.6	37.2	36.6	35.1	
	2104c	2317c	2528r	2642c		53.3	29.3/27.4	37.2	36.0	
	2105r	2318a	2529r	2643r		89.6	18.9	37.5	68.0	
	2207a	2419c	2530a	2645r		18.3	9.8	40.2	107.3	
	2208r	2420c	2531r			34.1	14.6	44.5		
	2210r	2421c	2532c			36.6	19.2	50.3		
	2211r	2422r	2637r			42.1	24.1	21.3		
Caecum floridanum	2104c	2531c				53.3	44.5			
	2211r	2532r				42.1	50.3			
	2315r					36.6				
	2318r					18.9				
	2529a					37.5				
	2530c					40.2				
Caecum plicatum	2315d					36.6				
	2532r					50.3				
	2534r					72.5				
	2645a					107.3				
Meioceras cubitatum	2101a	2210d	2422c	2531c	2644r	11	36.6	24.1	44.5	70.7
	2102d	2211c	2423c	2532a	2645r	17.4	42.1	29.6	50.3	107.3
	2103a	2313r	2424d	2533a		36.6	164.6	28.3	66.4	
	2104d	2315d	2425d	2534r		53.3	36.6	36.6	72.5	
	2105c	2316a	2426a	2640a		89.6	37.2	86.3	35.7	
	2207r	2317d	2528r	2641r		18.3	29.3/27.4	37.2	35.1	
	2208a	2318r	2529c	2642a		34.1	18.9	37.5	36.0	
	2209a	2421r	2530c	2643c		29.3	19.2	40.2	68.0	
Finella dubia	2103d	2314a	2423d	2533r	2645c	36.6	42.7	29.6	66.4	107.3
	2104d	2316d	2424d	2534r		53.3	37.2	28.3	72.5	
	2207d	2317d	2425a	2639c	2101c	18.3	29.3/27.4	36.6	32.0	11
	2208a	2318a	2528d	2640a	2102c	34.1	18.9	37.2	35.7	17.4
	2209d	2419a	2529a	2641d		29.3	9.8	37.5	35.1	
	2210d	2420a	2530a	2642c	2315d	36.6	14.6	40.2	36.0	36.6
	2211a	2421d	2531a	2643a		42.1	19.2	44.5	68.0	
	2212r	2422a	2532c	2644a		186.5	24.1	50.3	70.7	
Certhiopsis crystallinum	2211r	2536c				42.1	180.4			
	2212c					186.5				
	2313a					164.6				
	2423r					29.6				
	2427r					172.2				
	2534r					72.5				
Seila adamsi	2101r	2317c	2529r			11	29.3/27.4	37.5		
	2103r	2421r	2530r			36.6	19.2	40.2		
	2104r	2422c	2531c			53.3	24.1	44.5		
	2105r	2423r	2532c			89.6	29.6	50.3		
	2207r	2425c	2639r			18.3	36.6	32.0		
	2211r	2428c	2644r			42.1	37.2	70.7		

	Localities					Depths				
alyptraea entralis	2101r	2643r				11	68.0			
	2102r					17.4				
	2422r					24.1				
	2423r					29.6				
	2640r					35.7				
atica pusilla	2101a	2210c	2421c	2532r		11	36.6	19.2	50.3	
	2102c	2211r	2422c	2637a		17.4	42.1	24.1	21.3	
	2103r	2315c	2423c	2639c		36.6	36.6	29.6	32.0	
	2104r	2316c	2425c	2640a		53.3	37.2	36.6	35.7	
	2207c	2317r	2428r	2641a		89.6	29.3/27.4	37.2	35.1	
	2208c	2318c	2529c	2642a		34.1	18.9	37.5	36.0	
	2209c	2419c	2531r	2643r		29.3	9.8	44.5	68.0	
arginella sp.	2103r	2318r	2532r			36.6	18.9	50.3		
	2105c	2422r	2535r			89.6	24.1	115.8		
	2211r	2424r	2642r			42.1	28.3	36.0		
	2313r	2425c				164.6	36.6			
	2315r	2529r				36.6	37.5			
anulina uliformis	2104r	2530r				53.3	40.2			
	2105r	2531r				89.6	44.5			
	2106r	2532r				161.5	50.3			
	2315r	2536r				36.6	180.4			
	2419r	2643r				9.8	68.0			
	2422r	2645c				24.1	107.3			
	2529r					37.5				
dostomia didyma	2423r					29.6				
	2644r					70.7				
cteocina candei	2101r	2208r	2216r	2423c	2639r	11	34.1	37.2	29.6	32.0
	2102r	2209r	2317r	2425r	2641r	17.4	29.3	29.3/27.4	36.6	35.1
	2103r	2210c	2318c	2529r	2643r	36.6	36.6	18.9	37.5	68.0
	2104r	2211r	2421r	2530r		53.3	42.1	19.2	40.2	
	2207c	2215r	2422c	2638r		18.3	36.6	24.1	25.6	
yrunculus caelatus	2103r	2426r	2534r			36.6	86.3	72.5		
	2105r	2427c	2643r			89.6	172.2	68.0		
	2211r	2529r	2644r			42.1	37.5	70.7		
	2212r	2530r	2645r			186.5	40.2	107.3		
	2213r	2532r				164.6	50.3			
	2215r	2533r				36.6	66.4			
Retusa sulcata	2103c	2216r				36.6	37.2			
	2104c	2317r				53.3	29.3/27.4			
	2208r	2318r				34.1	18.9			
	2209r	2422r				29.3	24.1			
	2210r	2423r				36.6	29.6			
	2211r	2532r				42.1	50.3			
	2215r	2533r				36.6	66.4			

	Localities					Depths				
Volvulella	2101r	2208r	2216r	2424r	2533r	11	34.1	37.2	28.3	66.4
persimilis	2102r	2209r	2317r	2529r	2535r	17.4	29.3	29.3/27.4	37.5	115.8
	2103r	2210r	2421r	2530r	2639r	36.6	36.6	19.2	40.2	32.0
	2104r	2211r	2422r	2531r	2640c	53.3	42.1	24.1	44.5	35.7
	2106r	2215r	2423r	2532r	2641r	161.5	36.6	29.6	50.3	35.1
	2207r				2643r	18.3				68.0
Cadulus iota	2104r	2533r	2643c			53.3	66.4	68.0		
	2105r					89.6				
	2426a	2534r	2644r			86.3	72.5	70.7		
	2531r	2535c	2645r			44.5	115.8	107.3		
	2532r	2639r				50.3	32.0			
Cadulus mayori	2426r					86.3				
	2535r					115.8				
Nucula crenulata	2106r					161.5				
	2212r					186.5				
	2313r					164.6				
Nuculana apecta	2105a	2535r				89.6	115.8			
	2106r	2643r				161.5	68.0			
	2212r	2645r				186.5	107.3			
	2313r					164.6				
	2426d					86.3				
Solemya	2101r					11				
occidentalis	2102r					17.4				
	2421r					19.2				
Crassinella	2105r	2643r				89.6	68.0			
dupliniana	2207r					18.3				
	2315r					36.6				
	2318d					18.9				
	2528r					37.2				
Cuna dalli	2425r					36.6				
Diplodonta sp.	2101r	2208r	2420c	2529r	2542r	11	34.1	14.6	37.5	36.0
	2102r	2209r	2421r	2532r		17.4	29.3	19.2	50.3	
	2103r	2210r	2422r	2533r		36.6	36.6	24.1	66.4	
	2104r	2315r	2423r	2534r		53.3	36.6	29.6	72.5	
	2207r	2419r	2424r	2637c		18.3	9.8	28.3	21.3	
Ervilia	2101a	2316r	2422r	2533r		11	164.6	24.1	66.4	
concentrica	2102a	2318a	2423r	2641c		17.4	18.9	29.6	35.1	
	2207r	2419d	2424c	2642a		18.3	9.8	28.3	36.0	
	2211r	2420d	2425r			42.1	14.6	36.6		
	2315r	2421c	2528c			36.6	19.2	37.2		
Abra aequalis	2103r	2210r				36.6	36.6			
	2104r	2314a				53.3	42.7			
	2105r	2315r				89.6	36.6			
	2208r	2422r				34.1	24.1			
	2209r	2535r				29.3	115.8			

	Localities					Depths				
Semele nuculoides	2102r	2318c	2425r			17.4	18.9	36.6		
	2207r	2420c	2642r			18.3	14.6	36.0		
	2209r	2422r				29.3	24.1			
	2317r	2423r				29.3/27.4		29.6		
Parastarte triquetra	2207r					18.3				
	2318r					18.9				
	2419c					9.8				
Verticordia fischeriana	2535r					115.8				
Scissurella proxima	2313r					164.6				
Skenea sp.	2102r	2208r	2316r	2423r	2531r	17.4	34.1	37.2	29.6	44.5
	2103r	2209r	2317r	2424c	2532c	36.6	29.3	29.3/27.4	28.3	50.3
	2104r	2210r	2318c	2528r	2642r	53.3	36.6	18.9	37.2	36.0
	2207r	2315c	2422r	2531r	2643r	18.3	36.6	24.1	44.5	68.0
Didianema pauli	2207r					18.3				
	2318r					18.9				
	2423r					29.6				
Zebina browniana	2101r					11				
	2103r					36.6				
	2314r					42.7				
	2422r					24.1				
Parviturboides interruptus	2207r	2317r	2423c			18.3	29.3/27.4	29.6		
	2208r	2419c	2428r			34.1	9.8	37.2		
	2209r	2421r	2640r			29.3	19.2	35.7		
	2313r	2422c				164.6	24.1			
Cyclostremiscus jeannae	2103r	2529r				36.6	37.5			
	2316r					37.2				
	2422r					24.1				
	2423r					29.6				
Solariobis shimeri	2422r					24.1				
	2423r					29.6				
Anticlimax pilsbryi	2103r					36.6				
	2208r					34.1				
	2423r					29.6				
Teinostoma parvicallum	2422r					24.1				
Caecum clava	2422r					24.1				
	2423r					29.6				
Macromphalina palmalitoris	2207r	2423c				18.3	29.6			
		2529r					37.5			
Caecum ryssotitum	2428r					37.2				
	2643r					68.0				

	Localities	Depths
90) Caecum heladum	2207r 2534r	18.3 72.5
91) Brochina sp. antillarum(?)	2207r 2424r 2530r 2211r 2425r 2531r 2318r 2528r 2532r 2420r 2529r 2533r	18.3 28.3 40.2 42.1 36.6 44.5 18.9 37.2 50.3 14.6 37.5 66.4
92) Meioceras nitidum	2207r 2211r 2318r 2534r	18.3 42.1 18.9 72.5
93) Meioceras cornucopiae	2318r 2530r	18.9 40.2
94) Bittium varium	2101r 2421r 2207r 2314d 2420r	11 19.2 18.3 42.7 14.6
95) Marginella lavalleeana	2101r 2423r 2211r 2316r 2422r	11 29.6 42.1 37.2 24.1
96) Cyclostremella humilis	2101r	11
97) Odostomia dianthophila	2103r 2211r 2529r 2105r 2316r 2534r 2207r 2423r 2644c	36.6 42.1 37.5 89.6 37.2 72.5 18.3 19.2 70.7
98) Acteon punctostiratus	2317r	29.3/27.4
99) Ringicula semistriata	2645r	107.3
100) Cylichna verrilli	2106r 2212r	161.5 186.5
101) Chaetopleura apiculata	2101r	11
102) Olivella pusilla	2102r	17.4
103) Abra sp.	2532r	50.3
104) Niso aegles	2105r	89.6
105) Caecum sp.	2423r	29.6
106) Nucinella sp.	2105r	89.6
107) Acteocina canaliculata	2314a	42.7

	Localities	Depths
108) Pleuromalaxis balesi	2423r	29.6
109) Dimya tigrina	2644	70.7
	2645	107.3

r - rare
c - common
a - abundant
d - dominant

HEAVY METAL ANALYSES OF BOTTOM SEDIMENT ON THE WEST FLORIDA SHELF

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INTRODUCTION

In continuation of the baseline evaluation of the Mississippi-Alabama-Florida continental shelf sponsored by the Bureau of Land Management, SUSIO has sampled stations along the six transects depicted in Figures 1 and 2. As seen in Figure 2, four of the transects pass through the five areas blocked off during the original baseline survey conducted in 1974-75. Within the scope of this baseline continuation study, we have received and analyzed surface sediment samples from 42 of the 45 stations. 21 of these stations were sampled on two different occasions resulting in a total of 63 samples (station data is contained in Appendix I).

This report presents the results of our analyses of these 63 samples for barium, cadmium, chromium, copper, iron, lead, nickel and vanadium.

METHODS

Samples were prepared for analysis by initially drying the entire aliquot (∿50 g) of wet sediment at 105°C and then reducing it to a fine powder with a porcelain-lined Spex mixer-mill. Cadmium, chromium, copper, iron, lead and nickel were determined by atomic absorption spectrophotometry after dissolution of the sediment. Barium and vanadium were determined by instrumental neutron activation analysis of the solid sample.

For total dissolution, approximately two grams of finely powdered sediment were heated in a muffle furnace at 350°C for eight hours to ash the organic matter present. After heating, the samples were transferred

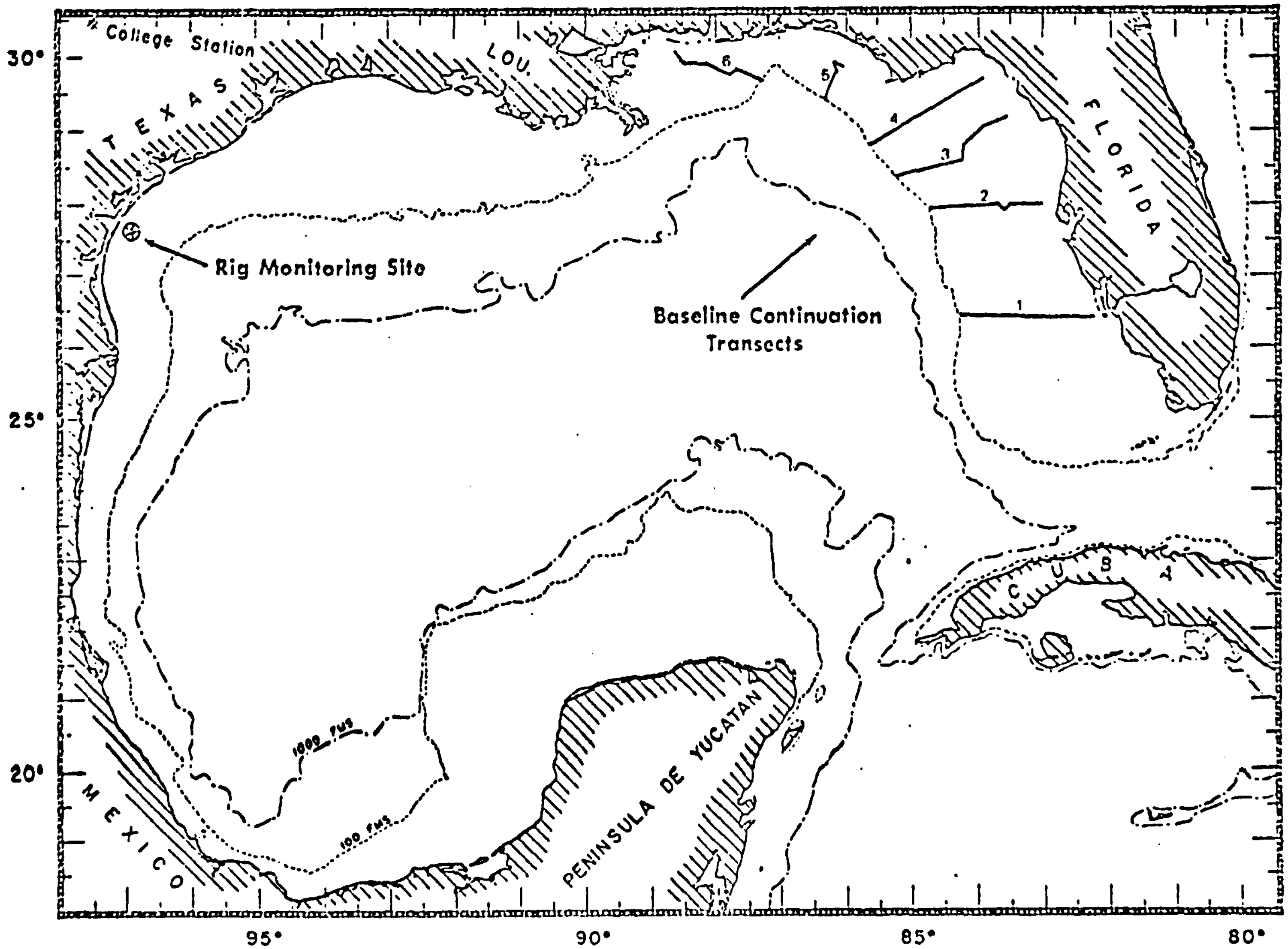
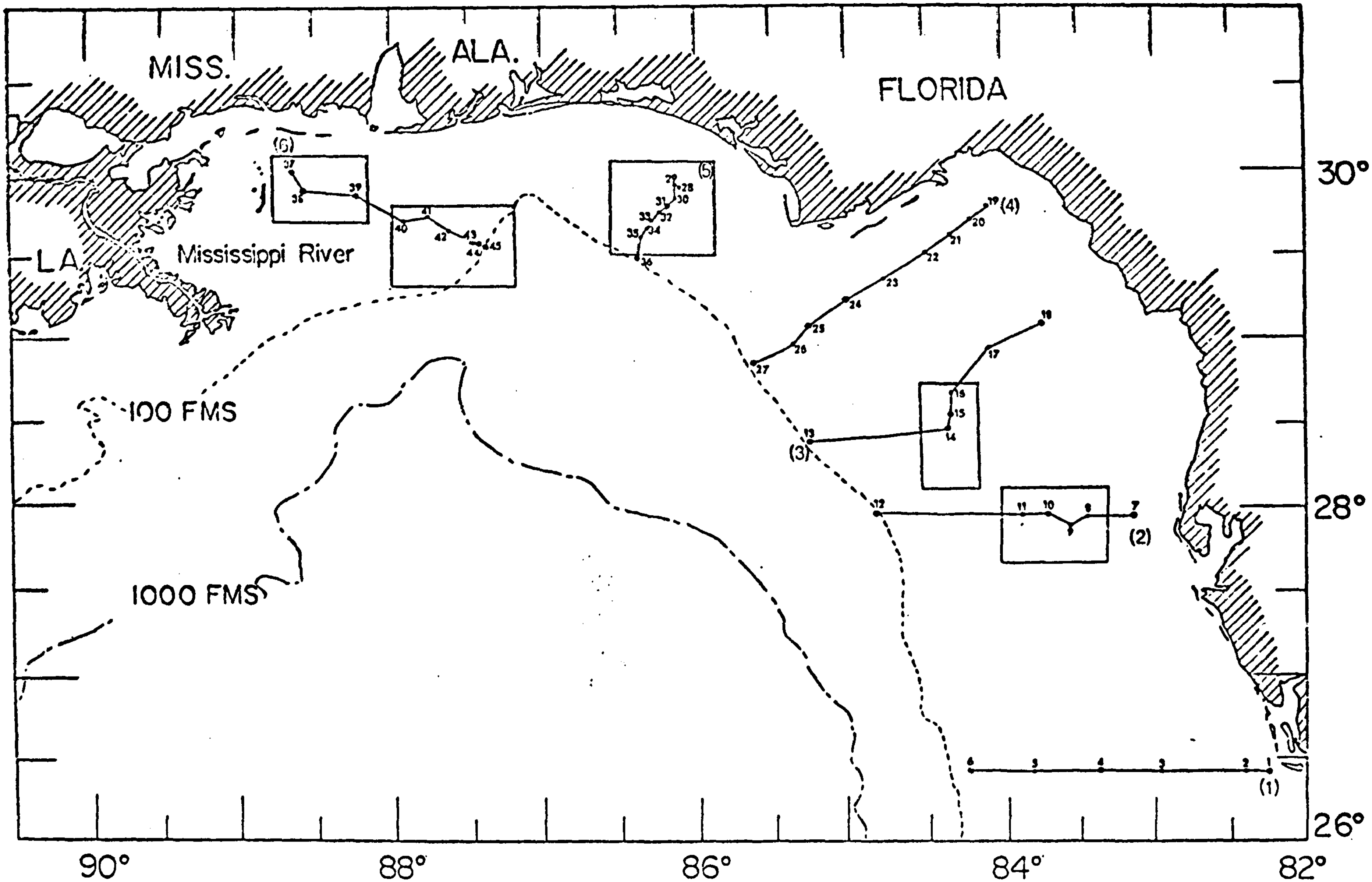


Fig. 1. Sampling areas for the MAFLA Rig Monitoring and Baseline Continuation Studies.



MAFLA Baseline Continuation sampling stations. Numbers in ( ) indicate transect. Blocked sections indicate quadrants from MAFLA Baseline study. Large circles (⊙) indicate stations sampled for sediment trace metals during both periods (21); small circles (•) indicate those sampled only during first period (45).

to teflon beakers and the $CaCO_3$ was reacted by dropwise addition of 1 N HNO_3, and the resulting solution removed. Next, five milliliters of HF (48%) and two milliliters of $HClO_4$ were added and the acid-sediment mixture was refluxed for approximately two hours before heating to near dryness. A second acid mixture (three milliliters HF, two milliliters $HClO_4$) was then added and again heated to near dryness. The residue was redissolved in two milliliters of 16 N HNO_3, recombined with the $CaCO_3$ solution, and diluted to 25 ml with deionized water.

Cadmium, chromium, copper, lead and nickel were determined by direct aspiration into a Jarrell-Ash model 810, two channel atomic absorption spectrophotometer. Iron was determined after appropriate dilution by the same technique. Background absorbance, due to molecular absorption was monitored, where necessary, by simultaneously measuring the absorbance of a non-resonance line and the analytical line of the element of interest. Cadmium and chromium concentrations were also checked by flameless atomic absorption techniques using a Perkin-Elmer 306 atomic absorption spectrophotometer equipped with an HGA-2100 graphite atomizer and a deuterium background corrector.

Instrumental neutron activation analysis was used for vanadium determination. Initial preparation for neutron activation involved accurately weighing about 0.5 g of sediment, which had been dried at 105°C, into a small one gram capacity polyethylene vial. The vial was heat-sealed to prevent any loss of sample during the analysis. The marked, encapsulated samples were irradiated by the one MW Triga reactor at the Texas A&M University Nuclear Science Center. Each sample was irradiated separately for two minutes. This process was facilitated by a pneumatic transport system which can rapidly transfer samples in and out of the reactor core. The sample vial was placed in a secondary polyethylene vial, together with an aluminum flux monitor, and transported to the core for the two minute time period.

After return of the sample and a one minute delay, the aluminum flux monitor was counted by a multichanneled pulse height analyzer. After an appropriate delay period (usually three to five minutes, so that the dead time was <30%) the irradiated sediment sample was placed on an Ortec Ge(Li) detector and counted using a separate GEOS Quanta 4096 channel multichannel pulse height analyzer. The analyzer was set for a gain of 1.0 keV per channel. The vanadium peak for the ^{52}V analyzed is at 1434 keV. After a five minute counting period, the spectrum was stored on magnetic tape.

Data reduction was done using the program HEVESY. The program calculates peak intensities and converts these to concentration by comparison with appropriate USGS standard rocks (DTS-1 and AGV-1). Corrections are made for varying delay times, dead times, and neutron fluxes.

Barium analysis was also done by activation analysis. In the barium procedure the sediments were irradiated for a 14 hr period in aluminum Swagelok tubes along with standards and blanks which were set in a rotisserie in the reactor core. After irradiation the samples were allowed to "cool" for two weeks. The irradiated samples were counted for two hours using an Ortec Ge(Li) detector and a Canberra model 8700, 1024 channel multichannel pulse height analyzer. The peak of interest was that produced by xenon X-rays at 29 keV; the gain was set so that the peak was recorded in channel 160. After the two hour counting period, the spectrum was stored on magnetic tape and data reduction performed by HEVESY using the USGS standard rock W-1 as a basis for sample concentration calculation.

USGS standard rocks were analyzed to obtain some idea of the accuracy of our analyses. Our agreement for replicate analyses is, overall, quite good with our results being consistently within 10% of the published values. The precisions of the metal analyses were considerably lower for sediments with high metal content than for sediment with low metal content. Quadruplicate dissolutions and analyses were made on separate sediment aliquots for five of the study samples. The selected sediments are representative of the predominance of low metal-bearing samples received. Precisions were calculated by dividing standard deviation by the mean and are as follows: Cd, 35%; Cr, 20%; Cu, 12%; Fe, 9%; Pb, 15%; Ni, 11%; and V, 25%.

RESULTS AND DISCUSSION

Sediment metal concentrations for the 63 samples analyzed during the baseline continuation study are listed in Table 1. Wide variations in the % Fe (Figure 3), % $CaCO_3$ (Figure 4) and % fine-grained material (Figure 5) are observed not only for the overall MAFLA area but even within each transect. Trace metal concentrations show a similar variability, no doubt primarily in response to the changes in both chemistry and mineralogy implied by the grain size, $CaCO_3$ and Fe variations. Past experience has shown that high metal concentrations are found with fine-grained material, organic matter and Fe and Mn hydrous oxides, whereas lower concentrations

Table 1. Surface Sediment Trace Metal Concentrations, MAFLA Baseline Continuation Study. (See Figure 2 and Appendix I for Station Location).

Station Number	Sample Period	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Pb (ppm)	Ni (ppm)	V (ppm)	$CaCO_3$ (%)	Fines (%)	Water Depth (m)
2101	I	53±27	< .05	2	1	.13	6	5	9	47.8	8.6	11.0
	II		0	3.2	1.1	.13	3.7	1.5	24	42.4	13.9	11.3
2102	I	<30	< .05	2	1	.07	5	5	5	27.5	3.8	17.4
2103	I	<32	.06	9	1	.22	8	6	3	61.3	4.0	36.6
2104	I	<34	.10	4	2	.09	9	8	4	90.1	4.7	53.3
	II	<86	.13	5.1	1.7	.10	5.0	1.5	3	88.2	13.0	53.3
2105	I	<36	.10	6	3	.07	10	9	4	92.0	4.0	89.6
2106	I	<44	.10	8	4	.39	10	13	5	83.0	14.2	161.5
	II	<41	.20	7.8	2.9	.33	5.8	7.0	7	91.2	28.0	167.6
2207	I	<41	.10	3	1	.08	7	2	7	43.5	11.0	18.3
	II		.11	3.9	0.6	.08	2.0	1.1	-	37.6	10.5	19.2
2208	I	<73	< .05	6	1	.12	9	9	4	83.4	58.6	34.1
2209	I	<36	< .05	8	1	.13	10	5	6	83.6	42.4	29.3
2210	II	<79	.04	6.0	1.1	.11	5.9	1.3	5	90.1	37.8	37.2
2211	I	<34	.10	8	1	.20	10	8	5	93.2	11.9	42.1
2212	I	<53	.10	14	5	.81	11	14	13	88.0	43.4	186.5
	II	<97	.13	13.3	4.8	.78	5.3	7.9	11	86.8	47.7	189.6

Table 1. (continued)

Station Number	Sample Period	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Pb (ppm)	Ni (ppm)	V (ppm)	$CaCO_3$ (%)	Fines (%)	Water Depth (m)
2313	I	< 58	.10	16	5	1.05	12	18	13	85.1	58.0	164.6
	II	< 102	0	13.8	3.6	.74	2.2	9.1	15	80.4	67.4	176.8
2314	II	< 89	.12	5.4	2.3	.17	8.1	5.2	6	63.6*	29.4*	29.0
2315	II	--	.13	0.7	1.0	.06	4.1	0.9	3	62.3	30.6	38.1
2316	I	< 34	.10	6	1	.13	9	8	6	70.6	8.4	37.2
2317	I	< 41	.10	6	1	.21	12	10	6	79.5	19.2	29.3
2318	I	< 65	<.05	1	1	.02	2	2	2	10.8	1.8	18.9
	II	< 47	0	2.4	0.5	.00	0.8	0.0	7	3.7	2.7	20.4
2419	I	< 30	<.05	1	1	.06	4	2	4	19.2	2.2	9.8
2420	I	< 32	.06	3	1	.26	7	8	5	46.9	2.5	14.6
2421	I	< 35	.07	3	1	.16	7	6	5	51.6	10.0	19.2
2422	I	< 35	.07	4	2	.25	6	9	9	43.8	9.3	24.1
2423	I	< 54	.95	5	2	1.67	11	9	27	72.5	14.5	29.6
2424	I	< 24	<.05	5	1	.08	2	2	3	9.0	4.0	28.3
	II	< 59	0	4.6	0.7	.10	2.0	1.4	7	7.8	7.2	32.6
2425	I	81±25	.05	3	1	.08	3	3	-	8.3	1.5	36.6
	II	< 49	.04	3.4	0.4	.05	2.2	1.2	10	14.5	4.0	35.7
2426	I	< 43	.09	5	2	.38	8	8	7	35.4	4.2	86.3

Table 1. (continued)

Station Number	Sample Period	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Pb (ppm)	Ni (ppm)	V (ppm)	$CaCO_3$ (%)	Fines (%)	Water Depth (m)
2427	I	<67	.07	17	7	1.70	11	17	20	-	59.6	172.3
	II	<123	.08	14.9	6.4	1.29	9.5	12.4	24	70.3	64.8	175.0
2528	I	<35	.08	3	2	.31	7	7	12	58.7	5.2	37.2
2529	I	<35	.10	4	2	.61	8	8	9	71.9	2.0	37.5
2530	I	<35	.15	6	2	.44	8	8	9	74.7	1.4	40.2
2531	I	<39	.15	13	2	.60	9	11	8	84.7	2.6	44.5
	II	<80	.10	10.8	1.8	.52	6.1	9.2	8	88.3	2.2	44.8
2532	I	<42	-	10	2	.54	8	9	8	75.8	8.3	50.3
2533	I	<45	.15	10	2	.59	10	11	13	86.9	2.6	66.4
2534	I	<44	.10	11	1	.66	17	9	15	88.0	4.7	72.5
2535	I	<73	.98	26	5	.95	17	14	31	70.1	76.1	115.8
2536	I	<76	.10	23	8	1.34	15	20	45	-	79.7	180.4
	II	<138	.02	13.4	5.9	1.05	10.1	14.2	39	67.5	85.6	189.6
2637	I	321±76	.08	35	8	2.17	15	14	78	13.3	62.9	21.3
	II	-	.07	36.7	8.3	1.87	16.1	15.0	-	8.2	59.4	19.5
2638	I	288±72	.10	45	10	2.87	15	22	101	17.6	78.2	25.6
	II	288±77	.05	48.3	10.1	2.34	18.0	16.7	-	12.3	78.9	23.8
2639	I	<59	<.05	12	3	.94	12	8	23	20.8	14.3	32.0
	II	<89	0	14.1	2.3	.78	8.2	0	19	16.4	19.4	32.0

Table 1. (continued)

Station Number	Sample Period	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Pb (ppm)	Ni (ppm)	V (ppm)	$CaCO_3$ (%)	Fines (%)	Water Depth (m)
2640	I	<31	.06	3	1	.33	5	1	6	19.7	1.7	35.7
2641	I	<34	<.05	6	3	.16	3	2	7	5.3	4.1	35.1
2642	I	136±45	<.05	5	1	.09	3	1	2	6.5	1.7	36.0
2643	I	<72	.10	10	2	1.63	18	12	28	84.0	5.9	68.0
	II	<86	.04	14.6	2.1	1.43	11.0	7.5	23	76.4	3.9	71.6
2644	I	<75	.10	10	2	1.12	20	9	31	88.6	3.0	70.7
	II	<76	.70	10.1	1.7	1.05	5.4	5.1	29	87.5	4.6	73.8
2645	I	<59	.10	13	3	1.04	20	9	18	84.3	11.4	107.3
	II	107±34	.07	11.3	2.4	.80	9.0	4.0	21	84.7	13.0	106.7
% Error From Replication			35%	20%	12%	9%	15%	11%				

509 Holmes, 1973 (N.W. Gom. Aug.)
140 Holmes, 1973 (N.E. Gom. Shelf Aug.)
66 Holmes, 1973 (S. Florida Shelf Aug.)
35 Horn and Adams, 1966 (World Wide Carbonate Arz.)
233 Horn and Adams, 1966 (Mobile belt Aug.)

xx< indicates limit of detection determined for each sample.

* Sediment Data from Sample Period III

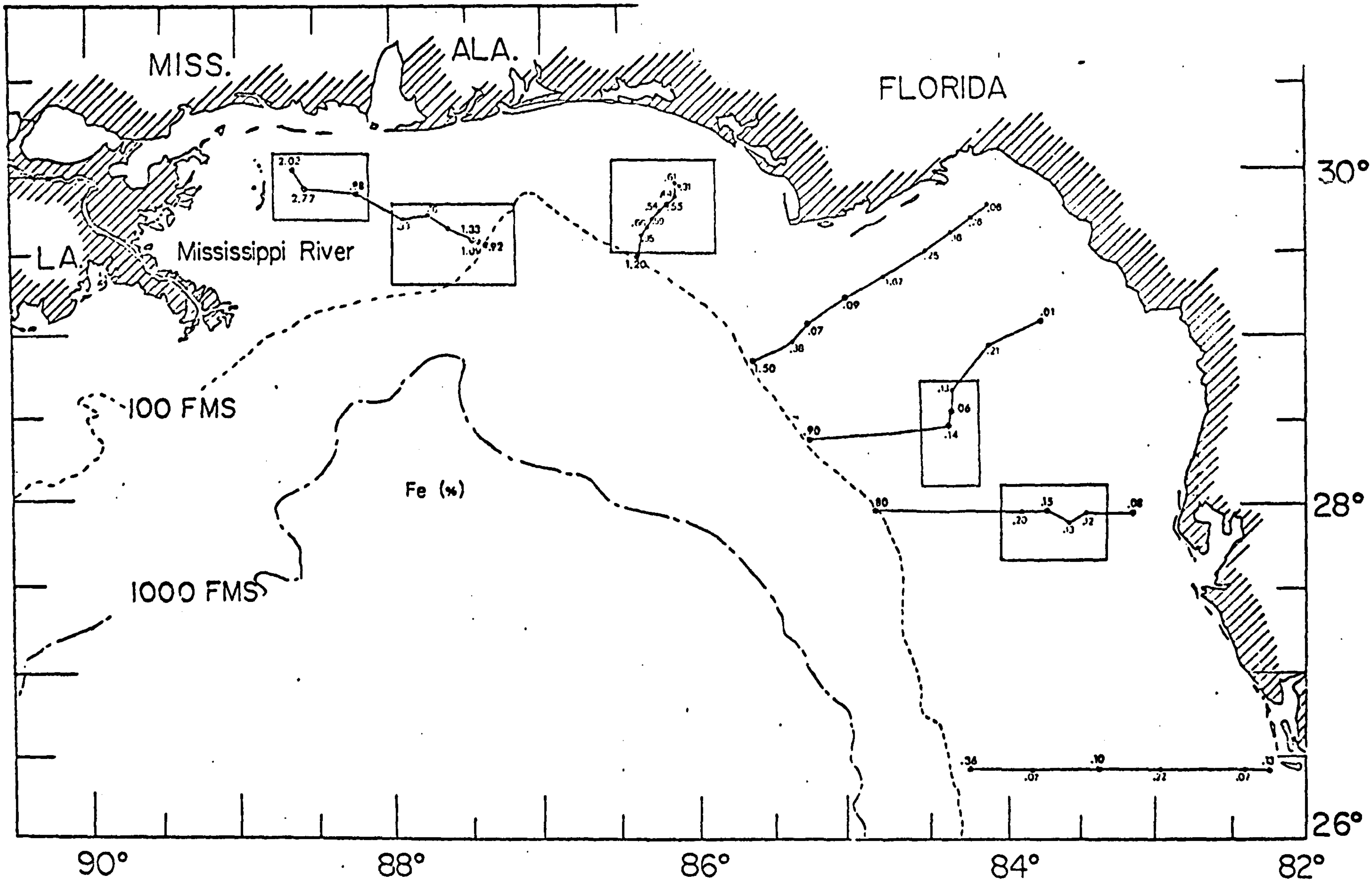


Fig. 3. Surface sediment iron content (%) averaged for two sampling periods of MAFLA Baseline Continuation Study.

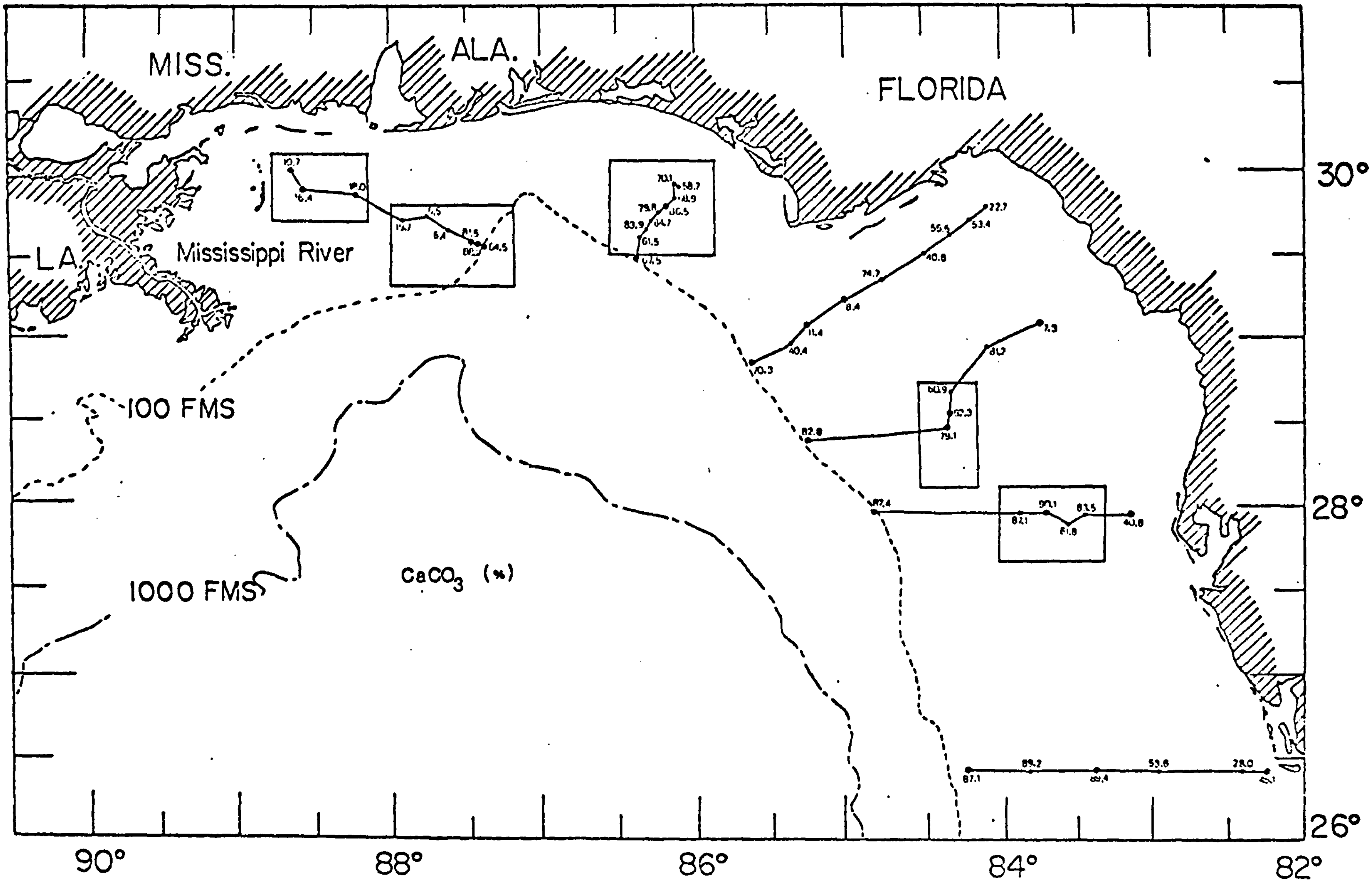


Fig. 4. Surface sediment calcium carbonate content (%) averaged for two sampling periods of MAFLA Baseline Continuation Study.

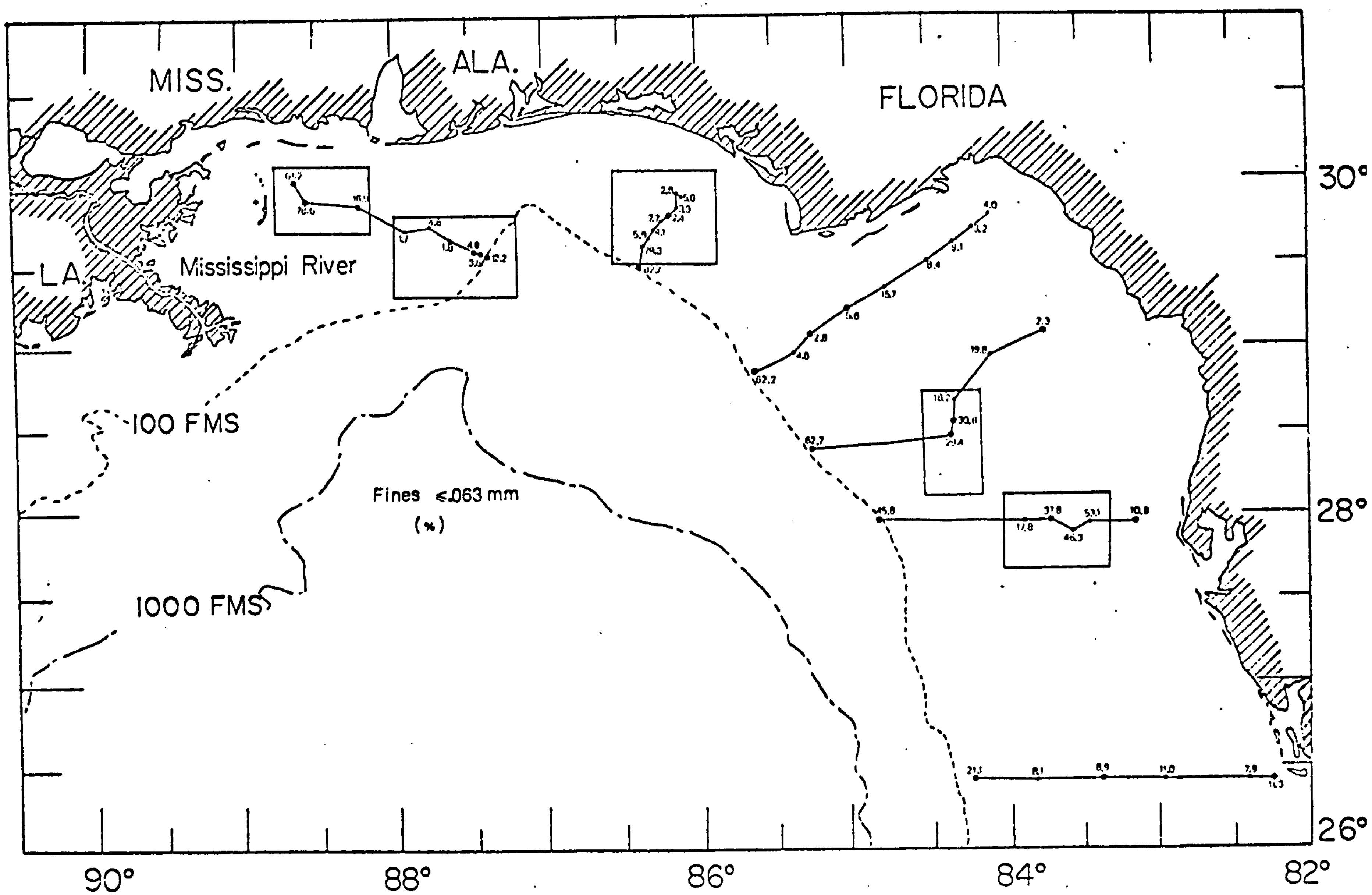


Fig. 5. Surface sediment fine grain (≤ .063 mm) content (%) averaged for two sampling periods of MAFLA Baseline Continuation Study.

are observed when sediments contain appreciable amounts of quartz, carbonate and coarse-grained material.

To examine the interrelationships between possible controlling factors and metal concentrations, Trefry, et al., (1976) and Trefry and Presley (1976) have normalized metal concentrations to Fe. Sediment with metal concentrations which deviate from their expected ratio to Fe have been cited as having an anthropogenic contribution. This is reasonable because metals, including Fe, are well correlated with grain size, organic matter, $CaCO_3$, etc., but Fe is unlikely to be added by man in amounts which would increase natural levels.

At the completion of the initial study of the MAFLA area, we showed that metal concentrations correlated well with the fundamental sediment characteristics and that there was no indication of metal pollution (Presley, et al., 1975). This observation also holds for the 63 second year samples. To examine all of the interrelationships between metal concentrations and their controlling factors would require an extensive analytical program and a rigorous statistical treatment of the data. It is more convenient to normalize observed metal concentrations to a single index which encompasses the more important concentration controlling factors. As mentioned, Fe provides such an index and in an effort to evaluate the distributions found in this study we have applied this approach to the data presented in Table 1.

Figures 6-10 give the metal to Fe scatter plots for the 1974-1976 MAFLA sediment data. In each case, there is a significant linear correlation of the metals with Fe. This occurs despite the three areas of provenance for MAFLA sediments. The plots provide a prediction interval for evaluating

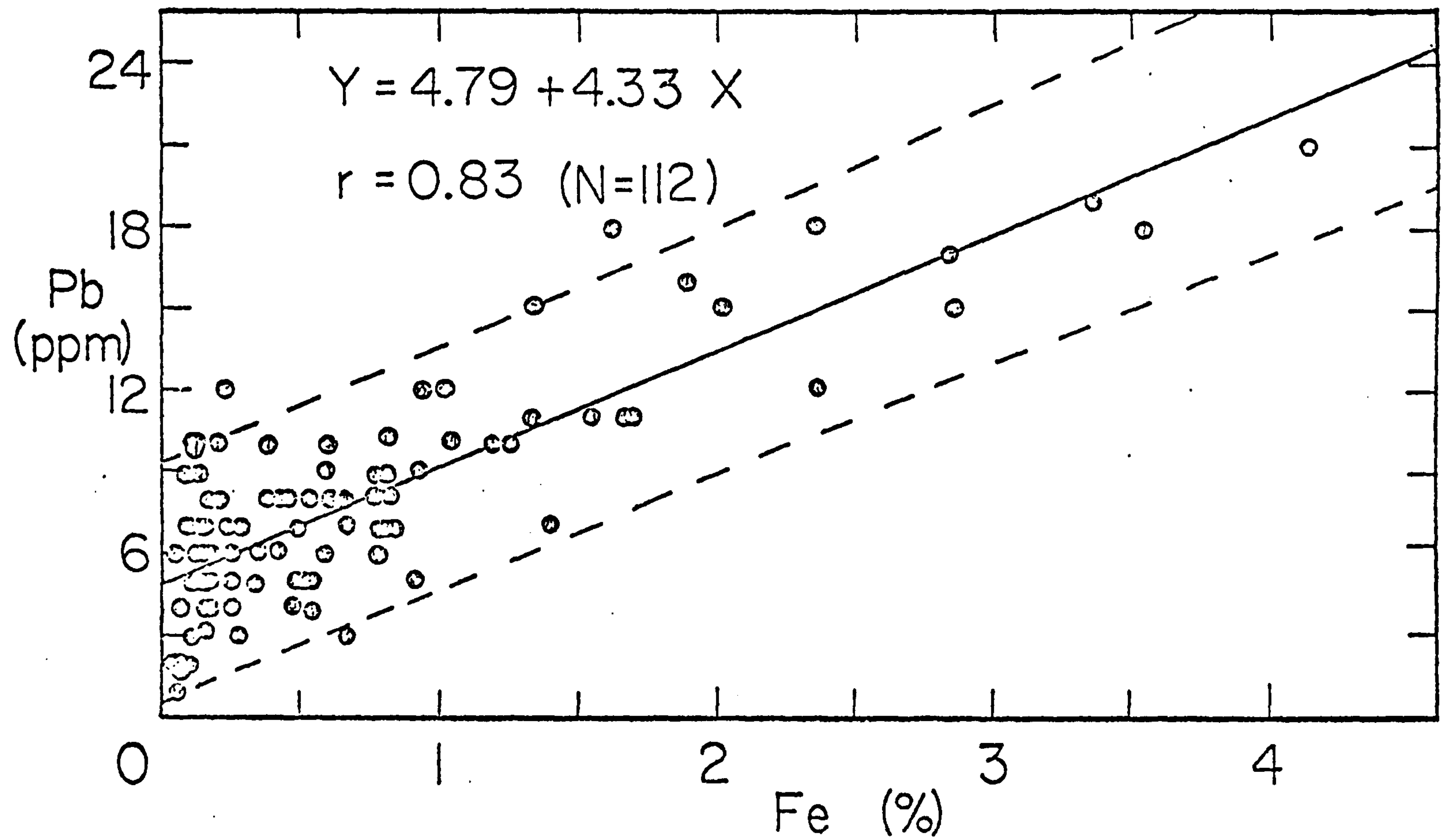


Fig. 6. Pb vs Fe scatter plot for MAFLA shelf sediments with 95% prediction interval.

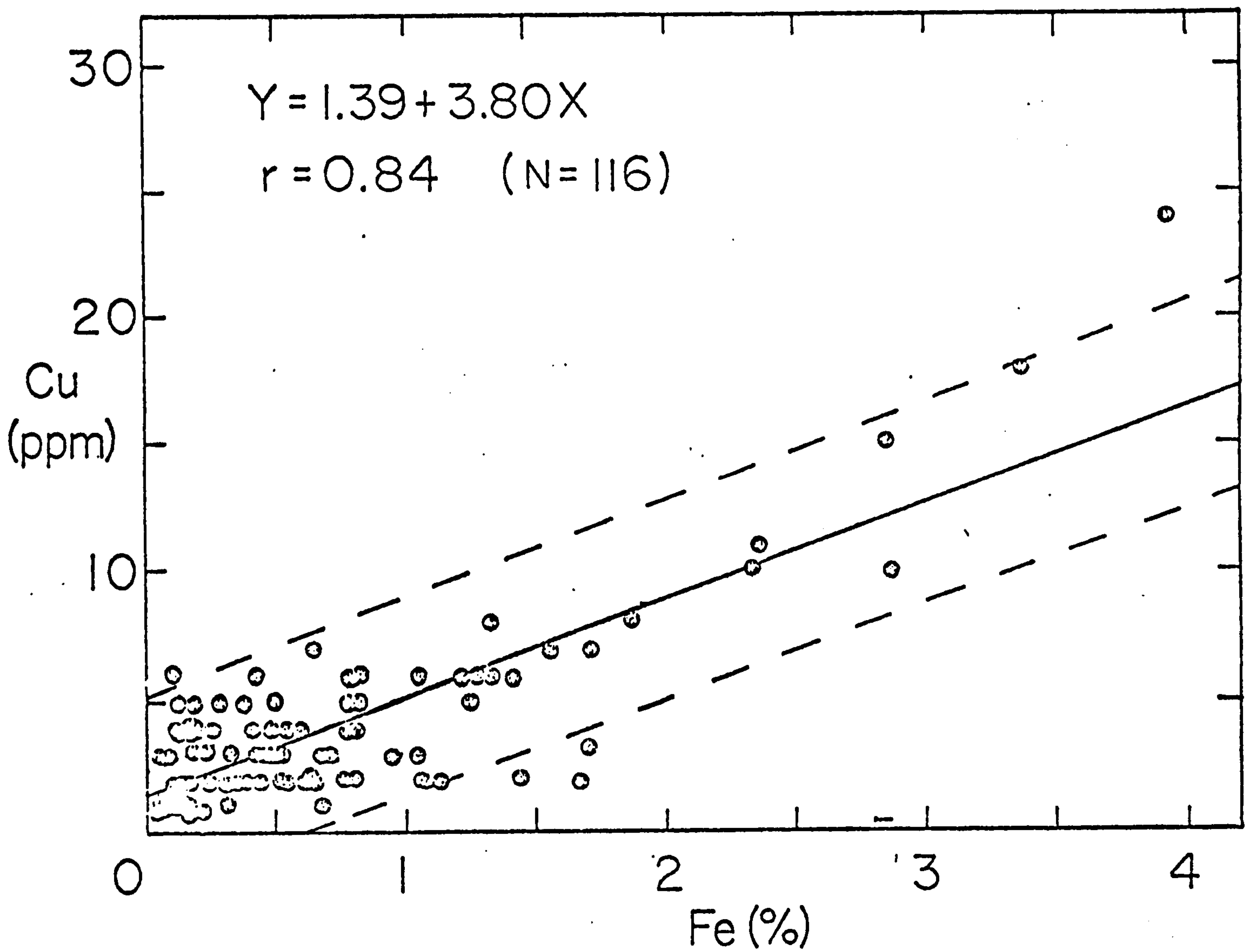


Fig. 7. Cu vs Fe scatter plot for MAFLA shelf sediments with 95% prediction interval.

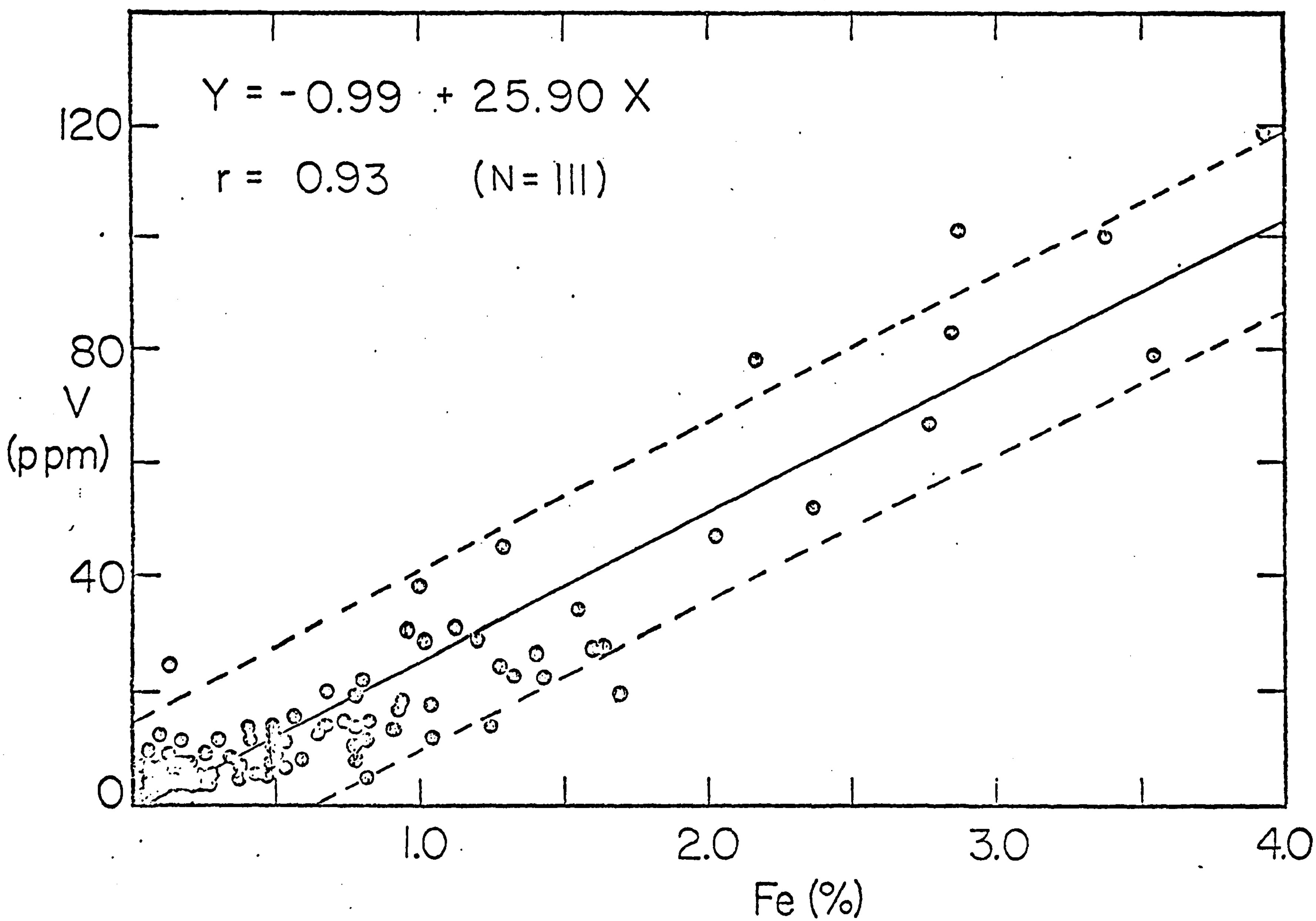
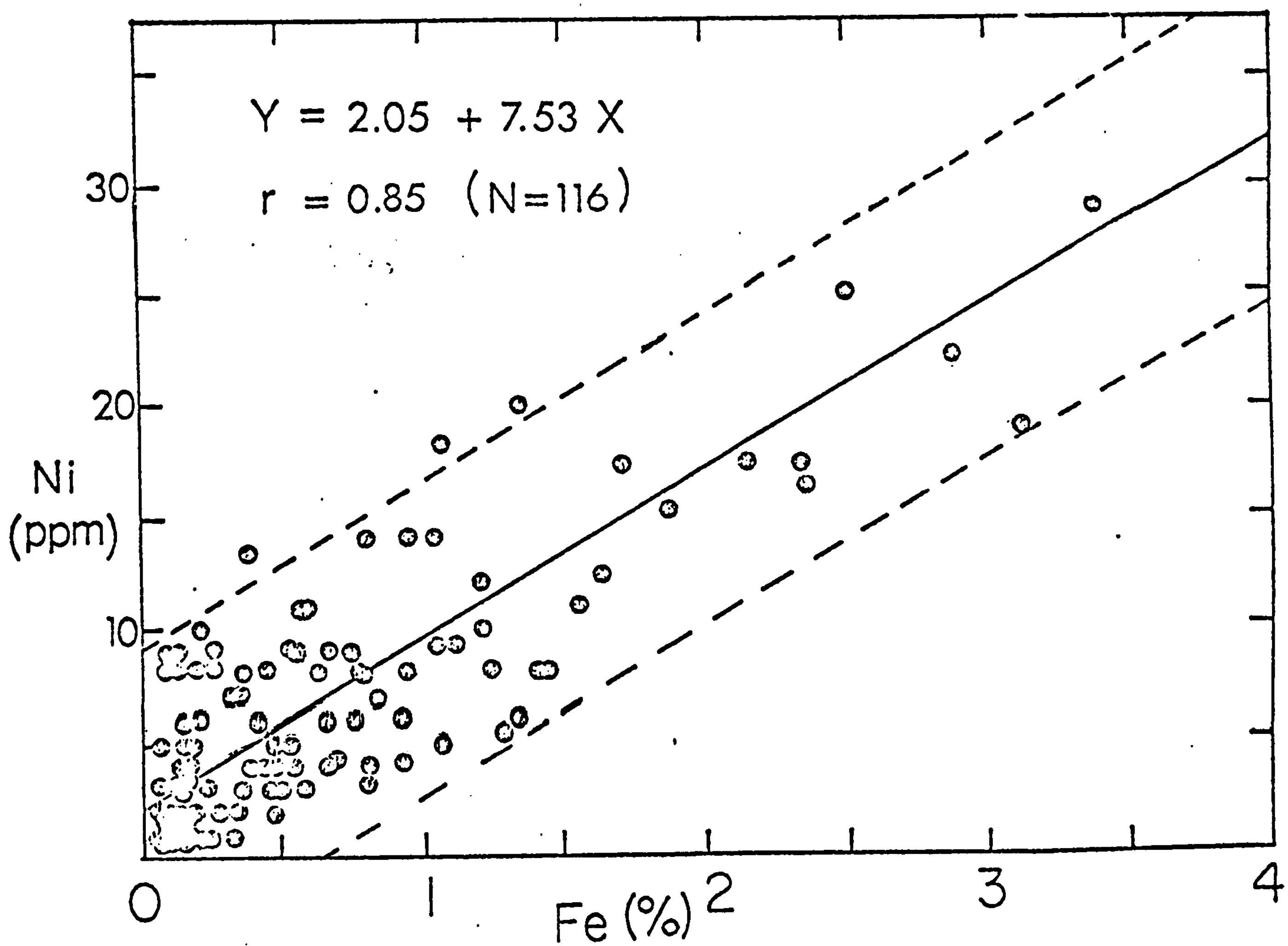


Fig. 10. V vs Fe scatter plot for MAFLA shelf sediments with 95% prediction interval.



Ni vs Fe scatter plot for MAFLA shelf sediments with 95% prediction interval.

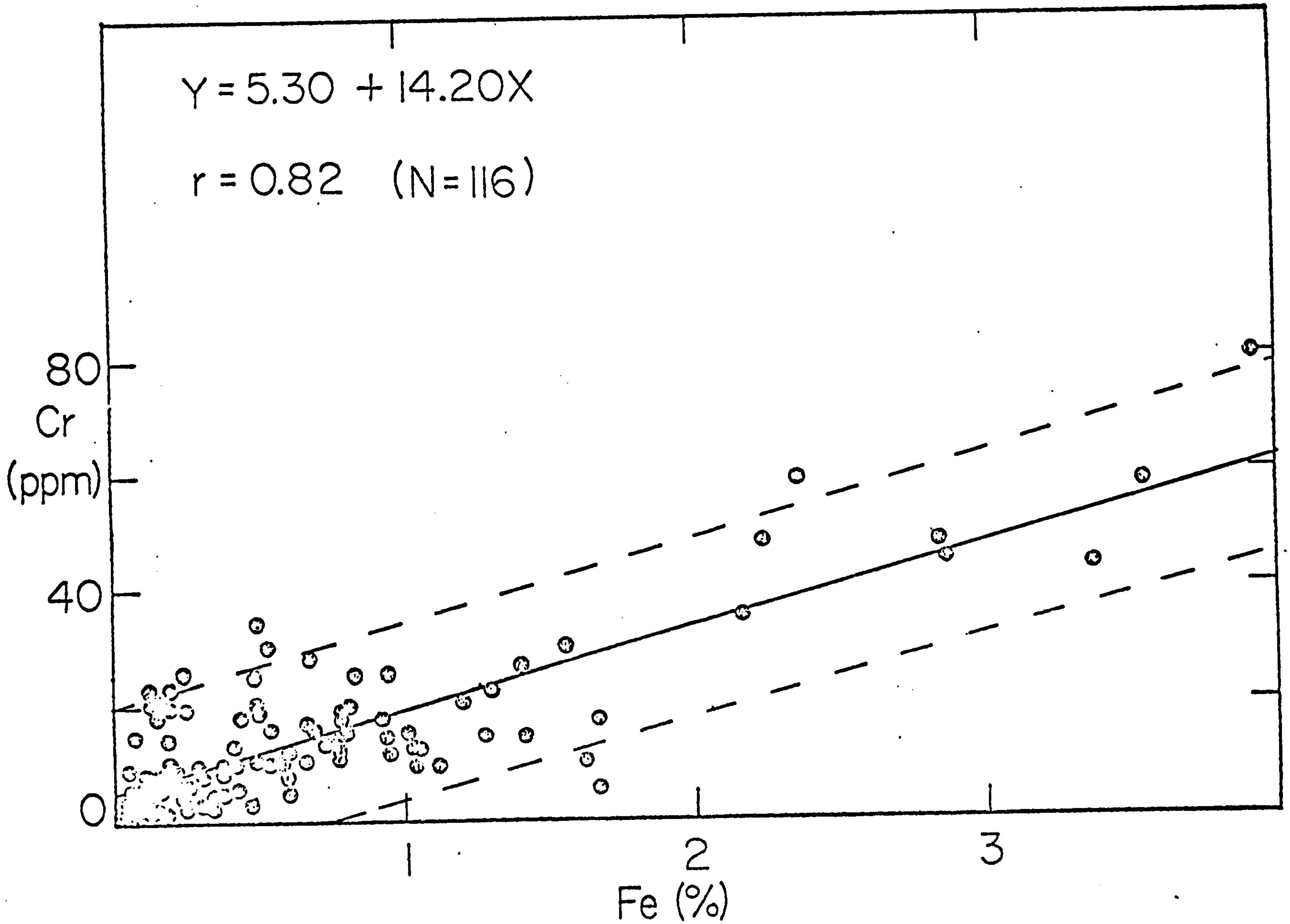


Fig. 9. Cr vs Fe scatter plot for MAFLA shelf sediments with 95% prediction interval.

future sediment analyses and show no present-day evidence of pollution. Any input of trace metals from oil-related activities would result in data points which deviate from linearity in the positive y-direction on the scatter plots, assuming that anthropogenic Fe input is not high enough to influence the normal sediment Fe content and that trace metal concentrations could be more easily and noticeably increased. Such an approach may be subject to difficulty in some of the extremely low iron Florida shelf areas; however, any appreciable metal increase to these areas will be observable due to the very low natural levels.

We have now characterized the basic metal distribution patterns for the MAFLA area and have shown that Fe may be used as an index for predicting trace metal concentrations, thus providing a means for assessing possible future anthropogenic input. The next step in this study should be to evaluate the form and "biological availability" of the naturally occurring toxic metals, so as to allow comparisons to man-introduced metals.

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APPENDIX I

Station locations for box cores taken during sampling periods 1 and 2 of the MAFLA Baseline Continuation Study

Sampling Period 1

Cruise Number	Station Number*	Latitude	Longitude	Date
10	2101	26°25'00"	82°15'01"	75 05 28
10	2102	26 25 00	82 25 01	75 05 28
10	2103	26 24 59	82 58 02	75 05 28
10	2104	26 24 59	83 23 00	75 05 29
10	2105	26 24 59	83 49 59	75 05 29
10	2106	26 24 58	84 15 03	75 05 29
10	2637	30 02 02	88 37 02	75 06 01
10	2638	29 55 31	88 33 29	75 06 02
10	2639	29 53 28	88 12 24	75 06 02
10	2640	29 43 31	87 54 32	75 06 02
10	2641	29 45 35	87 46 41	75 06 02
10	2642	29 40 28	87 37 01	75 06 02
10	2643	29 36 24	87 27 07	75 06 03
10	2644	29 36 10	87 23 32	75 06 03
10	2645	29 35 00	87 19 59	75 06 03
10	2528	29 54 59	86 05 00	75 06 04
10	2529	29 55 59	86 06 28	75 06 04
10	2530	29 50 59	86 06 30	75 06 04
10	2531	29 47 59	86 09 30	75 06 04
10	2532	29 45 58	86 12 28	75 06 04
10	2533	29 42 59	86 15 29	75 06 05
10	2534	29 39 59	86 16 59	75 06 05
10	2535	29 36 59	86 19 59	75 06 05
10	2536	29 30 01	86 25 01	75 06 05
10	2419	29 46 58	84 05 01	75 06 06
10	2420	29 51 48	84 11 01	75 06 06
10	2421	29 36 58	84 17 01	75 06 06
10	2422	29 30 00	84 27 01	75 06 07
10	2423	29 20 00	84 44 02	75 06 08
10	2424	29 13 00	84 59 59	75 06 08
10	2425	29 04 58	85 15 03	75 06 08
10	2426	28 57 57	85 23 01	75 06 08
10	2427	28 49 59	85 37 06	75 06 08
10	2318	29 04 59	83 45 01	75 06 09
10	2317	28 56 00	84 06 01	75 06 09
14	2207	27 56 59	83 09 00	75 07 22
14	2208	27 55 57	83 27 32	75 07 22
14	2209	27 52 30	83 34 00	75 07 22
14	2210	27 57 35	83 42 27	75 07 23
14	2211	27 56 29	83 53 02	75 07 23
14	2212	27 57 03	84 48 02	75 07 23
14	2313	28 24 04	84 14 53	75 07 24
14	2317	28 56 02	84 06 04	75 07 25
14	2316	28 42 01	84 20 01	75 07 25
17	2314	28 29 00	84 21 01	75 07 31
17	2315	28 34 00	84 20 13	75 07 31

* Second digit of station number indicates transect number as per Figure 1.

Sampling Period 2

Cruise Number	Station Number*	Latitude	Longitude	Date
21	2101	26°25.0'	82°15.0'	75 09 15
21	2102	26 25.0	82 25.0	75 09 15
21	2103	26 25.0	82 58.0	75 09 15
21	2104	26 25.0	83 23.0	75 09 15
21	2105	26 25.0	83 50.0	75 09 16
21	2106	26 25.0	84 15.0	75 09 16
21	2207	27 57.0	83 09.0	75 09 16
21	2208	27 56.0	83 27.5	75 09 16
21	2209	27 52.5	83 34.0	75 09 17
21	2210	27 57.5	83 42.5	75 09 17
21	2211	27 56.5	83 53.0	75 09 17
21	2212	27 57.0	84 48.0	75 09 17
21	2313	28 24.0	85 15.1	75 09 18
21	2314	28 29.0	84 21.0	75 09 19
21	2315	28 34.0	84 20.1	75 09 19
21	2316	28 42.0	84 20.0	75 09 19
21	2317	28 56.0	84 06.0	75 09 19
21	2318	29 05.1	83 45.1	75 09 19
21	2419	29 47.0	84 05.0	75 09 19
21	2420	29 42.0	84 11.0	75 09 19
21	2421	29 37.0	84 17.0	75 09 20
21	2422	29 30.0	84 27.0	75 09 20
21	2423	29 20.0	84 44.0	75 09 20
21	2424	29 13.0	85 00.0	75 09 21
21	2425	29 05.0	85 15.0	75 09 21
21	2426	28 58.0	85 23.0	75 09 21
21	2427	28 50.0	85 37.1	75 09 22
21	2528	29 54.9	86 05.0	75 09 25
21	2529	29 56.0	86 06.5	75 09 25
21	2530	29 50.9	86 06.4	75 09 25
21	2531	29 48.0	86 09.5	75 09 25
21	2532	29 45.9	86 12.3	75 09 25
21	2533	29 42.9	86 15.5	75 09 26
21	2534	29 40.0	86 17.0	75 09 26
21	2535	29 37.0	86 20.0	75 09 26
21	2536	29 30.0	86 24.9	75 09 26
21	2645	29 35.0	87 20.1	75 09 26
21	2644	29 36.2	87 23.5	75 09 27
21	2643	29 36.5	87 27.0	75 09 27
21	2642	29 40.5	87 37.0	75 09 27
21	2641	29 45.5	87 46.5	75 09 27
21	2640	29 43.5	87 54.5	75 09 27
21	2639	29 53.5	88 12.5	75 09 27
21	2638	29 55.5	88 33.5	75 09 28
21	2637	30 02.0	88 37.0	75 09 28

* Second digit of station number indicates transect number as per Figure 1.

DATA SUPPLEMENT TO THE PRELIMINARY FINAL REPORT OF HEAVY METAL ANALYSIS OF BOTTOM SEDIMENT ON THE WEST FLORIDA SHELF

Barium

31 August 1976

Principal Investigator:
B. J. Presley

Associate Investigator:
R. F. Shokes

INTRODUCTION

This supplement contains the results of barium analysis by instrumental neutron activation (INAA) of the 63 sediment samples collected during the two trace metal sampling periods of the MAFLA Baseline Continuation Study.

METHODS

The samples of this study were collected and prepared as described in Presley, et al. (1976). Barium was then determined by instrumental neutron activation analysis (INAA) on the whole sediments. This method included weighing about 0.2 g of dried sediment into a small (one gram capacity) polyethylene irradiation vial. After heat-sealing, the encapsulated samples were irradiated by the one MW Triga reactor at the Texas A&M University Nuclear Science Center for a 14 hr period. After a two-week delay period, the samples were counted 3000 sec using an Ortec Ge(Li) detector and a Canberra model 8700, 1024 channel multichannel pulse height analyzer. The peak of interest is the barium-131 gamma at 497 keV. Data reduction was done by comparison with USGS standard rock GSP-1 (1300 ppm Ba).

CONCLUSIONS

The results of barium analysis for the MAFLA Florida Shelf samples are listed in Table 1. For most of the samples, a barium peak was not detected and the results represent the limit of detection (3 σ) calculated

Table 1. Surface sediment barium concentrations
MAFLA Baseline Continuation Study.

Station Number	Set	Ba (ppm)*
2101	I	53±27
	II	-
2102	I	<30
2103	I	<32
2104	I	<34
	II	<86
2105	I	<36
2106	I	<44
	II	<41
2207	I	<41
	II	-
2208	I	<73
2209	I	<36
2210	II	<79
2211	I	<34
2212	I	<53
	II	<97

Station Number	Set	Ba (ppm)*
2313	I	<58
	II	<102
2314	II	<89
2315	II	-
2316	I	<34
2317	I	<41
2318	I	<65
	II	<47
2419	I	<30
2420	I	<32
2421	I	<35
2422	I	<35
2423	I	<54
2424	I	<24
	II	<59
2425	I	81±25
	II	<49

Station Number	Set	Ba (ppm)*
2426	I	<43
2427	I	<67
	II	<123
2528	I	<35
2529	I	<35
2530	I	<35
2531	I	<39
	II	<80
2532	I	<42
2533	I	<45
2534	I	<44
2535	I	<73
2536	I	<76
	II	<138
2637	I	321±76
	II	-

Table 1 continued.

Station Number	Set	Ba (ppm)*	Station Number	Set	Ba (ppm)*	Station Number	Set	Ba (ppm)*
2638	I	288±72	2641	I	<34	2644	I	<75
	II	288±77					II	<76
			2642	I	136±45			
2639	I	<59				2645	I	<59
	II	<89	2643	I	<72		II	107±34
				II	<86			
2640	I	<31						

Holmes, 1973 (N.W. GOM ave.)	509
Holmes, 1973 (Northeastern GOM shelf ave.)	140
Holmes, 1973 (S. Florida shelf ave.)	66
Horn and Adams, 1966 (Worldwide carbonate ave.)	35
Horn and Adams, 1966 (Mobile belt sediment)	233

*< indicates limit of detection determined for each sample

for each sample from the background activity surrounding the Ba-131 channel (497 keV). The only samples indicating significant detectable barium are located adjacent to the eastern influence of the Mississippi River and approach values documented for similar clay rich sediments (Holmes, 1973). As confirmation of this mineralogical distribution from the other samples, Table 1 of Presley, et al. (1976) shows only stations 2637 and 2638 of the 45 sampled to have a combination of high iron, low carbonate and high percent fines.

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HEAVY METAL ANALYSIS OF BOTTOM SEDIMENT FROM THE MAFLA RIG MONITORING AREA

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B. J. Presley

Associate Investigators:
M. C. Dobson
R. F. Shokes (data supplement)

INTRODUCTION

As one phase of the BLM-sponsored environmental evaluation of off-shore drilling activity, SUSIO has conducted a "rig-monitoring" study in order to examine the "before, during and after" effects on the localized environments of an actual drilling rig. This rig monitoring program was conducted at a site off Mustang Island, Texas, designated in Block 792 (27°37" 13.87" lat, 96°57' 55.17" long; Figure 1). Sampling was done on cruises conducted before (BLM Cruise #24, 15 November-4 December 1975), during (BLM Cruise #27, 6-21 January 1976) and after (BLM Cruise #36, 25 March-5 April 1976) the construction of a working rig at that site.

The sampling effort for this study was systematized by establishing a circular grid of 2000 m diameter containing 25 stations (Figure 2). Surface sediments were collected by divers during all three cruises and shipped to our laboratory for trace metal analysis (Ba, Cd, Cr, Cu, Fe, Pb, Ni, and V). These samples were identified within this report by the system used in Figure 2 and by the indication TS1, TS2, and TS3 signifying the three sampling cruises respectively.

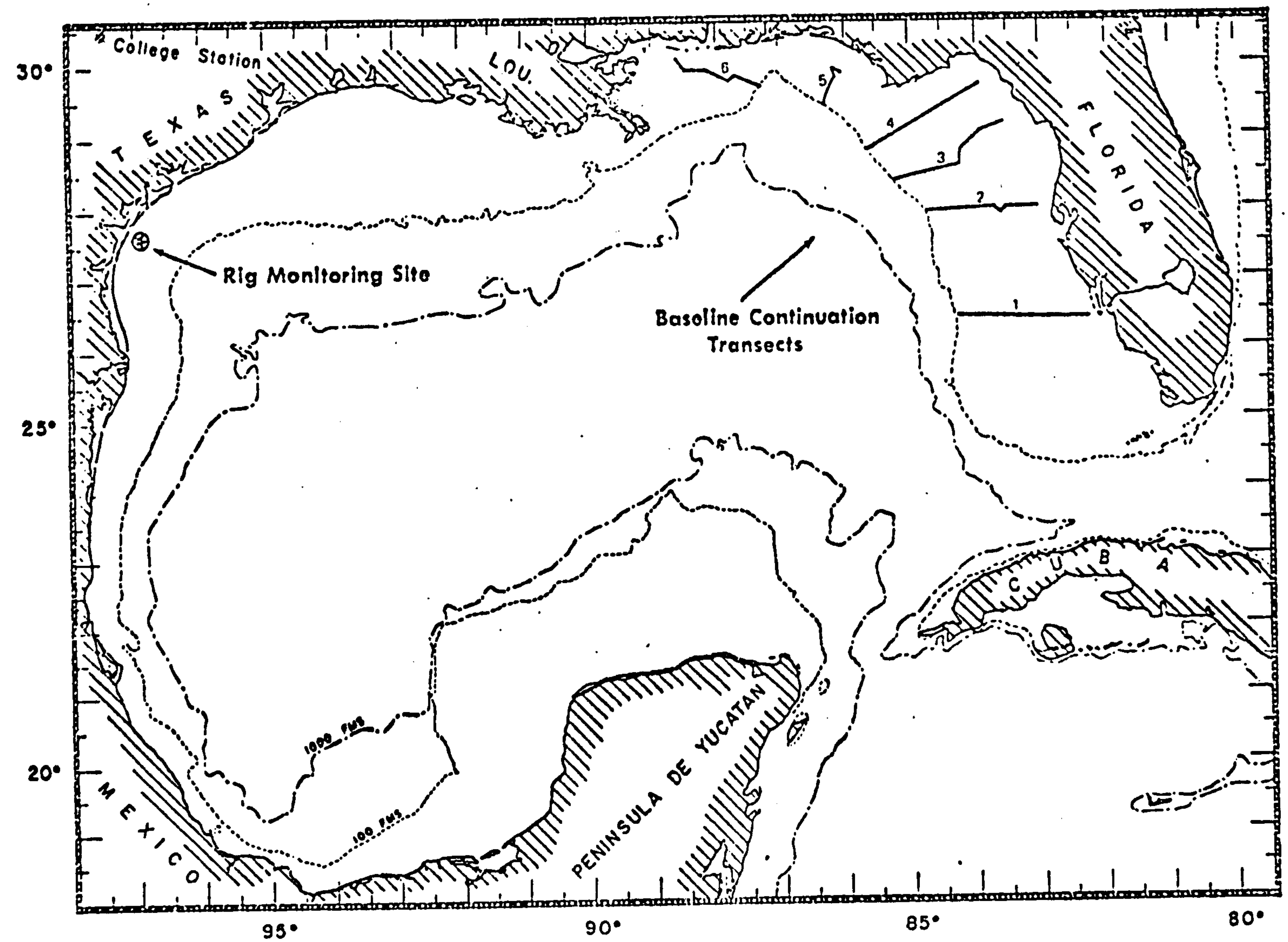

Fig. 1. Sampling areas for the MAFLA Rig Monitoring and Baseline Continuation Studies.

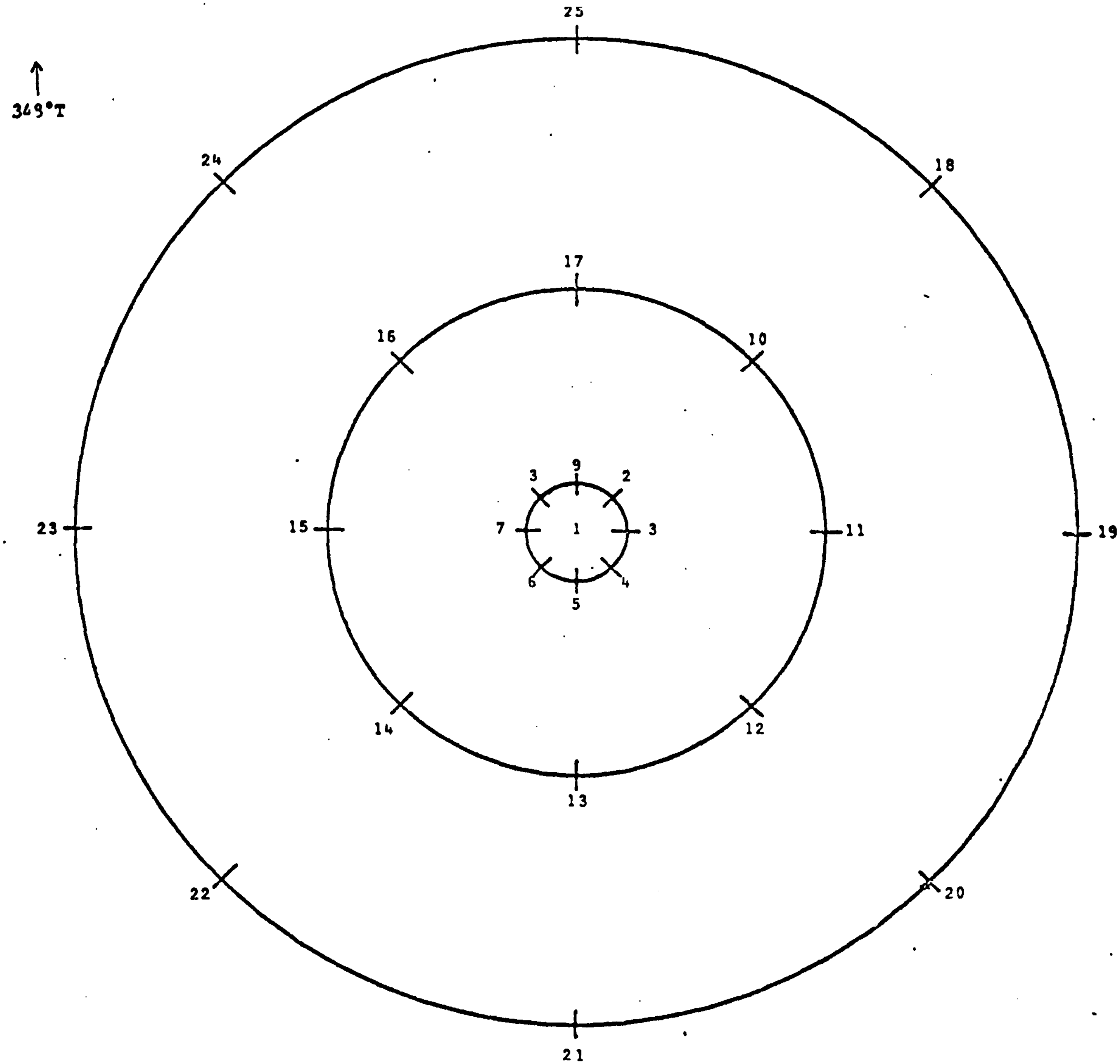

Fig. 2. Sampling grid for MAFLA Rig Monitoring Study. Numbers indicate station identification. Station 1 (rig site) is located at 27°37' 13.87" N, 96°57' 55.17"W; grid diameter is 2000 m.

This report contains data from the analyses of Cd, Cr, Cu, Fe, Pb, Ni, and V for all three sampling periods. The analysis of Ba in these samples has been repeatedly delayed by difficulties in scheduling the long irradiation times required at the Texas A&M Nuclear Science reactor. At the time of the writing of this report, however, all samples have been at last irradiated (within the last two weeks) and final results can therefore be guaranteed no later than 31 August 1976.

METHODS

Samples were prepared for analysis by initially drying the entire aliquot (∿50 g) of wet sediment at 105°C and then reducing it to a fine powder with a porcelain-lined Spex mixer-mill. Cadmium, chromium, copper, iron, lead and nickel were determined by atomic absorption spectrophotometry after dissolution of the sediment. Vanadium was determined by instrumental neutron activation analysis of the solid sample

For total dissolution, 0.5-1.0 g of finely powdered sediment were heated in a muffle furnace at 350°C for eight hours to ash the organic matter present. After heating, the samples were transferred to teflon beakers and four milliliters of HF (48%) and one milliliter of $HClO_4$ were added. The acid-sediment mixture was heated to near dryness. A second acid mixture (four milliliters HF, one milliliter $HClO_4$) was then added and again heated to near dryness. The residue was redissolved in two milliliters of 16 N HNO_3 and diluted to 25 ml with deionized water.

Cadmium, chromium, copper, lead, and nickel were determined by direct aspiration into a Jarrell-Ash model 810, two channel atomic absorption spectrophotometer. Iron was determined after appropriate dilution by the same technique. Background absorbance, due to molecular band absorption and light scattering, was monitored, where necessary, by simultaneously measuring the absorbance of a non-specific line and the analytical line of the element of interest. Cadmium and chromium concentrations were also checked by flameless atomic absorption techniques using a Perkins-Elmer 306 atomic absorption spectrophotometer equipped with an HGA-2100 graphite atomizer and a deuterium background corrector.

Instrumental neutron activation analysis was used for vanadium determination. Initial preparation for neutron activation involved accurately weighing about 0.2 g of sediment, which had been dried at 105°C, into a small one gram capacity polyethylene vial. The vial was heat-sealed to prevent any loss of sample during the analysis. The marked, encapsulated samples were irradiated by the one MW Triga reactor at the Texas A&M University Nuclear Science Center. Each sample was irradiated separately for two minutes. This process was facilitated by a pneumatic transport system which can rapidly transfer samples in and out of the reactor core. The sample vial was placed in a secondary polyethylene vial, together with an aluminum flux monitor, and transported to the core for the two minute time period.

After return of the sample and a one minute delay, the aluminum flux monitor was counted by a multichanneled pulse height analyzer. After an approximate delay period (usually three to five minutes, so that the dead time was <30%) the irradiated sediment sample was placed on an Ortec Ge(Li) detector and counted using a separate GEOS Quanta 4096 channel multichannel pulse height analyzer. The analyzer was set for a gain of 1.0 keV per channel and the 1434 keV^{52} peak analyzed. After a five minute counting period, the spectrum was stored on magnetic tape.

Data reduction was done using the program HEVESY (Schlueter, 1972). The program calculates peak intensities and converts these to concentration by comparison with appropriate USGS standard rocks (DTS-1 and AGV-1). Corrections are made for varying delay times, dead times and neutron fluxes.

Barium analysis is being carried out on the same samples prepared for vanadium determination. The samples have been irradiated for a 14 hr period in aluminum Swagelok tubes along with standards and blanks and set in a rotisserie in the reactor core. Once irradiated the samples require a period of two weeks to "cool" before they can be counted. At this time the samples are being or are about to be counted for two hours using an Ortec Ge(Li) detector and a Canberra model 8700, 1024 channel multichannel pulse height analyzer. The peak of interest is produced by xenon x-rays at 29 keV and is recorded in channel 160. Subsequent to counting, the spectral data is being stored on magnetic tape and will finally be reduced by the program HEVESY using USGS rocks standards W-1 and GSP-1 to calculate sample concentration.

USGS standard rocks were analyzed to obtain some idea of the accuracy of our analyses. Our agreement for replicate analyses is, overall, quite good with our results being consistently within 10% of the published values. Quadruplicate dissolutions and analyses were made on separate sediment aliquots for five of the study samples. Precisions were calculated by dividing standard deviation by mean and are as follows: Cd, 35%; Cr, 15%; Cu, 5%; Fe, 5%; Pb, 8%; Ni, 15%; and V, 20%.

RESULTS AND DISCUSSION

The 25 rig monitoring sampling stations can be reasonably assumed to represent a single sediment sample at any given time, because the uniform topography (grade = 1:2000) and sediment type in this small area (3.14 km^2) should give little natural variation in metal concentrations. Any localized perturbation such as that from drilling should, therefore, be easily detectable.

The results of sediment metal analyses made during this study are found in Tables 1 and 2. Inspection of the raw (Table 1) and averaged (Table 2) data reveals variations in the 74 samples in spite of the assumed uniformity referred to above. These variations are likely due to errors involved in analysis combined with minor mineralogical and textural differences certain to exist among the samples. In fact, the averaged values shown in Table 2 for both location and sampling period indicate standard deviations which are essentially those of the analytical techniques alone. (While nickel appears to have an observable change between the second and third sampling periods-TS2 and TS3 - the standard deviations of the three periods do overlap and we feel the "trend" is coincidental. Nickel is a particularly difficult element to analyze by atomic absorption, due to interferences by Al, Ca, and Fe, all of which exist in high concentration in these sediments and to losses in small amounts of insoluble residues which sometimes form during sample preparation. The nickel data must, therefore, be interpreted somewhat cautiously.)

To further support the observations just made, Table 3 lists the metal/iron ratio for Cu, Cr, Pb, Ni, and V (Cd is excluded due to its extremely low level and resulting higher degree of uncertainty). Being at percent levels and extremely immobile in oxic water, iron can be considered to act as a fairly good mineralogical indicator and to be immune to man-induced changes which might alter the more trace (ppm level) metals (Trefry, 1974). The data in Table 3 are treated from both an areal and temporal aspect and

Table 1. Rig Monitoring Study, Surface

Sediment Trace Metal Concentrations.

Station	Set	Ba (μg/g)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Ni (μg/g)	Pb (μg/g)	V (μg/g)
501101	TS1		.05	58.1	13.0	3.09	27.6	17.9	58
	TS3		.05	46.6	14.0	3.15	26.1	22.2	92
510201	TS1		.08	46.1	13.5	2.67	29.2	18.5	84
	TS2		.08	59.9	15.8	2.82	26.3	23.8	75
	TS3		.10	54.4	13.9	2.95	27.0	21.9	89
510301	TS1		.05	56.3	13.5	3.21	21.8	19.1	91
	TS2		.07	57.1	14.8	2.83	24.4	21.2	84
	TS3		.05	44.4	13.4	2.72	37.9	22.7	83
510401	TS1		.07	56.2	14.3	3.16	26.7	20.7	87
	TS2		.04	58.8	15.0	3.31	31.8	29.8	76
	TS3		.05	55.7	15.5	3.08	30.9	22.4	137
510501	TS1		.11	49.8	14.0	3.07	28.3	19.7	81
	TS2		.10	57.7	14.4	2.81	26.8	22.7	98
	TS3		.10	40.2	9.9	2.36	21.7	19.4	69
510601	TS1		.06	53.5	14.5	2.48	26.5	17.1	105
	TS2		.07	53.5	13.7	2.90	22.8	20.2	86
	TS3		.05	-	15.2	2.99	34.8	25.1	71
510701	TS1		.04	38.2	11.2	2.22	21.5	15.0	71
	TS2		.04	57.2	14.3	3.03	23.3	21.3	100
	TS3		.05	46.1	13.2	2.86	34.6	20.5	79
510801	TS1		.09	60.1	13.4	2.90	25.6	21.9	68
	TS2		.03	48.2	14.7	3.02	22.6	22.6	83
	TS3		.05	52.4	13.3	2.85	27.5	22.0	96

Table 1 (continued)

Station	Set	Ba (μg/g)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Ni (μg/g)	Pb (μg/g)	V (μg/g)
510901	TS1		.06	58.4	15.0	2.91	26.7	19.4	107
	TS2		.05	56.8	14.6	2.93	23.8	23.0	79
	TS3		.05	51.0	13.8	3.02	32.8	21.4	76
551001	TS1		.03	56.1	16.2	3.26	25.9	20.2	95
	TS2		.04	48.5	13.9	2.94	24.9	23.7	-
	TS3		.05	55.8	13.6	2.95	33.1	19.6	93
551101	TS1		.07	51.1	15.4	3.14	29.0	17.5	84
	TS2		.10	56.1	14.8	3.02	24.4	22.6	70
	TS3		.10	51.2	12.7	2.57	26.5	20.4	91
551201	TS1		.05	55.8	14.7	3.41	22.6	20.8	78
	TS2		.11	48.8	13.7	2.40	23.2	18.3	82
	TS3		.10	42.3	10.8	2.20	22.3	19.4	88
551301	TS1		.07	44.8	15.8	3.12	27.1	20.8	88
	TS2		.04	52.3	13.6	2.80	26.6	21.9	86
	TS3		.05	57.7	14.2	2.79	27.0	23.2	74
551401	TS1		.11	53.9	14.4	3.11	26.4	20.8	78
	TS2		.07	53.8	13.7	2.84	23.9	21.2	90
	TS3		.10	54.3	14.9	2.82	(37.0)	20.6	66
551501	TS1		.09	44.2	14.0	3.16	25.6	19.0	86
	TS2		.05	56.7	13.9	2.85	24.1	20.2	81
	TS3		.10	54.7	15.5	3.05	(43.0)	21.0	78
551601	TS1		.07	35.3	14.2	3.01	26.5	19.6	105
	TS2		.11	66.2	15.7	3.32	27.1	22.7	95
	TS3		.10	39.4	10.6	2.38	21.1	19.4	-
551701	TS1		.08	49.5	14.1	2.80	26.5	19.0	79
	TS2		.05	48.5	13.3	2.73	24.8	18.6	80
	TS3		.05	52.6	14.3	2.75	27.2	21.4	49

Table 1 (con

Station	Set	Ba (µg/g)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	(%)	(µg/g)	Pb (µg/g)	(µg/g)
591801	TS1		.04	49.8	13.3	2.62	24.4	20.0	68
	TS2		.06	57.7	14.7	2.91	24.5	21.5	76
	TS3		.05	54.7	14.0	2.85	28.0	22.8	97
591901	TS1		.09	46.2	14.1	2.75	26.2	17.7	93
	TS2		.10	58.4	13.6	3.00	23.1	20.6	104
	TS3		.10	57.8	14.8	3.00	33.5	23.8	95
592001	TS1		.06	43.0	13.0	2.08	23.4	18.1	67
	TS2		.12	55.5	13.8	3.10	23.4	20.5	82
	TS3		.10	61.8	13.9	2.89	(38.0)	21.8	61
592101	TS1		.06	38.0	13.7	2.87	26.0	18.7	109
	TS2		.05	59.9	14.0	3.12	23.2	22.8	100
	TS3		.05	57.8	14.7	3.20	31.1	22.9	99
592201	TS1		.03	54.3	15.2	3.25	24.6	20.7	98
	TS2		.10	59.5	15.2	3.04	24.9	22.6	85
	TS3		.05	60.5	14.6	2.91	28.3	22.2	86
592301	TS1		.05	32.1	11.3	2.73	19.8	18.1	-
	TS2		.07	63.5	15.2	3.19	24.8	23.4	70
	TS3		.05	59.5	15.3	3.14	32.2	25.5	95
592401	TS1		.12	50.4	15.1	2.89	27.1	20.2	110
	TS2		.06	57.8	14.2	3.19	23.8	22.9	77
	TS3		.10	54.6	15.8	2.83	(37.2)	27.5	71
592501	TS1		.07	56.2	15.0	3.17	24.4	20.4	101
	TS2		.04	46.8	11.8	2.52	21.0	21.0	73
	TS3		.05	55.4	15.5	2.90	33.0	21.8	108

Table 2. Rig Monitoring Study, Surface Sediment Trace Metal Concentrations Averaged at Each Station for all Three Sampling Periods (TS1, TS2, TS3.).

Station	Ba (µg/g)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (%)	Pb (µg/g)	Ni (µg/g)	V (µg/g)
500101		.05 ± 0	52.4 ± 8.1	13.5 ± .5	3.12 ±.04	20.1 ± 3.0	26.9 ± 1.1	75 ± 24
510201		.09 ± .01	53.5 ± 7.0	14.4 ± 1.2	2.81 ±.14	21.4 ± 2.7	27.5 ± 1.5	83 ± 7
510301		.06 ± .01	52.6 ± 7.1	13.9 ± .8	2.92 ±.26	21.0 ± 1.8	23.1 ± 1.8	86 ± 4
510401		.05 ± .02	56.9 ± 1.7	14.9 ± .6	3.18 ±.12	24.3 ± 4.8	29.8 ± 2.7	100 ± 33
510501		.10 ± .01	49.2 ± 8.8	12.8 ± 2.5	2.75 ±.36	20.6 ± 1.8	25.6 ± 3.5	83 ± 15
510601		.06 ± .01	53.5 ± -	14.5 ± .8	2.79 ±.27	20.8 ± 4.0	28.0 ± 6.2	87 ± 17
510701		.04 ± .01	47.2 ± 9.5	12.9 ± 1.6	2.70 ±.43	18.9 ± 3.4	26.5 ± 7.1	83 ± 15
510801		.06 ± .03	53.6 ± 6.0	13.8 ± .8	2.92 ±.09	22.2 ± .4	25.2 ± 2.5	82 ± 14
510901		.05 ± .01	55.4 ± 3.9	14.5 ± .6	2.95 ±.06	21.3 ± 1.8	27.8 ± 4.6	87 ± 17
551001		.04 ± .01	53.5 ± 4.3	14.6 ± 1.4	3.05 ±.18	21.2 ± 2.2	28.8 ± 4.5	94 ± 1
551101		.09 ± .02	52.8 ± 2.9	14.3 ± 1.4	2.91 ±.30	20.2 ± 2.6	26.6 ± 2.3	82 ± 11
551201		.09 ± .03	49.0 ± 6.8	13.1 ± 2.0	2.67 ±.65	19.5 ± 1.3	22.7 ± .5	83 ± 5
551301		.05 ± .02	51.6 ± 6.5	14.5 ± 1.1	2.90 ±.19	22.0 ± 1.2	26.9 ± .3	83 ± 8
551401		.09 ± .02	54.0 ± .3	14.3 ± .6	2.92 ±.16	20.9 ± .3	25.2 ± 1.8	78 ± 12
551501		.08 ± .03	51.9 ± 6.7	14.5 ± .9	3.02 ±.16	20.1 ± 1.0	24.9 ± 1.1	82 ± 4
551601		.09 ± .02	47.0 ±16.8	13.5 ± 2.6	2.90 ±.48	20.6 ± 1.9	24.9 ± 3.3	100 ± 5
551701		.06 ± .02	50.2 ± 2.1	13.9 ± .5	2176 ±.04	19.7 ± 1.5	26.2 ± 1.2	69 ± 18

Table 2 (continued)

Station	Ba (μg/g)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Pb (μg/g)	Ni (μg/g)	V (μg/g)
591801		.05 ± .01	54.1 ± 4.0	14.0 ± .7	2.79 ± .15	21.4 ± 1.4	25.6 ± 2.1	80 ± 15
591901		.10 ± .01	54.1 ± 6.9	14.2 ± .6	2.92 ± .14	20.7 ± 3.1	27.6 ± 5.3	97 ± 6
592001		.09 ± .03	53.4 ± 9.6	13.6 ± .5	2.69 ± .54	20.1 ± 1.9	23.4 ± 0	70 ± 11
592101		.05 ± .01	51.9 ±12.1	14.1 ± .5	3.06 ± .17	21.5 ± 2.4	26.8 ± 4.0	103 ± 6
592201		.06 ± .04	58.1 ± 3.3	15.0 ± .4	3.07 ± .17	21.8 ± 1.0	25.9 ± 2.1	90 ± 7
592301		.06 ± .01	51.7 ±17.1	13.9 ± 2.3	3.02 ± .25	22.3 ± 3.8	25.6 ± 6.2	83 ± 18
592401		.09 ± .03	54.3 ± 3.7	15.0 ± .8	2.97 ± .19	23.5 ± 3.7	25.5 ± 2.3	86 ± 21
592501		.05 ± .01	52.8 ± 5.2	14.1 ± 2.0	2.86 ± .33	21.1 ± .7	26.1 ± 6.2	94 ± 19
Average of all stations		.07 ± .03 (n=74)	52.6 ± 6.9 (n=73)	14.1 ± 1.2 (n=74)	2.91 ± .27 (n=74)	21.1 ± 2.3 (n=74)	26.2 ± 3.4 (n=69)	85 ± 14 (n=71)
Trefry, 1974 (ave. NW GOM; hot HNO_3-HCl leach)	1.5	.2	-	7.2		9.8	15.9	-

Table 2 (continued)

Station	Ba (μg/g)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Pb (μg/g)	Ni (μg/g)	V (μg/g)
TS1 Average		.07 ± .02 (n=25)	49.5 ± 7.8 (n=25)	14.0 ± 1.2 (n=25)	3.00 ± .3 (n=25)	19.2 ± 1.6 (n=25)	25.6 ± 2.3 (n=25)	87 ± 15 (n=24)
TS2 Average		.07 ± .03 (n=25)	55.4 ± 5.2 (n=25)	14.2 ± .9 (n=25)	2.90 ± .3 (n=25)	22.0 ± 2.2 (n=25)	24.6 ± 2.1 (n=25)	84 ± 10 (n=24)
TS3 Average		.07 ± .03 (n=24)	52.7 ± 6.4 (n=22)	14.0 ± 1.7 (n=24)	2.90 ± .3 (n=24)	21.9 ± 2.0 (n=23)	29.1 ± 4.3 (n=19)	85 ± 18 (n=23)

Table 3. Rig monitoring study, surface sediment metal/iron ratios.

Station	Sample Set	Ba/Fe (x 10^4)	Cr/Fe (x 10^4)	Cu/Fe (x 10^4)	Fe (%)	Pb/Fe (x 10^4)	Ni/Fe (x 10^4)	V/Fe (x 10^4)
500101	TS1	181	18.8	4.2	3.09	5.8	8.9	18.8
	TS2	-	14.8	4.4	3.15	7.1	8.3	29.2
	TS3	524	-	-	-	-	-	-
	Average	352	16.8±2.8	4.3±0.1	3.12±0.04	6.4±0.9	8.6±0.4	29.2
510201	TS1	199	17.3	5.1	2.67	6.9	10.9	31.5
	TS2	1,464	21.2	5.6	2.82	8.4	9.3	26.6
	TS3	572	18.4	4.7	2.95	7.4	9.2	30.2
	Average	745	19.0±2.0	5.1±0.5	2.81±0.14	7.6±0.8	9.8±1.0	29.4±2.5
510301	TS1	163	17.5	4.2	3.21	6.0	6.8	28.4
	TS2	291	20.2	5.2	2.83	7.5	8.6	29.7
	TS3	366	16.3	4.9	2.72	8.4	(13.9)	30.5
	Average	273	18.0±2.0	4.8±0.5	2.92±0.26	7.3±1.2	7.7±1.3	29.5±1.1
510401	TS1	154	17.8	4.5	3.16	6.6	8.5	27.5
	TS3	391	17.8	4.5	3.31	9.0	9.6	23.0
	TS3	-	18.1	5.0	3.08	7.3	10.0	44.5
	Average	273	17.9±0.2	4.7±0.3	3.18±0.12	7.6±1.2	9.4±0.8	31.7±11.3
510501	TS1	227	15.9	4.6	3.07	6.4	9.2	26.4
	TS2	217	20.5	5.1	2.81	8.1	9.5	35.9
	TS3	-	17.0	4.2	2.36	8.2	9.2	29.2
	Average	222	17.8±2.4	4.6±0.5	2.75±0.36	7.6±1.0	9.3±0.2	30.5±4.9
510601	TS1	211	21.6	5.9	2.48	6.9	10.7	42.3
	TS2	445	18.5	4.7	2.90	7.0	7.9	29.7
	TS3	1,062	-	5.1	2.99	8.4	11.6	23.8
	Average	573	20.1±2.2	5.2±0.6	2.79±0.27	7.4±0.8	10.1±1.9	31.9±9.5

Table 3. Continued.

Station	Sample Set	Ba/Fe (x 10^4)	Cr/Fe (x 10^4)	Cu/Fe (x 10^4)	Fe (%)	Pb/Fe (x 10^4)	Ni/Fe (x 10^4)	V/Fe (x 10^4)
510701	TS1	359	17.2	5.1	2.22	6.8	9.7	32.0
	TS2	312	18.9	4.7	3.03	7.0	7.7	33.0
	TS3	-	16.1	4.6	2.86	7.2	12.1	27.6
	Average	336	17.4±1.4	4.8±0.3	2.70±0.43	7.0±0.2	9.8±2.2	30.9±2.9
510801	TS1	252	20.7	4.6	2.90	7.6	8.8	23.5
	TS2	264	16.0	4.9	3.02	7.5	7.5	27.5
	TS3	-	18.4	4.7	2.85	7.7	9.7	33.7
	Average	258	18.4±2.4	4.7±0.2	2.92±0.09	7.6±0.1	8.7±1.1	28.2±5.1
510901	TS1	183	20.1	5.2	2.91	6.7	9.2	36.8
	TS2	375	19.4	5.0	2.93	7.9	8.1	27.0
	TS3	1,053	16.9	4.6	3.02	7.1	10.9	25.2
	Average	537	18.8±1.7	4.9±0.3	2.95±0.06	7.2±0.6	9.4±1.4	29.7±6.2
551001	TS1	148	17.2	5.0	3.26	6.2	7.9	29.1
	TS2	203	16.5	4.7	2.94	8.1	8.5	-
	TS3	251	18.9	4.6	2.95	6.6	11.2	31.5
	Average	201	17.5±1.2	4.8±0.2	3.05±0.18	7.0±1.0	9.2±1.8	30.3±1.7
551101	TS1	164	16.3	4.9	3.14	5.6	9.2	26.8
	TS2	194	18.6	4.9	3.02	7.5	8.1	23.2
	TS3	-	19.9	4.9	2.57	7.9	10.3	35.4
	Average	179	18.3±1.8	4.9	2.91±0.30	7.0±1.2	9.2±1.1	28.5±6.3
551201	TS1	-	16.4	4.3	3.41	6.1	6.6	22.9
	TS2	273	20.3	5.7	2.40	7.6	9.7	34.2
	TS3	-	19.2	4.9	2.20	8.8	10.1	40.0
	Average	273	18.6±2.0	5.0±0.7	2.67±0.65	7.5±1.4	8.8±1.9	32.4±8.7

Table 3. Continued.

Station	Sample Set	Ba/Fe (x 10^4)	Cr/Fe (x 10^4)	Cu/Fe (x 10^4)	Fe (%)	Pb/Fe (x 10^4)	Ni/Fe (x 10^4)	V/Fe (x 10^4)
551301	TS1	179	14.4	5.1	3.12	6.7	8.7	28.2
	TS2	242	18.7	4.9	2.80	7.8	9.5	30.7
	TS3	-	20.7	5.1	2.79	8.3	9.7	26.5
	Average	211	17.9±3.2	5.0±0.1	2.90±0.19	7.6±0.8	9.3±0.5	28.5±2.1
551401	TS1	182	17.3	4.6	3.11	6.7	8.5	25.1
	TS2	-	18.9	4.8	2.84	7.5	8.4	31.7
	TS3	213	19.3	5.3	2.82	7.3	(13.1)	23.4
	Average	198	18.5±1.1	4.9±0.4	2.92±0.16	7.2±0.4	8.5±0.1	26.7±4.4
551501	TS1	196	14.0	4.4	3.16	6.0	8.1	27.2
	TS2	205	19.9	4.9	2.85	7.1	8.5	28.4
	TS3	178	17.9	5.1	3.05	6.9	(14.1)	25.6
	Average	193	17.3±3.0	4.8±0.4	3.02±0.16	6.7±0.6	8.3±0.2	27.1±1.4
551601	TS1	173	11.7	4.7	3.01	6.5	8.8	34.9
	TS2	193	19.9	4.7	3.32	6.8	8.2	28.6
	TS3	-	16.6	4.5	2.38	8.2	8.9	-
	Average	183	18.3±2.3	4.6±0.1	2.90±0.48	7.2±0.9	8.6±0.4	31.8±4.5
551701	TS1	193	17.7	5.0	2.80	6.8	9.5	28.2
	TS2	199	17.8	4.9	2.73	6.8	9.1	29.3
	TS3	277	19.1	5.2	2.75	7.8	9.9	17.8
	Average	223	18.2±0.8	5.0±0.2	2.76±0.04	7.1±0.6	9.5±0.4	28.8±0.8
591801	TS1	248	19.0	5.1	2.62	7.6	9.3	26.0
	TS2	244	19.8	5.1	2.91	7.4	8.4	26.1
	TS3	-	19.2	4.9	2.85	8.0	9.8	34.0
	Average	246	19.3±0.4	5.0±0.1	2.79±0.14	7.7±0.3	9.2±0.7	28.7±4.6

Table 3. Continued.

Station	Sample Set	Ba/Fe (x 10^4)	Cr/Fe (x 10^4)	Cu/Fe (x 10^4)	Fe (%)	Pb/Fe (x 10^4)	Ni/Fe (x 10^4)	V/Fe (x 10^4)
591901	TS1	192	16.8	5.1	2.75	6.4	9.5	33.8
	TS2	267	19.5	4.5	3.00	6.9	7.7	34.7
	TS3	211	19.3	4.9	3.00	7.9	11.2	31.7
	Average	223	18.5±1.5	4.8±0.3	2.92±0.14	7.1±0.8	9.5±1.8	33.4±1.5
592001	TS1	266	20.7	6.3	2.08	8.7	11.3	32.2
	TS2	250	17.9	4.5	3.10	6.6	7.6	26.5
	TS3	207	21.4	4.8	2.89	7.5	(13.2)	21.1
	Average	241	20.0±1.9	5.2±1.0	2.69±0.54	7.6±1.1	9.5±2.6	26.6±5.6
592101	TS1	230	(13.2)	4.8	2.87	6.5	9.1	38.0
	TS2	225	19.2	4.5	3.12	7.3	7.4	32.1
	TS3	174	18.1	4.6	3.20	7.2	9.4	30.9
	Average	210	18.7±0.8	4.6±0.2	3.06±0.17	7.0±0.4	8.7±1.2	33.7±3.8
592201	TS1	173	16.7	4.7	3.25	6.4	7.6	30.2
	TS2	239	19.6	5.0	3.04	7.4	8.2	28.0
	TS3	202	20.8	5.0	2.91	7.6	9.7	29.6
	Average	205	19.0±2.1	4.9±0.2	3.07±0.17	7.1±0.6	8.5±1.1	29.3±1.1
592301	TS1	191	(11.8)	4.1	2.73	6.6	7.3	-
	TS2	186	19.8	4.8	3.19	7.3	7.8	21.9
	TS3	176	19.0	4.9	3.14	8.1	10.3	30.3
	Average	184	19.4±0.4	4.6±0.4	3.02±0.25	7.3±0.8	8.5±1.6	26.1±5.9
592401	TS1	-	17.4	5.2	2.89	7.0	9.4	38.1
	TS2	198	18.1	4.5	3.19	7.2	7.5	24.1
	TS3	236	19.3	5.6	2.83	(9.7)	(13.1)	25.1
	Average	217	18.3±1.0	5.1±0.6	2.97±0.19	7.1±0.1	8.5±1.3	29.1±7.8

Table 3. Continued.

Station	Sample Set	Ba/Fe (x 10^4)	Cr/Fe (x 10^4)	Cu/Fe (x 10^4)	Fe (%)	Pb/Fe (x 10^4)	Ni/Fe (x 10^4)	V/Fe (x 10^4)
592501	TS1	-	17.7	4.7	3.17	6.4	7.7	31.9
	TS2	284	18.6	4.7	2.52	8.3	8.3	29.0
	TS3	199	19.1	5.3	2.90	7.5	11.4	37.2
	Average	242	18.5±0.7	4.9±0.4	2.86±0.33	7.4±1.0	9.1±2.0	32.7±4.2
Average of all stations		280	18.4±1.7 (n=70)	4.9±0.4 (n=74)	2.91±0.27 (n=74)	7.3±0.7 (n=73)	9.1±1.2 (n=69)	29.8±4.8 (n=69)
Trefry, 1974 (ave. N.W. GOM; hot HNO_3-HCl leach)				4.8 *T/P=0.98	1.5 *T/P=0.52	6.5 *T/P=0.89	10.6 *T/P=1.16	
TS1 Average		192	16.5±1.6	4.7±0.4	3.0±0.3	6.4±0.7	8.9±1.2	30.0±5.5
TS2 Average		345	19.1±1.7	4.9±0.3	2.9±0.2	7.6±0.7	8.5±0.7	28.8±3.7
TS3 Average		361	18.2±1.7	4.8±0.4	2.9±0.3	7.6±0.8	10.2±1.0	29.8±6.1

* T/P = the ratio of Trefry's values to the values of this report.

the ratioing technique refines the statistical variations even further than that of the raw data (Tables 1 and 2). Figures 3 through 8 illustrate the data of Table 3 from an areal perspective and verify that no spatial trends exist in the metal concentrations.

In conclusion, there is evidently very little real difference in the trace metal concentration in the 25 sampling sites utilized in this study, nor are there any observable changes in the trace metal levels at each site over the three sampling periods. There is no evidence from our data which would indicate any effects from the rig installation and operation. Barium concentrations have not yet been determined for these samples and it might well show an observable effect of drilling activity, but this statement is pure speculation until the barium analyses are completed.

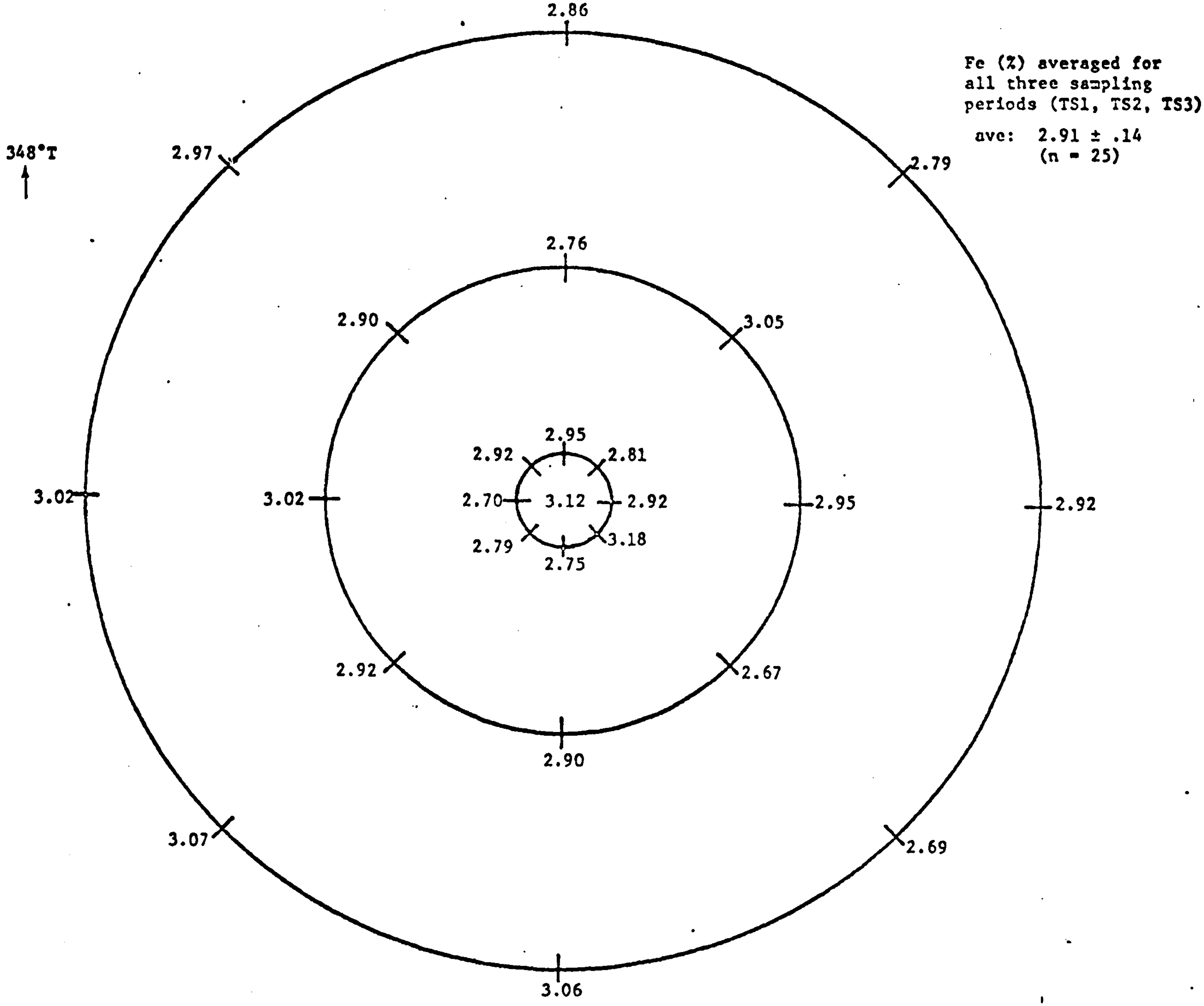

Fig. 3. Surface sediment iron (%) averaged for all three sampling periods (TS1, TS2, TS3) at each station.

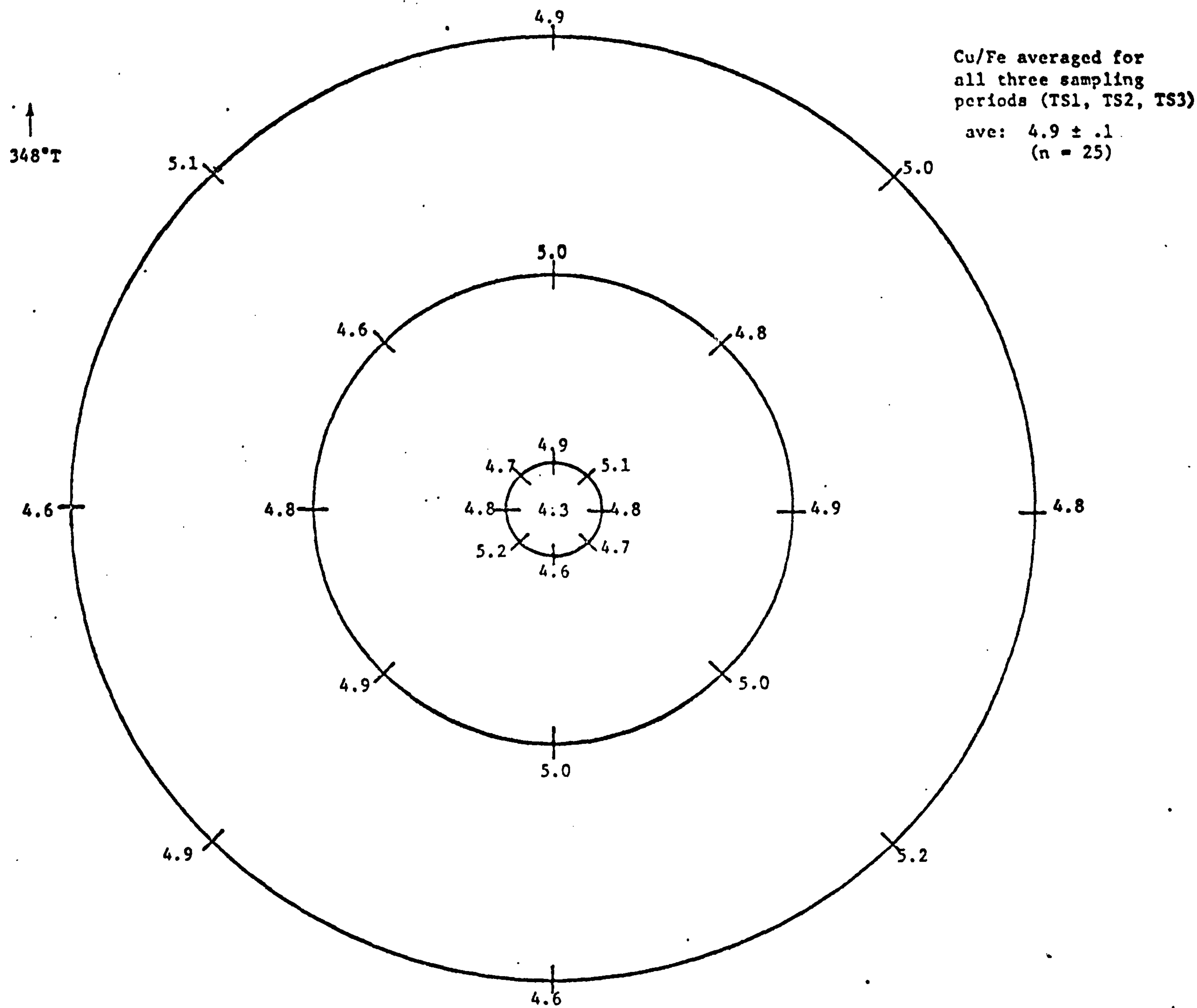

Fig. 4. Surface sediment Cu/Fe (x 10^4) averaged for all three sampling periods at each station.

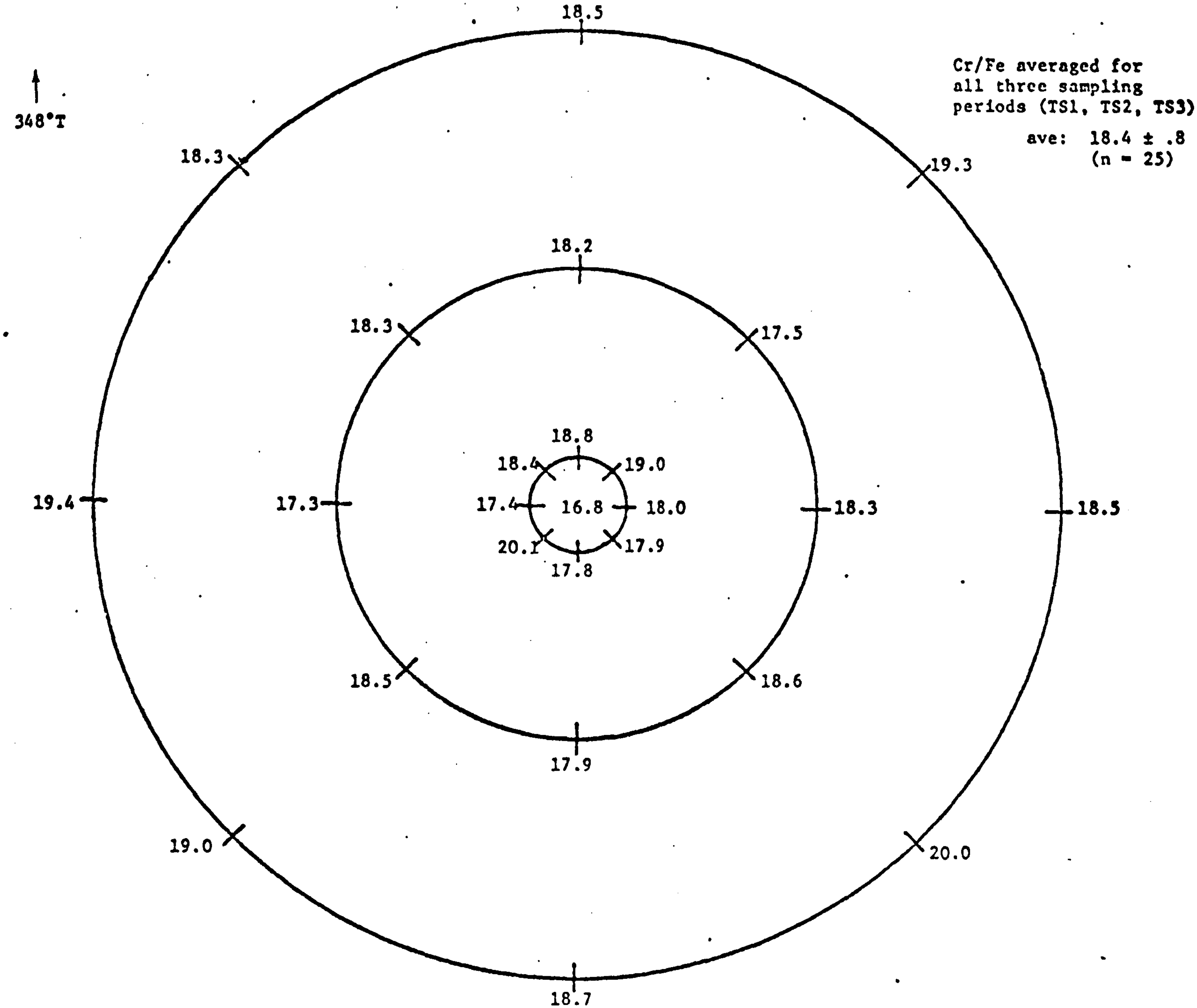

Fig. 5. Surface sediment Cr/Fe (x 10^4) averaged for all three sampling periods at each station.

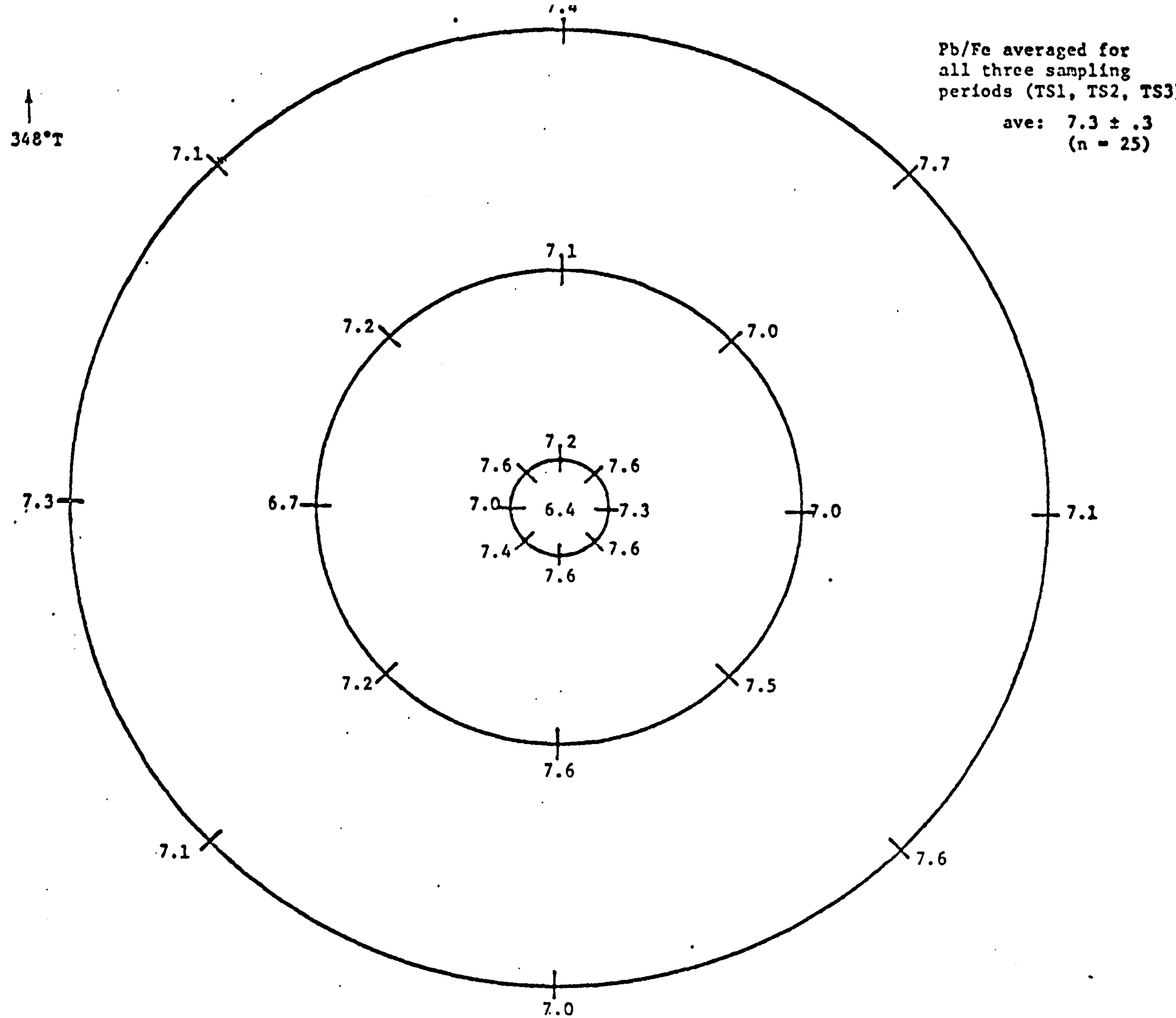

Fig. 6. Surface sediment Pb/Fe (x 10^4) averaged for all three sampling periods at each station.

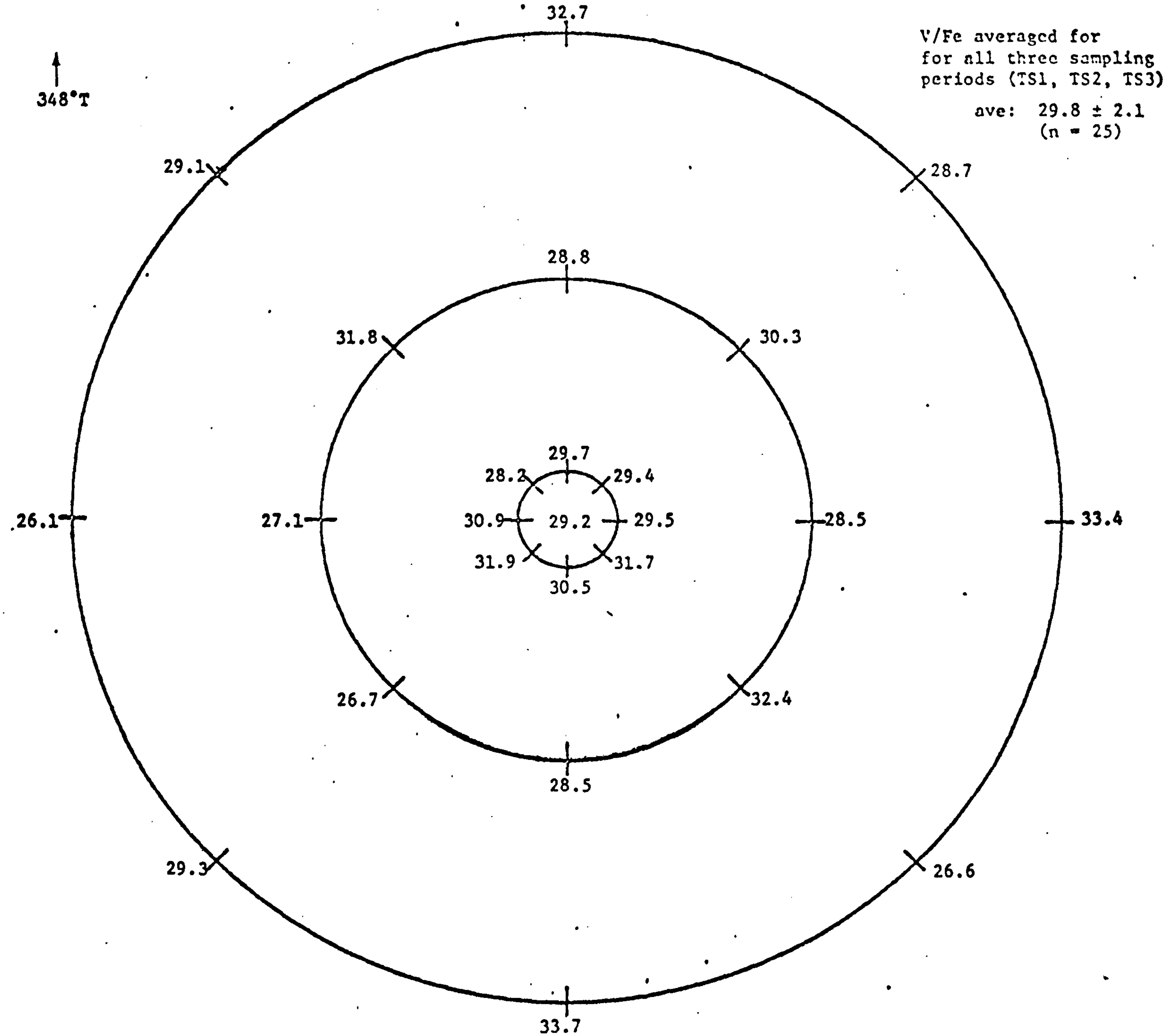

Fig. 7. Surface sediment V/Fe (x 10^4) averaged for all three sampling periods at each station.

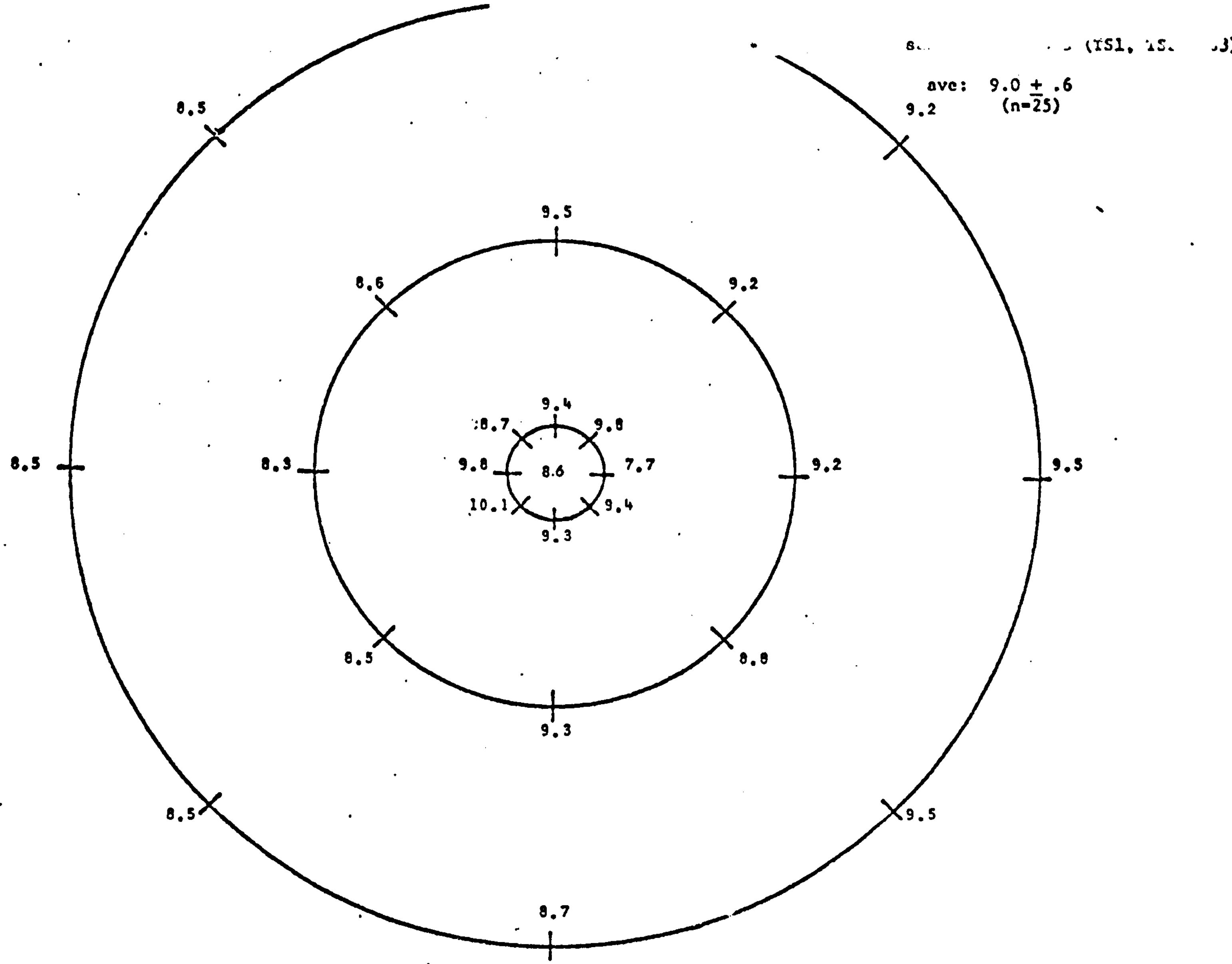

Fig. 8. Surface sediment Ni/Fe (x 10^4) averaged for all three sampling periods at each station.

REFERENCE

Trefry, J. H. 1974. "The Distribution of Potentially Toxic Heavy Metals in the Sediments of San Antonio Bay and the Northwest Gulf of Mexico." M.S. Thesis, Texas A&M University.

DATA SUPPLEMENT TO THE PRELIMINARY FINAL REPORT OF HEAVY METAL ANALYSIS OF BOTTOM SEDIMENT FROM THE MAFLA RIG MONITORING AREA

Barium

31 August 1976

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INTRODUCTION

Our analysis of barium in the sediments from the MAFLA Rig Monitoring site are now essentially complete and can be interpreted in the context of other metal values and the temporal/spatial sampling scheme employed (Presley, et al., 1976). The potential significance of barium results from its high levels in barite ($BaSO_4$) used in drilling mud, and the expectation that some trend in the sediment barium levels might be seen in correlation with sampling period and distance from the drilling site.

Samples represented by the 14 voids in Table 1 are currently being reprocessed and will be reported no later than 30 September 1976. These samples were inadvertently lost due to gas inclusions rupturing the sample vials during the 14 hr irradiation period. These missing numbers are not expected to alter our interpretation of the barium data, although they presumably will bolster the observed trends.

METHOD

The samples of this study were collected and prepared as described in Presley, et al. (1976). Barium was then determined by instrumental neutron activation analysis (INAA) on the whole sediments. This method included weighing about 0.2 g of dried sediment into a small (one gram capacity) polyethylene irradiation vial. After heat-sealing, the encapsuplated samples were irradiated by the one MW Triga reactor at the Texas A&M University Nuclear Science Center for a 14 hr period. After a two-week delay period, the samples were counted 3000 sec using an Ortec GE(Li)

Table 1

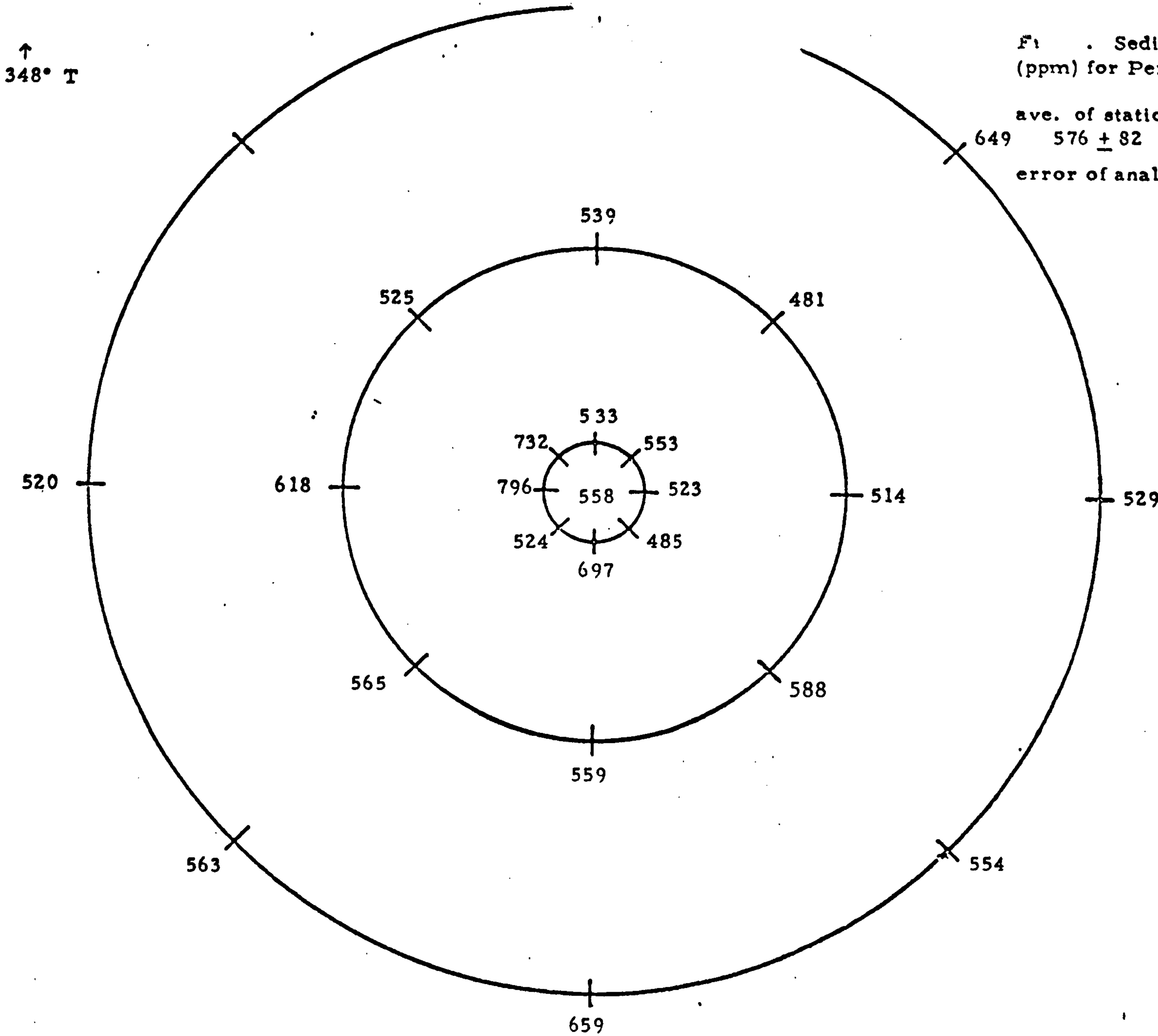
Rig Monitoring Study, Surface
Sediment Trace Metal Concentration

Station	Set	Ba (ppm)
500101	TS1	558±101
	TS2	- - -
	TS3	1651±114
510201	TS1	531±73
	TS2	4127±125
	TS3	1688±137
510301	TS1	523±103
	TS2	822±112
	TS3	1050±102
510401	TS1	485±73
	TS2	1295±95
	TS3	- - -
510501	TS1	697±119
	TS2	610±113
	TS3	- - -
510601	TS1	524±89
	TS2	1290±74
	TS3	3176±136
510701	TS1	796±112
	TS2	947±81
	TS3	- - -
510801	TS1	732±107
	TS2	797±97
	TS3	- - -
510901	TS1	533±98
	TS2	1098±94
	TS3	3181±127
551001	TS1	481±109
	TS2	596±85
	TS3	738±150
551101	TS1	514±95
	TS2	585±81
	TS3	- - -
551201	TS1	- - -
	TS2	656±80
	TS3	- - -
551301	TS1	559±95
	TS2	677±131
	TS3	- - -
551401	TS1	565±127
	TS2	- - -
	TS3	600±99
551501	TS1	618±97
	TS2	583±73
	TS3	543±74
551601	TS1	521±99
	TS2	642±79
	TS3	- - -
551701	TS1	539±85
	TS2	542±143
	TS3	761±144
591801	TS1	649±86
	TS2	711±108
	TS3	- - -
591901	TS1	529±98
	TS2	801±93
	TS3	634±122
592001	TS1	554±69
	TS2	774±183
	TS3	579±84
592101	TS1	659±71
	TS2	703±144
	TS3	557±90
592201	TS1	563±105
	TS2	725±90
	TS3	588±81
592301	TS1	520±72
	TS2	592±83
	TS3	551±95
592401	TS1	- - -
	TS2	630±97
	TS3	667±91
592501	TS1	- - -
	TS2	716±204
	TS3	577±99

detector and a Canberra model 8700, 1024 channel multichannel pulse height analyzer. The peak of interest is the barium-131 gamma at 497 KeV. Data reduction was done by comparison with USGS standard rock GSP-1 (1300 ppm Ba).

CONCLUSION

The barium results are shown in Table 1 and Figures 1-3. The obvious trend is that while all stations had the same barium content during period TS1, there is a marked increase within the 100 m circle at the time of sampling period TS2 and an even greater increase at period TS3. Stations on the 500 and 1000 m circles remain statistically the same for all three sampling periods. The data shows large concentration variation among the contaminated samples from periods TS2 and TS3. This is to be expected since the introduction of barite mud residue into surrounding sediments by drilling activity is not likely to be uniform or homogenous.



F1 . Sediment Ba (ppm) for Period TS1

ave. of stations 1-25: 576 ± 82

error of analysis: ± 95

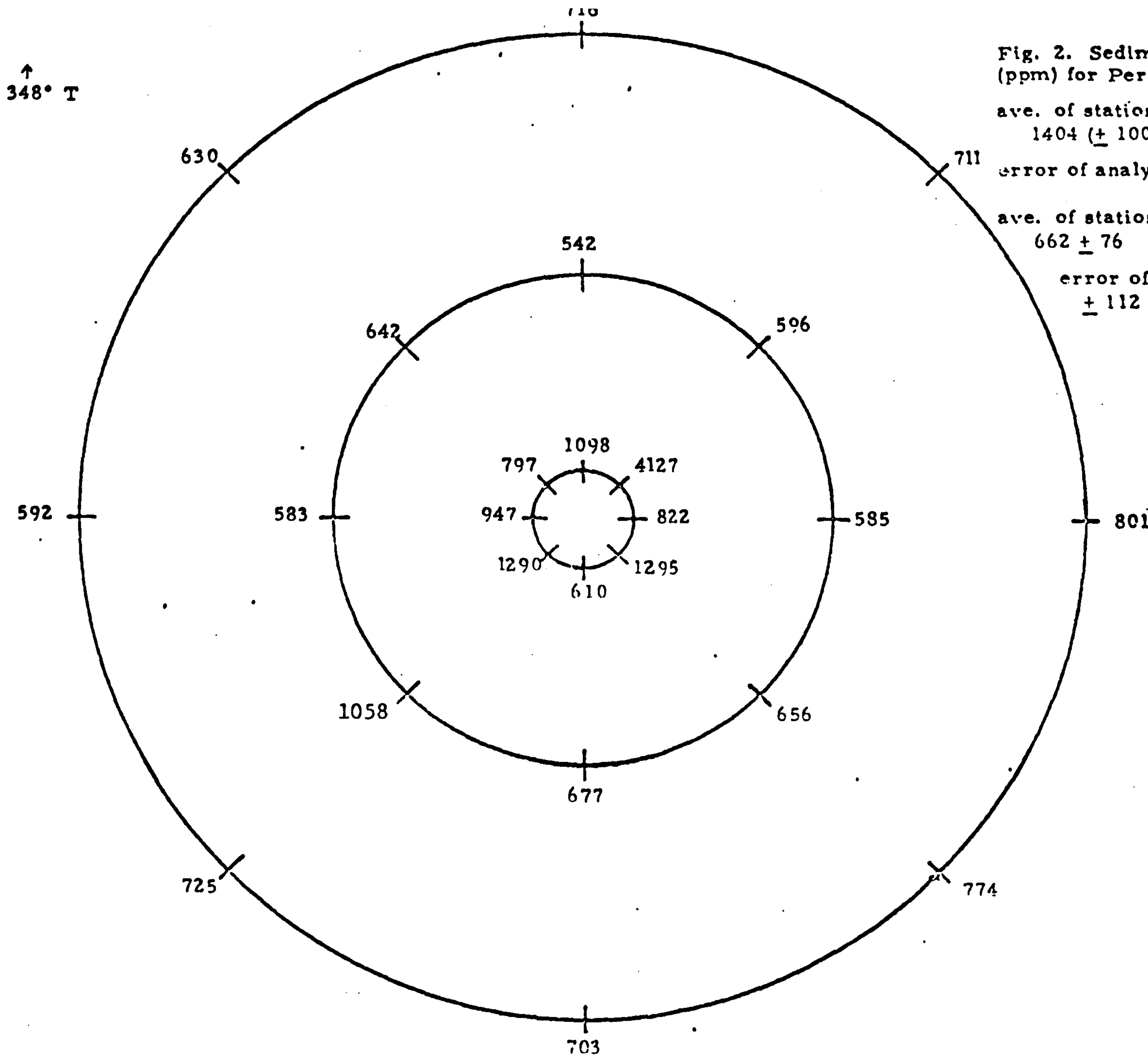


Fig. 2. Sediment Ba (ppm) for Period TS2

ave. of stations 1-9:
1404 (± 1000)

error of analysis: ± 101

ave. of stations 10-25:
662 ± 76

error of analysis:
± 112

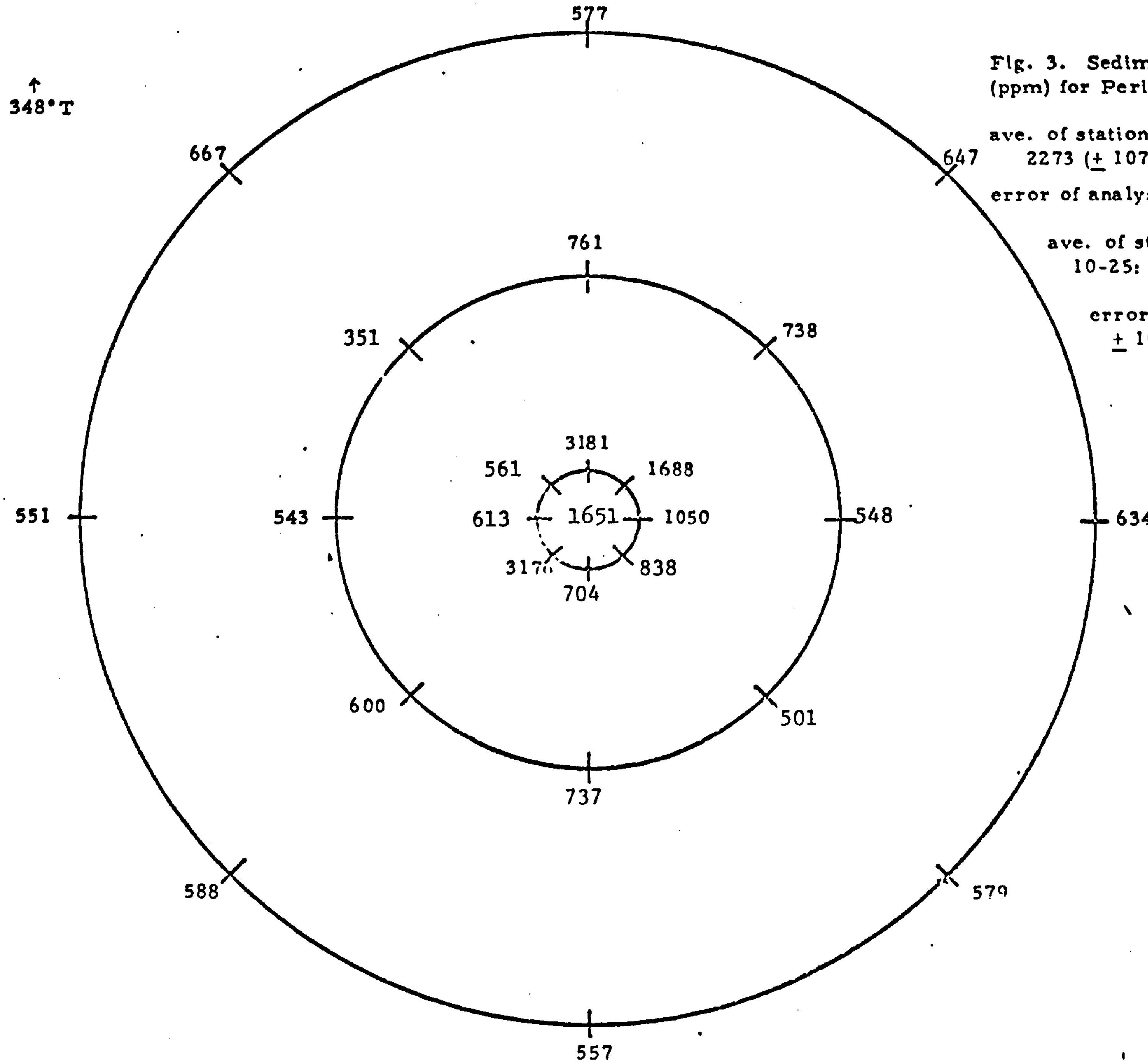


Fig. 3. Sediment Ba (ppm) for Period TS3

ave. of stations 1-9: 2273 (± 1077)

error of analysis: ± 126

ave. of stations 10-25: 618 ± 75

error of analysis: ± 103

REFERENCES

Holms, C. W. 1973. Distribution of Selected Elements in Surficial Marine Sediments of the Northern Gulf of Mexico Continental Shelf and Slope. Geological Survey Professional Paper 814.

Presley, B. J. and Dobson, M. C. 1976. Preliminary Final Report of Heavy Metal Analysis of Bottom Sediment from the MAFLA Rig Monitoring Area, 2 August 1976.

HEAVY METAL ANALYSIS OF MACROEPIFAUNA FROM THE MAFLA RIG MONITORING AREA

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INTRODUCTION

Numerous substances, including hydrocarbons, drill cuttings and drilling muds, are introduced into the marine environment from drilling rigs and production platforms during offshore petroleum development and production. Considerable quantities of these substances are almost certainly introduced, but there is little information available at present on their fate and effects. As part of the Bureau of Land Management's (BLM) environmental assessment program of offshore oil and gas exploration and development, the State (Florida) University System Institute of Oceanography (SUSIO) conducted a rig monitoring study at a site off Mustang Island, Texas, in petroleum lease block 792 (27°37'14"N 96°57'55"W, Figure 1). This study's purpose was to determine the spatial and temporal impact which a typical exploratory (temporary) drilling rig has on the biological, chemical, geological, meteorological and physical aspects of the environment in the immediate vicinity of the rig. The approach was to sample the immediate environment before, during and after a typical exploratory drilling operation. The three sampling cruises were conducted during the periods of 15 November-4 December 1975 (BLM Cruise No. 24), 6-21 January 1976 (BLM Cruise No. 27) and 25 March-5 April 1976 (BLM Cruise No. 36) respectively.

Our segment of this project involved measuring the concentrations of Cd, Cr, Cu, Fe, Pb, Ni and V in nine invertebrate species of macro-epifauna collected in the vicinity of the rig during all three phases of the project. Twenty-five stations were established around the rig as

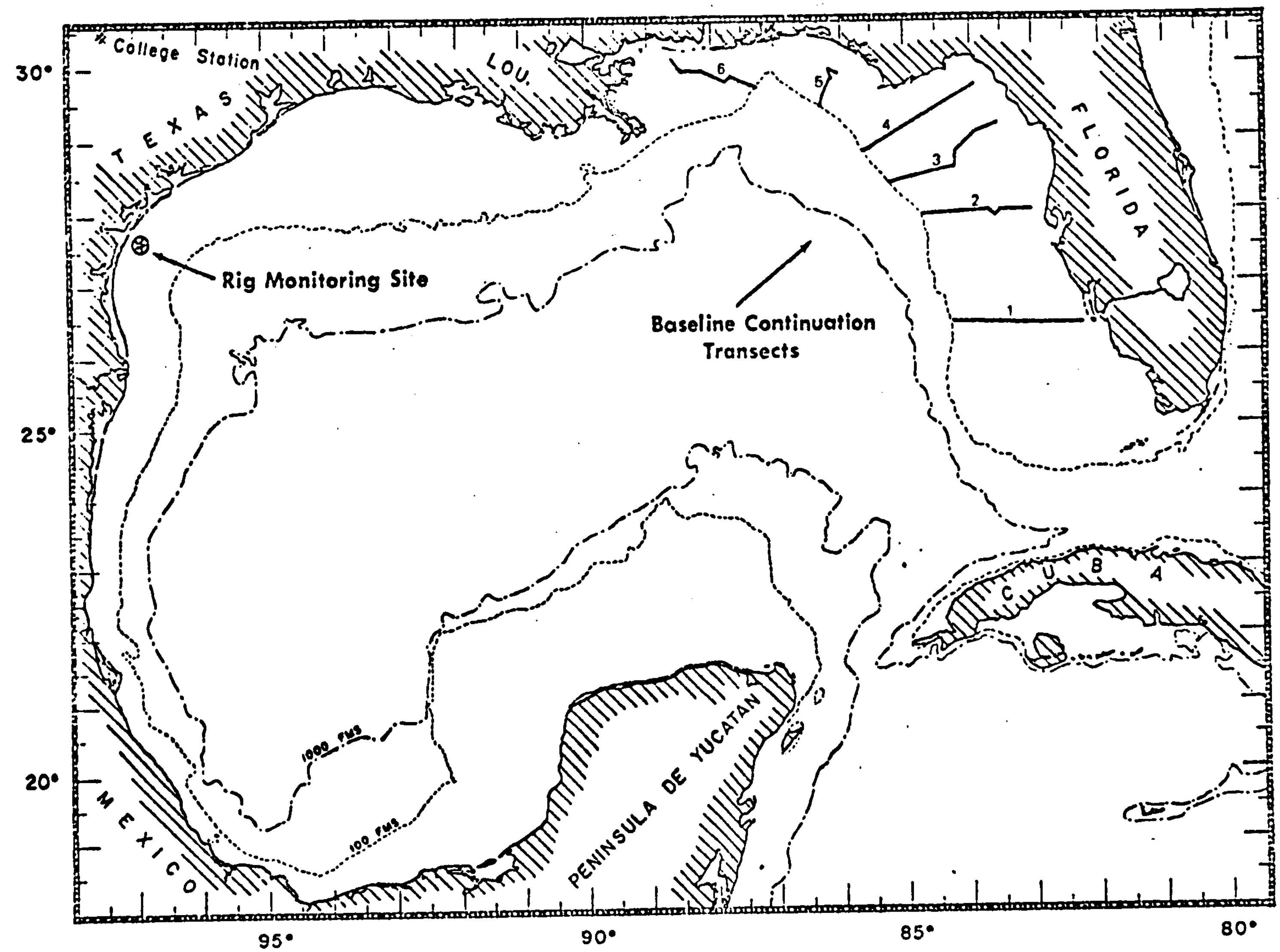

Fig. 1. Sampling areas for the MAFLA Rig Monitoring and Baseline Continuation Studies.

shown in Figure 2. The three stations on each of the eight equal-spaced "spokes" were 100, 500 and 1000 m respectively from the centrally located rig. Two to six samples of macroepifauna were collected by benthic trawl at 20 of these stations during each of the three sampling cruises. Several individual organisms of each species sampled were frozen in plastic bags for shipment to our laboratory. Due to the proximity of the eight stations on the 100 m circle it was possible to take discrete samples only at stations 2, 4, 6 and 8 by trawling. At no time before or after the rig's operation were samples collected from station 1.

METHODS

Sample preparation

Samples were received frozen in polyethylene bags and remained frozen until they could be prepared for analysis. Samples were thawed just prior to being prepared for freeze-drying. Preparation included dissections done in a clean room on plastic wrap or acrylic plastic "cutting boards" using stainless steel scalpels, scissors and glass filled PTFE tweezers as required. At no point during the dissection were the preparer's fingers allowed to touch the tissue to be analyzed. All dissecting equipment was thoroughly rinsed with 1 N HNO_3 and deionized water between each sample and at the end of each sample preparation session all equipment was thoroughly cleaned using a Na_2CO_3 solution, rinsed with 0.5 N HNO_3 and deionized water and stored in polyethylene bags until the next use. The acrylic boards were soaked in 0.5 N HNO_3 between each use.

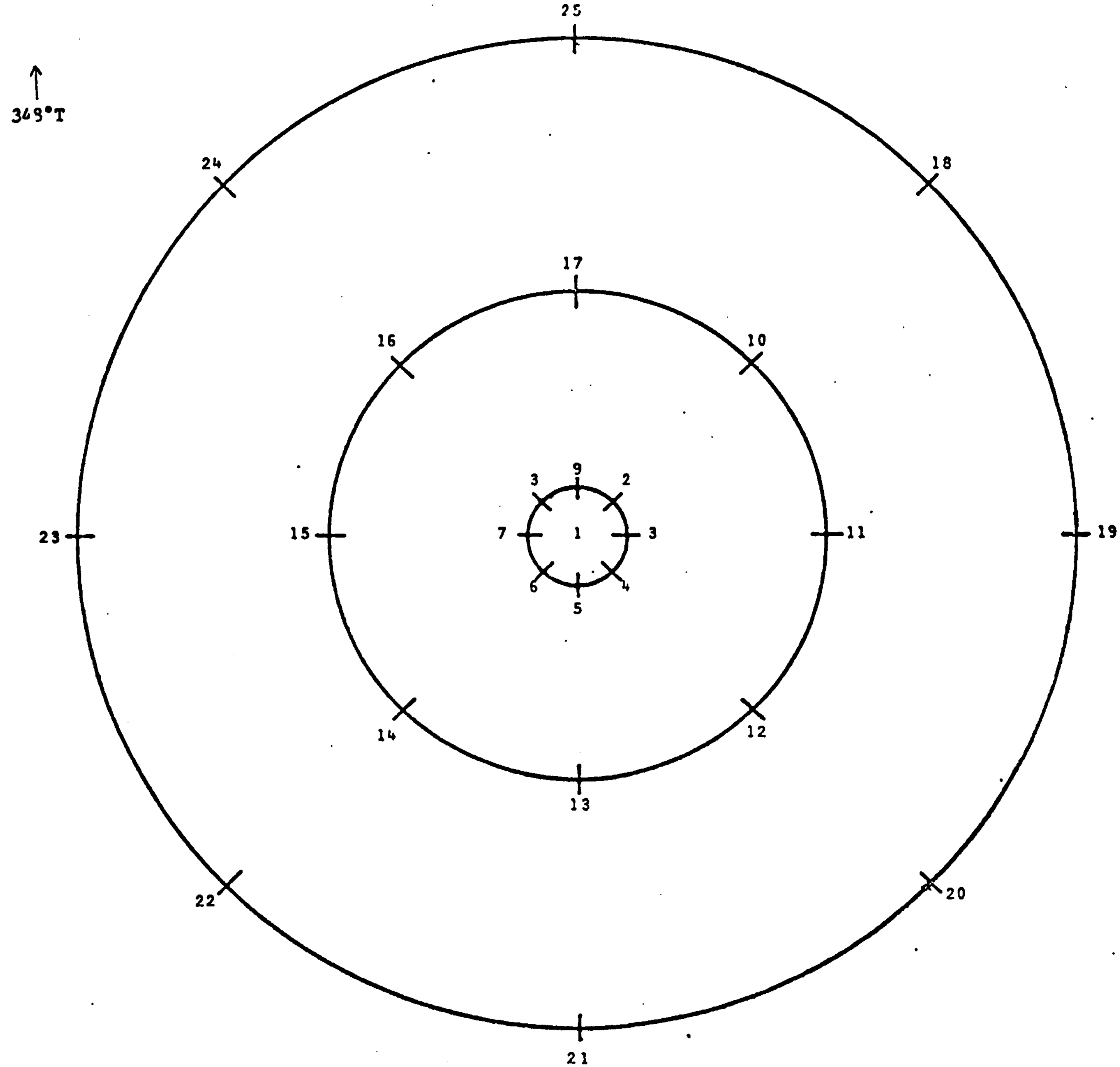

Fig. 2. Sampling grid for MAFLA Rig Monitoring Study. Numbers indicate station identification. Station 1 (rig site) is located at 27°37' 13.87" N, 96°57' 55.17"W; grid diameter is 2000 m.

Except where very large numbers of organisms were provided, all tissue from all individuals in each sample was pooled to make a single sample from which a representative aliquot was removed for analyses.

Shrimp samples (Penaeus setiferus, P. duorarum, Sicyonia sp., Trachypenaeus similis) were prepared by cutting off the head and thorax and removing the abdominal muscle by making a mid-ventral incision with scissors and peeling off the exoskeleton. The mid-ventral artery was removed from the surface of the muscle and the digestive tract excised by making a mid-dorsal incision. The muscle tissue was rinsed sparingly as necessary with deionized water to remove any remnants of the artery or digestive tract. Stomatopods (Squilla empusa, S. chydaea) were prepared similarly except that the gelatinous digestive gland adhering to the abdominal muscle was also removed. The starfish (Astropecten duplicatus) were small and were therefore prepared whole. Each individual was rinsed thoroughly with deionized water to remove any mud or other foreign material adhering to the exterior surfaces. The crabs (Callinectes sp., C. sapidus, Illiacantha sp.) were also prepared whole. The exterior was thoroughly rinsed and the dorsal carapace and telson removed.

The tissue from each sample was placed in a tared plastic snap-cap vial and weighed immediately to determine wet weight. The samples were covered with parafilm and placed in a freezer. When a sufficient number of samples accumulated, all were freeze-dried for 24-96 hr to a constant weight. After removal from the freeze-dryer, the samples were reweighed to determine dry weight and the percentage of moisture in each sample was calculated. Samples were then stored in a desiccator until they could be analyzed.

Digestion (wet oxidation) of samples

All glassware used in digesting samples was cleaned with detergent, rinsed thoroughly with deionized water and soaked in 2-3 N HNO_3 between each use. Reagent blanks were determined on all chemicals prior to their use. Samples were digested by placing a two to three gram dry weight aliquot in a spoutless, electrolytic style pyrex beaker and adding four to five milliliters of 70% HNO_3 (G. F. Smith Chemical Co. double redistilled) per gram of sample. The beaker was covered with a non-ribbed watchglass and allowed to sit overnight at room temperature. The mixture was then refluxed at low heat for 6-24 hr. One milliliter of $HClO_4$ (G. F. Smith Chemical Co. double redistilled) was then added and the original watchglass replaced with a ribbed one. The heat was increased and the HNO_3 allowed to evaporate. At the first sign of white $HClO_4$ fumes a clean non-ribbed watchglass was placed on the beaker and the sample was allowed to reflux until it cleared completely. If the sample charred, one to two milliliters of HNO_3 were added. In those rare cases when the sample still did not clear an additional one to two milliliters of HNO_3 and one milliliter of $HClO_4$ were added and the refluxing was continued until complete clearing occurred and the sample reached near dryness. The contents of the beaker were rinsed with several washings of 0.5 N HNO_3 into a screw-cap centrifuge tube and then diluted to a volume of approximately 25 ml. The tubes were weighed to determine the exact volume of acid added and were centrifuged to remove any suspended material. Concentrations were determined directly on this solution or on a further dilution of it.

Trace Metal Analysis

All trace metal analyses were done by atomic absorption spectroscopy. Copper and Fe were determined after appropriate dilution by direct aspiration into a Jarrell-Ash Model 810, two channel atomic absorption spectrophotometer (AAS). Non-specific or broad band molecular absorption was monitored, where necessary, by measuring simultaneously the absorbance of a non-specific line and the analytical line of the element of interest. Cadmium and V were determined using a Perkin-Elmer Model 306 AAS equipped with an HGA-2100 graphite furnace atomizer. Corrections for non-specific absorption were made by a deuterium arc background corrector. Initial analyses for Cr, Pb and Ni were done by flame atomization using the Jarrell-Ash AAS. However, due to the low levels of these elements in the organisms sampled, the bulk of the analyses were done by flameless atomization with the Perkin-Elmer AAS. The instrumental parameters used for both AAS were in accordance with the manufacturers recommendations with only slight modifications. The sensitivity of V analysis was improved by first coating the graphite furnace tubes with pyrolytic carbon according to the method of Manning and Ediger (1976). The concentration of trace metals in the samples was calibrated using "Titrasol" standards prepared with dilute HNO_3.

In each of the seven separate digestions at least 10% of the samples were procedural blanks. Also in every digestion one or more samples is in at least triplicate and two National Bureau of Standards (NBS) reference materials were included to determine the accuracy and precision of our trace metals analyses. Table 1 compares our values from two reference materials with those published by the NBS. The only value which is significantly different from the NBS value is Fe in orchard leaves. We have no explanation for this difference. However, because our Fe value was so consistent from numerous digestions conducted under varying conditions over a considerable period of time, we feel that our number is probably accurate. Table 2 lists the precision of our analyses for the seven metals studied as percent coefficient of variation. The precision is lower for Cd, Cr, Pb, Ni and V largely because of the low levels of these elements in the shrimp samples analyzed and because of the need to run Cd, Cr, Pb and Ni analyses at >1:10 dilution in order to minimize matrix interferences.

RESULTS AND DISCUSSION

Tables 3, 4 and 5 list the dry weight concentrations of Cd, Cr, Cu, Fe, Pb, Ni and V in organisms collected before, during and after rig operation. A total of 153 samples were received with 40 samples each from phase one and two and 73 from phase three. Of this total 148 samples were analyzed and are reported in the above Tables. Five stomatopod samples were inadvertently allowed to thaw for an excessive period of time and could not be analyzed. These values are generally low and are comparable to levels in organisms from other "clean" areas. The rig monitoring site is in close proximity to station 1 on Transect II of the BLM South Texas Outer Continental Shelf Baseline Study (27° 40'N 96° 59'W, depth 22 m. The values for shrimp reported here agree well with those levels found in shrimp collected from baseline station 1/II at three different times during 1975 (Presley, *et al*. 1976).

Table 6 shows the average trace metal concentrations in each species for each phase in which individuals were collected. Since only a few samples of crabs and the shrimp *Sicyonia* were collected their values are not included in this summary Table. The decrease in Cr, Pb and to a lesser extent in Ni levels from phase one through phase three is more likely a reflection of our changing from flame to flameless AAS techniques during the analysis of these samples than any real process occurring in the environment. Cadmium, Cu and V showed no really significant intraspecific variation among the three phases for any of the species analyzed. Due to the severe matrix effects resulting from the high Ca concentration in Astropecten amd crab samples, the Fe data, especially, for these samples should be viewed cautiously.

Iron was the only element which showed considerable and significant intraspecific change between the three phases of this study. For P. setiferus the phase two Fe concentration was significantly different from the levels for phase one or three as judged by a "t-test" for two population means (Sokal and Rohlf, 1969). The phase two Fe concentration was also significantly different ($\alpha < .01$) from the phase three level for T. similis and S. chydaea. For S. empusa the phase one Fe concentration was significantly ($\alpha < .01$) different from that for phase three. Plotting the Fe values for various species according to station location showed no spatial localization of significantly different Fe values among the phases. Organisms containing higher Fe levels during phase two were scattered over the entire rig monitoring study area and were not clustered around the rig site. Surface sediment iron concentrations in the vicinity of the rig were measured as part of a separate segment of this study (Presley and Dobson, 1976). No significant change in the sediment Fe concentration among the three phases was observed.

The increase in organismal Fe concentration observed during phase two of this study could be the result of drilling operations at the site or a physiological response by the organisms to some other change in the environment coincident with but unrelated to the presence of the rig. The data presented here is insufficient to establish the cause of the observed changes. The effect which the observed increase in body Fe would have on the organisms themselves is uncertain.

CONCLUSION

The presence of the drilling rig had no demonstrable effect on the concentrations of Cd, Cr, Cu, Pb, Ni and V in local organisms when compared with concentrations of the same metals in organisms of the same species collected before and after rig operations. However, the concentration of Fe compared in the same way was significantly higher in local organisms collected while the rig was operating on the site. This data suggests that there could be a causative relationship between drilling operations and the temporary increase in the concentration of Fe in benthic organisms existing in the area.

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Sokal, R.R. and F.J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco. 776 pp.

Table 1. Accuracy of Trace Metals Analyses

Concentrations in μg/g dry weight ± one standard deviation

Sample No.	Number of Replicates Analyzed	Cd	Cr	Cu	Fe	Pb	Ni	V
Bovine Liver (NBS #1577	7	0.4±0.2	0.4±0.4	188±7	258±13	0.7±0.5	0.2±0.3	0.1±0.2
NBS Value (1 Oct 74)	-	0.27±0.04	*	193±10	270±20	0.34±0.08	*	*
Orchard Leaves (NBS #1571)	7	0.1±0.05	2.3±0.6	12±1	232±20	39±4	1.4±0.3	0.1±0.2
NBS Value (1 Oct 74)	-	0.11±0.02	2.6±0.2	12±1	300±20	45±3	1.3±0.2	*

* No NBS value available

Table 2 Precision of Trace Metals Analyses

Percent Coefficient of Variation (C.V. = Standard Deviation/Mean x 100)

Sample	No.	Number of Replicates	Cd	Cr	Cu	Fe	Pb	Ni	V
4106	1	4	23	37	3	15	25	67	61
4511	1	4	0	5	5	23	10	38	*
4919	2	4	35	17	1	30	25	*	*
4106	4	4	45	41	4	7	37	*	56
4108	3	3	58	*	17	1	*	64	*
4921	8	3	64	*	3	4	13	85	*
4921	9	4	35	28	10	12	43	52	*
Average C.V.			37	26	6	13	26	61	58
Average concentrations of all replicates (ppm dry weight)			0.04	0.3	25	12	0.4	0.3	0.1

* All concentrations were "less than" values. No calculation of C.V. possible.

Table 3. Trace Metal Concentrations in O.

Phase 1 (pre-dri...

Concentrations in µg/g dry weight

Station	#	Organism	Cd	Cr	Cu	Fe	Pb	Ni	V	Factor*
4102 TE	1	Penaeus setiferus	0.02	1.0	31	5.3	0.4	0.1	>0.1	.25
	2	Trachypenaeus similis	>0.01	1.0	24	22	1.2	0.1	0.2	.24
4104 TE	1	Penaeus setiferus	0.03	0.6	24	14	0.3	>0.1	0.1	.25
	2	Trachypenaeus similis	0.01	0.1	22	52	1.0	0.7	0.2	.22
4106 TE	1	Penaeus setiferus	0.05	1.3	22	6.1	0.9	0.2	>0.3	.25
	2	Trachypenaeus similis	0.03	0.8	17	25	0.8	0.4	0.1	.26
4108 TE	1	Penaeus setiferus	0.03	1.3	26	8.3	0.3	>0.1	0.1	.25
	2	Trachypenaeus similis	0.02	0.6	24	22	1.0	0.3	>0.1	.24
4510 TE	1	Penaeus setiferus	0.06	1.5	27	23	0.9	0.2	0.4	.25
	2	Astropecten duplicatus	0.6	>2.0	11	500	7.2	4.0	1.1	.46
4511 TE	1	Penaeus setiferus	0.03	1.7	19	8.7	1.6	>0.6	>0.1	.24
	2	Astropecten duplicatus	0.5	0.6	7.8	370	12	2.1	0.4	.49
4512 TE	1	Penaeus setiferus	0.2	0.8	29	14	0.9	0.8	>0.1	.25
	2	Trachypenaeus similis	0.01	1.4	24	13	0.6	0.4	0.2	.24
4513 TE	1	Penaeus setiferus	0.02	1.3	27	4.8	1.0	0.3	0.3	[illegible]
	2	Trachypenaeus similis	0.02	0.9	27	14	0.9	0.9	0.1	.24
4514 TE	1	Penaeus setiferus	0.01	1.3	22	6.2	0.6	>0.1	>0.1	.25
	2	Trachypenaeus similis	0.03	1.4	21	16	0.5	0.1	0.1	.22

Table 3 (continued)

Station	#	Organism	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
4515 TE	1	Penaeus setiferus	0.02	1.4	26	7.8	0.9	0.5	0.2	.25
	2	Trachypenaeus similis	0.03	1.4	22	16	0.4	0.8	0.2	.22
4516 TE	1	Penaeus setiferus	0.02	1.4	36	6.5	< 0.8	0.5	< 0.1	.25
	2	Trachypenaeus similis	0.01	0.5	19	140	0.2	0.7	0.5	.24
4517 TE	1	Penaeus setiferus	0.02	1.2	32	22	< 0.7	1.2	0.1	.25
	2	Trachypenaeus similis	0.02	0.3	26	27	0.2	1.0	0.3	.24
4918 TE	1	Penaeus setiferus	0.04	3.2	23	20	0.3	0.4	0.2	.24
	2	Callinectes sapidus	0.4	3.1	64	370	1.6	7.7	1.0	.32
4919 TE	1	Squilla empusa	2.1	0.6	62	36	0.6	2.0	0.7	.20
	2	Penaeus setiferus	0.04	1.6	17	12	< 0.9	1.2	< 0.1	.24
4920 TE	1	Penaeus setiferus	0.02	1.6	33	6.8	0.2	0.9	< 0.1	.12
	2	Squilla empusa	1.1	0.9	62	34	0.7	0.7	< 0.1	.22
4921 TE	1	Penaeus setiferus	0.03	2.2	25	11	0.1	0.4	< 0.1	.24
	2	Squilla empusa	1.6	1.3	81	47	1.3	1.4	0.6	.20
4922 TE	1	Penaeus setiferus	0.02	1.2	22	10	0.1	0.6	0.1	.25
	2	Squilla empusa	1.5	0.6	53	29	0.9	0.6	0.6	.21
4923 TE	1	Penaeus setiferus	0.02	1.5	23	7.6	0.2	0.6	< 0.1	.25
	2	Trachypenaeus similis	0.01	1.1	26	20	0.2	0.6	0.6	.23

Table 3 (continued)

Station		#	Organism	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
4924	TE	1	*Penaeus setiferus*	0.04	1.5	24	7.0	< 0.7	0.8	< 0.1	.25
		2	*Trachypenaeus similis*	0.1	1.4	25	20	0.8	1.0	0.2	.24
4925	TE	1	*Penaeus setiferus*	0.02	0.8	30	6.2	0.2	0.8	0.1	.26
		2	*Trachypenaeus similis*	0.02	1.6	21	14	0.3	1.0	0.4	.23

* Dry weight concentration multiplied by factor gives wet weight concentration.

Table 4. Trace Metal Concentrations in Organisms from Rig Monitoring Study Area

Phase 2 (during drilling)

Concentrations in μg/g dry weight

Station	#	Organism	Cd	Cr	Cu	Fe	Pb	Ni	V	Factor*
4102 TE	3	*Squilla chydaea*	2.4	0.7	74	58	1.4	0.6	0.5	.21
	4	*Penaeus setiferus*	0.04	0.6	23	14	0.3	0.3	< 0.2	.23
4104 TE	3	*Squilla chydaea*	3.2	0.8	97	46	3.3	1.5	0.3	.18
	4	*Penaeus setiferus*	0.03	0.5	28	11	0.6	< 0.3	< 0.4	.24
4106 TE	3	*Squilla chydaea*	2.0	1.5	66	136	0.9	0.9	0.5	.22
	4	*Penaeus setiferus*	0.07	1.0	31	30	< 0.1	< 0.7	0.3	.22
4108 TE	3	*Penaeus setiferus*	0.03	< 0.4	27	16	0.3	0.1	< 0.2	.24
	4	*Squilla chydaea*	1.4	0.4	87	60	0.4	0.9	0.5	.23
4510 TE	3	*Astropecten duplicatus*	0.2	1.1	4.1	378	2.1	0.2	2.1	.45
	4	*Trachypenaeus similis*	0.03	0.4	24	67	0.7	1.3	0.5	.22
4511 TE	3	*Squilla chydaea*	1.1	0.3	88	206	2.4	1.4	0.7	.21
	4	*Trachypenaeus similis*	0.03	1.4	21	96	< 0.1	0.6	0.4	.22
4512 TE	3	*Astropecten duplicatus*	0.2	< 0.3	5.6	419	5.8	0.4	2.3	.48
	4	*Trachypenaeus similis*	0.02	< 0.3	26	50	1.0	0.2	0.6	.23
4513 TE	3	*Trachypenaeus similis*	0.02	0.6	30	24	0.3	0.1	< 0.2	.24
	4	*Squilla chydaea*	1.2	1.4	74	25	0.6	0.9	0.2	.20
4514 TE	3	*Trachypenaeus similis*	0.20	< 0.3	27	32	1.0	0.2	< 0.2	.23
	4	*Squilla chydaea*	3.3	7.7	79	70	0.2	1.6	0.6	.23

Table 4 (continued)

Station		#	Organisms	Cd	Cr	Cu	Fe	Pb	Ni	V	Factor*
4515	TE	3	Squilla chydaea	2.2	0.3	102	123	2.4	1.6	0.4	.19
		4	Trachypenaeus similis	0.06	0.4	25	43	0.8	0.1	< 0.2	.23
4516	TE	3	Squilla chydaea	1.5	0.8	72	73	0.9	1.3	0.4	.21
		4	Astropecten duplicatus	0.1	< 0.3	2.5	260	< 0.1	0.3	2.2	.49
4517	TE	3	Squilla chydaea	1.4	0.9	71	81	< 1.0	1.5	0.6	.20
		4	Penaeus setiferus	0.1	< 0.4	33	22	1.2	0.1	< 0.2	.23
4913	TE	3	Squilla chydaea	1.7	3.7	87	172	< 1.0	2.1	1.2	.16
		4	Penaeus setiferus	0.03	0.4	24	20	0.4	0.1	0.3	.24
4919	TE	3	Squilla chydaea	1.9	1.1	80	187	< 1.0	1.4	0.8	.23
		4	Penaeus setiferus	0.06	0.8	24	36	0.1	0.2	0.7	.24
4920	TE	3	Astropecten duplicatus	0.2	< 0.3	4.1	486	< 12	2.1	2.6	.45
		4	Trachypenaeus similis	< 0.01	0.9	24	82	0.2	1.0	0.2	.21
4921	TE	3	Astropecten duplicatus	0.1	< 0.3	5.6	473	1.7	3.0	2.1	.47
		4	Trachypenaeus similis	< 0.01	< 1.1	23	74	< 0.5	0.6	0.3	.23
4922	TE	3	Astropecten duplicatus	0.2	< 0.3	7.7	416	13	0.4	1.9	.46
		4	Trachypenaeus similis	0.01	0.1	2.8	48	< 0.5	0.2	0.4	.22
4923	TE	3	Trachypenaeus similis	0.01	0.8	2.2	33	0.2	0.4	0.3	.23
		4	Astropecten duplicatus	0.4	< 0.4	5.8	583	4.3	0.4	4.5	.45

Table 4 (continued)

Station	#	Organism	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
4924 TE	3	*Astropecten duplicatus*	0.1	< 0.3	7.7	444	1.5	5.1	2.1	.46
	4	*Penaeus setiferus*	0.05	0.5	30	15	0.1	0.2	0.4	.24
4925 TE	3	*Callinectes sapidus*	0.2	0.7	64	572	0.4	4.0	2.7	.53
	4	*Trachypenaeus similis*	0.02	< 0.6	29	81	0.6	0.3	0.4	.22

* Dry weight concentration multiplied by factor gives wet weight concentration.

Table 5 Trace Metal Concentrations in O

Phase 3 (post-dri

Concentrations in µg/g dry weight

Station		#	Organism	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
102	TE	5	Squilla empusa	1.3	0.1	82	18	1.1	< 0.1	0.4	.17
		6	Penaeus duorarum	0.02	< 0.1	22	9.2	0.1	< 0.1	< 0.1	.24
104	TE	5	Squilla empusa	0.98	0.2	68	14	0.9	0.4	0.2	.19
		6	Squilla chydaea	0.06	0.2	82	21	0.6	0.2	0.2	.21
		7	Sicyonia sp.	0.04	0.2	27	34	1.8	0.1	< 0.1	.20
		8	Trachypenaeus similis	0.02	0.1	20	21	0.2	0.1	< 0.1	.22
106	TE	5	Squilla empusa	1.6	0.2	67	12	3.4	< 0.1	0.2	.21
		6	Squilla chydaea	1.0	0.2	91	28	1.2	0.2	0.4	.20
		7	Sicyonia sp.	0.03	0.2	27	50	1.3	0.1	0.1	.19
		8	Trachypenaeus similis	< 0.01	< 0.1	22	13	0.1	< 0.1	< 0.1	.22
108	TE	5	Trachypenaeus similis	< 0.04	0.1	20	53	< 0.1	< 0.1	< 0.1	.22
		6	Squilla empusa	1.5	0.2	82	16	1.7	0.1	0.2	.18
		7	Sicyonia sp.	0.04	0.1	22	60	0.8	0.1	0.2	.20
		8	Penaeus setiferus	0.02	0.1	25	13	0.2	0.1	< 0.1	.24
510	TE	5	Squilla empusa	0.63	2.6	54	27	1.5	0.1	0.3	.20
		6	Trachypenaeus similis	0.02	< 0.1	21	17	0.2	0.2	< 0.1	.23
511	TE	5	Penaeus duorarum	0.12	< 0.1	23	5.3	<0.1	0.2	< 0.1	.25
		6	Trachypenaeus similis	0.03	0.2	17	11	5.6	0.1	0.1	.21
		7	Penaeus duorarum	0.04	< 0.1	25	4.8	0.1	0.1	< 0.1	.22
		8	Squilla chydaea	1.4	0.2	113	35	5.8	0.1	0.5	.19
		9	Squilla empusa	1.9	0.1	92	13	1.0	0.1	0.4	.18
512	TE	5	Trachypenaeus similis	0.03	< 0.1	21	11	< 0.1	< 0.1	< 0.1	.23
		6	Squilla chydaea	0.83	1.9	85	52	1.3	0.2	0.6	.19

Table 5 (continued)

tation	#	Organism	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
513 TE	5	Trachypenaeus similis	0.02	< 0.1	16	18	0.2	0.1	< 0.1	.22
	6	Squilla empusa	0.69	0.3	64	11	1.6	0.1	0.1	.20
	7	Penaeus setiferus	0.02	< 0.1	26	4.4	0.1	0.1	< 0.1	.24
	8	Squilla chydaea	1.4	0.2	76	21	1.4	0.2	0.6	.21
514 TE	5	Squilla empusa	1.3	0.1	75	12	1.3	< 0.1	< 0.1	.20
	6	Trachypenaeus similis	0.02	0.1	21	17	0.3	< 0.1	< 0.1	.21
	7	Squilla chydaea	0.26	0.3	96	26	1.5	0.1	0.4	.19
515 TE	5	Squilla empusa	1.60	0.1	72	13	1.6	< 0.1	0.2	.19
	6	Penaeus setiferus	0.02	0.1	28	3.7	< 0.1	0.1	< 0.1	.25
	7	Sicyonia sp.	0.02	0.1	24	33	0.7	0.1	< 0.1	.20
	8	Squilla chydaea			lost					
	9	Trachypenaeus similis	0.02	< 0.1	18	17	0.2	0.1	< 0.1	.21
516 TE	5	Squilla empusa			lost					
	6	Squilla chydaea	0.92	0.2	100	26	1.7	0.2	0.9	.19
	7	Illiacantha sp.	0.3	0.4	25	87	6.7	0.7	0.9	.28
	8	Callinectes sp.	0.2	0.3	52	172	0.9	0.2	1.0	.26
	9	Trachypenaeus similis	0.01	< 0.1	16	33	0.4	< 0.1	< 0.1	.26
	10	Sicyonia sp.	0.01	0.1	25	34	0.6	< 0.1	0.4	.19
517 TE	5	Penaeus duorarum	0.04	< 0.1	20	6.2	0.2	0.1	< 0.1	.24
	6	Squilla empusa	3.1	0.1	91	18	2.9	< 0.1	0.2	.18
918 TE	5	Penaeus setiferus	0.03	< 0.1	20	3.9	< 0.1	0.2	< 0.1	.23
	6	Trachypenaeus similis	0.02	< 0.1	19	20	0.1	0.1	< 0.1	.21
919 TE	5	Trachypenaeus similis	0.02	0.1	23	11	0.1	< 0.1	< 0.1	.21
	6	Penaeus duorarum	0.08	< 0.1	22	3.5	< 0.1	0.1	< 0.1	.23
920 TE	5	Penaeus setiferus	0.01	0.1	24	7.4	< 0.1	0.2	< 0.1	.24
	6	Trachypenaesur similis	0.02	< 0.1	13	96	0.1	0.1	< 0.1	.21

Table 5 (continued)

Station		#	Organisms	Cd	Cr	Cu	Fe	Ni	Pb	V	Factor*
4921	TE	5	*Squilla empusa*			lost					
		6	*Trachypenaeus similis*	0.02	< 0.1	19	11	0.1	0.2	< 0.1	.23
		7	*Trachypenaeus similis*	0.03	< 0.1	22	13	0.2	< 0.1	< 0.1	.22
		8	*Penaeus setiferus*	< 0.02	< 0.2	22	3.3	< 0.1	0.1	< 0.1	.23
		9	*Penaeus duorarum*	0.04	< 0.1	21	5.2	0.1	0.2	< 0.1	.23
4922	TE	5	*Penaeus setiferus*	< 0.02	< 0.1	19	2	< 0.1	0.1	< 0.1	.23
		6	*Trachypenaeus similis*	0.04	0.3	18	25	0.8	0.1	< 0.1	.21
		7	*Trachypenaeus similis*	0.02	< 0.1	17	12	0.1	< 0.1	< 0.1	.20
		8	*Squilla empusa*	0.6	0.2	90	12	2.0	0.1	0.4	.19
		9	*Astropecten duplicatus*	0.4	0.6	14	273	2.2	0.9	1.2	.55
4923	TE	5	*Penaeus setiferus*	0.03	< 0.1	18	4.2	< 0.1	0.2	< 0.1	.22
		6	*Penaeus duorarum*	0.04	< 0.1	20	2.9	0.1	0.1	< 0.1	.24
		7	*Squilla empusa*	1.0	0.1	75	16	1.5	< 0.1	0.3	.20
		8	*Astropecten duplicatus*	0.6	0.6	9	230	0.9	0.3	1.0	.58
		9	*Trachypenaeus similis*	0.1	< 0.1	20	16	0.1	< 0.1	< 0.1	.22
4924	TE	5	*Penaeus duorarum*	0.06	< 0.1	15	3.6	< 0.1	0.2	< 0.1	.23
		6	*Trachypenaeus similis*	0.03	< 0.1	22	22	0.2	< 0.1	< 0.1	.22
		7	*Squilla empusa*			lost					
		8	*Penaeus setiferus*	0.03	< 0.1	20	8	0.4	0.1	< 0.1	.25
4925	TE	5	*Penaeus duorarum*	< 0.02	< 0.1	24	5	0.2	0.1	< 0.1	.23
		6	*Penaeus setiferus*	0.07	< 0.1	20	15	0.5	0.5	< 0.1	.22
		7	*Squilla empusa*			lost					
		8	*Trachypenaeus similis*	0.02	< 0.1	18	17	0.2	0.1	0.1	.21
		9	*Penaeus duorarum*	0.02	0.1	19	5	< 0.1	0.1	< 0.1	.22

* Dry weight concentration multiplied by factor gives wet weight concentration.

Table 6. Average Trace Metal Concentrations in Individual Species Before (Phase 1), During (Phase 2) and After (Phase 3) Rig Operation

Average concentration in ppm dry weight ± one standard deviation

Organism	Phase	Number of Samples Analyzed	Cd	Cr	Cu	Fe	Ni	Pb	V
Penaeus setiferus	1	20	0.04 ± 0.04	1.4 ± 0.5	26 ± 5	10 ± 6	0.3 ± 0.3	0.7 ± 0.3	0.2 ± 0.1
	2	8	0.05 ± 0.02	0.6 ± 0.2	28 ± 4	20 ± 9	0.2 ± 0.1	0.4 ± 0.4	0.4 ± 0.2
	3	10	0.03 ± 0.02	0.1 ± 0.04	22 ± 3	7 ± 4	0.3 ± 0.2	0.2 ± 0.1	< 0.1
Penaeus duorarum	1	none collected							
	2	none collected							
	3	10	0.35 ± 0.03	< 0.1	21 ± 3	5.1 ± 1.8	0.13 ± 0.05	0.14 ± 0.05	< 0.1
Trachypenaeus similis	1	13	0.03 ± 0.03	1.0 ± 0.5	23 ± 3	31 ± 34	0.4 ± 0.3	0.9 ± 0.2	0.3 ± 0.2
	2	11	0.04 ± 0.06	0.7 ± 0.4	25 ± 3	57 ± 24	0.5 ± 0.4	0.6 ± 0.4	0.4 ± 0.1
	3	20	0.03 ± 0.02	0.2 ± 0.1	19 ± 3	23 ± 20	0.5 ± 1.3	0.1 ± 0.04	< 0.1
Squilla empusa	1	4	1.6 ± 0.4	0.8 ± 0.3	64 ± 12	36 ± 8	0.9 ± 0.3	1.2 ± 0.7	0.6 ± 0.1
	2	none collected							
	3	12	1.4 ± 0.7	0.4 ± 0.7	76 ± 12	15 ± 4	1.7 ± 0.7	0.2 ± 0.1	0.3 ± 0.1
Squilla chydaea	1	none collected							
	2	12	1.9 ± 0.7	1.6 ± 2.1	81 ± 11	103 ± 60	1.3 ± 0.4	1.4 ± 1.1	0.6 ± 0.3
	3	7	0.8 ± 0.5	0.5 ± 0.6	92 ± 12	30 ± 11	1.9 ± 1.7	0.2 ± 0.05	0.5 ± 0.2
Astropecten duplicatus	1	2	0.55 ± 0.07	0.6 ± 0	9.4 ± 2.3	440 ± 90	3.0 ± 1.3	9.6 ± 3.4	0.8 ± 0.5
	2	8	0.2 ± 0.1	< 0.4	5.4 ± 1.8	432 ± 93	1.0 ± 1.0	5.3 ± 4.1	2.7 ± 1.0
	3	2	0.5 ± 0.1	0.6 ± 0	12 ± 4	252 ± 30	1.6 ± 0.9	0.6 ± 0.4	1.1 ± 0.1

GEOPHYSICAL INVESTIGATIONS OF THE MAFLA LEASE AREA

Thomas E. Pyle

See Volume V

FINAL REPORT

PHYSICAL OCEANOGRAPHY - INTERDISCIPLINARY ENVIRONMENTAL SUPPORT DATA

CONTRACT NO. 08550-CT5-30

By

Murice O. Rinkel

TABLE OF CONTENTS

PREFACE

According to the terms of BLM Contract No. 08550-CT5-30, no principal investigator was assigned for the data synthesis of the STD and XBT data collected as environmental information in support of interdisciplinary studies. The collection and reduction of these data were assigned to and budgeted for under the program data manager's activities.

Despite those limitations in regard to accountability, the Program Manager requested that quarterly reports and a final report be assembled by Murice O. Rinkel based on the results of the data obtained by the STD and XBT lowerings. This particular report, therefore, includes a discussion of results obtained from each of the four transects for the three seasons and their relation to the forcing mechanisms which might influence the shelf circulation both for environmental background information and the possible transport of materials or contaminants from each station.

While this report meets the requirements for supplying environmental information to the interdisciplinary program and investigators, it does not take into account the normality of the BLM data as related to environmental parameters of temperature, salinity, and sigma t or the influences of the various force mechanisms on the shelf circulation based on existing historical data. Although effort and energy have been expended in studying these different aspects and some of the results of such studies have been reported to the other investigators in the quarterly reports, no comparisons have been made in this report. While this information is not required under the contract, it is the intent to complete such a section and submit it as a special report to the BLM Chief Scientist as a continuation of Contract No. 08550-CT4-16. This analysis is not included at this time because preliminary analysis has indicated the need for additional information and data synthesis. These materials have not arrived from the different Government agencies from which the material has been requested and required by the time of submission of this final report.

SOURCES

The figures, tables, and general information statements appearing in this report have come from the following sources.

Temperature, salinity, and sigma t values represent measurements made by water bottle casts, STD lowerings, expendable BT's, and mechanical BT's. The data are from the MAFLE file compiled under BLM Contract No. 08550-CT4-16 supplemented by the results from the 1975-76 BLM program. These data are presently stored at NODC in a special data file labled "MAFLA." There is a MAFLA Coordinator at NODC who at present is Mr. James L. Berger.

The wind speed and wind direction for the three sampling periods of the 1975-76 program are from the ship deck logs of either the R/V TURSIOPS or the R/V BELLOWS. These data records are in the MAFLA data file at the University of South Florida. The river run-off information is from the "Compilation and Summation of Historical and Existing Physical Oceanographic Data From the Eastern Gulf of Mexico" (SUSIO, 1975); the "ESCAROSA I Report" (Jones and Rinkel, 1972); or historical data from the U. S. Geological Survey, U. S. Department of the Interior, for selected drainage areas between Tampa and the Mississippi River System.

The data for Hurricane ELOISE are from the "Preliminary Report, Hurricane ELOISE, September 13-24, 1975"; "The Natural Disaster Survey Report 75-1, Hurricane ELOISE -- the Gulf Coast. A Report to the Administrator, December 1975"; "The Marine Environmental Data Package ELOISE, 1975"; and "Data Report - Buoy Observations During Hurricane ELOISE - September 19 - October 11, 1975." These sources are all from the Environmental Science Division Data Buoy Office, NOAA, Bay St. Louis, Mississippi.

The STD and XBT data for Hurricane ELOISE are from "NODC Hydrographic Vertical Sections" from NOAA/EDS/NODC, Washington, D. C.

The "tide and storm surge" data and "tide and storm surge curves" data are from NOAA/Climatological Service Branch, Washington, D. C.

The wind direction and speed and wave height data are from "Stage I and Stage II" from the Environmental Sciences Division, Naval Coastal Systems Laboratory, Panama City, Florida.

The historical meteorological data are from "Environmental Guide for the U. S. Gulf Coast" (Brower, et al., 1975).

The meteorological data support information for the three seasons of the 1975-76 study are from "Daily Synoptic Weather Charts" and "Local Climatological Data" for Mobile, Pensacola, Apalachicola, and Tampa, Fla." from the NOAA/Environmental Data Services/National Climatological Center, Asheville, North Carolina.

The predicted currents on the shelf and eastern Gulf of Mexico are from "A Numerical Modeling and Observation Effort to Develop the Capability to Predict the Currents in the Gulf of Mexico for Use in the Pollutant Projectory Computation" (a final report BLM inter-agency Agreement 08550-IA5-26) (Molinari, 1976).

The historical data for the forcing mechanisms of tides, Loop Current, river run-off, and meteorological conditions are from the "Compilation and Summation of Historical and Existing Physical Oceanographic Data From the Eastern Gulf of Mexico" (SUSIO, 1975).

The depth of 20°C isotherm levels for the summer, fall, and winter months (1975-76) were furnished by Molinari especially for this report.

UNITS, DEFINITIONS, FIGURES, AND PRESENTATION OF DATA

Under the terms of the contract, the investigator is charged with using, if possible, existing NOAA/EDS/NODC formats and units or those specified in the Work Statement Contract. These formats and units result in data being recorded in both the metric and English systems. Further, the specifications of the digitization and the presentation of the STD data in EGMEX figure and horizontal chart formats so that proper inter-comparison could be made with the historical data resulted in a similar generation of units in the figures. In this report the figures were plotted and the tables constructed in the units as they were received from the different data sources. In an attempt to satisfy the unit purists, when data are used in the text, they are stated in the units as received and then converted into either the English or metric system as required for the purists. To be more specific, the following units were required by the contract:

Time (hour, month, day, and year): GMT

Depth to the bottom: In meters

Depth of samples or digitization levels: In meters

Temperature: ^{o}C

Salinity: $^{o}/oo$

Wind direction: In degrees - the direction from which the wind blows

Wind speed: In knots

Wave height: In feet

Wave period: In seconds

Current direction: In degrees - the direction toward which a current is flowing

Current speed: In cm/sec

Tide amplitude: In feet

Tide range: In feet

Precipitation: In inches

Distance: In nautical miles

Horizontal chart depths: In fathoms

The vertical figures of temperature and salinity have been prepared from the corrected in situ measurements resulting from either STD or XBT casts. These data were corrected according to techniques and methods discussed in the quarterly reports (SUSIO, 1975a, 1975b, and 1976). The figures have been constructed with the x axis either on latitude or longitude. If the transect is primarily north and south, latitude was used, and if it was primarily east and west, longitude was used. The nautical distance between the stations is based on U.S.C. & G. CHART 1003. The section, therefore, can be superimposed on that chart for details of bottom depth and surrounding environmental information. The depth, salinity, and temperature contour intervals are the same as the EGMEX and WFCSP historical data so that the BLM data and contour intervals can be compared with the atlas data resulting from those operations. The contour interval for salinity is 0.20 °/oo with each 1.00 °/oo contour line appearing as a dashed line. Water with salinity of 36.55 °/oo (Loop Current water) is indicated by a dotted contour line. Temperature contour interval is each whole degree centigrade with every five degrees entered as a dashed line (15, 20, 25, and 30°C).

Across the top of each vertical distribution figure appear the station values at the surface, ten meters, and the bottom of the parameter. These have been entered as environmental support information for the biologists who have collected data at the surface and at the bottom and for the chemists and biologists who were sampling the water column at ten meters. If the bottom value was collected within five meters of the bottom, the value was used in the presentation; if not, no value appears.

The record number of the STD or XBT trace appears at the top of each sub-plot of the figure (surface, ten meters, and bottom parameter presentation and vertical distribution). The master station numbers appear along the bottom.

If the figure was plotted along latitude, the longitude of the inshore station and the offshore stations is listed at the bottom of the vertical distribution sub-plot along with the actual dates over which the data were collected. The orientation of the shore appears either to the right or left of the figure on Transect IV and III depending upon whether the transect was oriented either east or west diagnally from the shore. On these figures for Transect II or I the shore is always to the right of the figure.

It is the policy in this report that vertical distribution patterns given in the figures represent the shortest collection interval possible where there are multi-lowerings at a station or stations on a transect.

The horizontal salinity and temperature figures (charts) have been drawn by superimposing the data over detailed (station spacing) historical data to help in the interpretation of areas without data. They are drawn to EGMEX standards, which means the originals can be superimposed on U.S.C. & G. CHART 1007. Distance is in nautical miles, and selected fathom lines have been inserted to allow proper orientation onto the U.S.C. & G. CHART 1007. These originals have then been reduced to page size.

The data have been presented in the text in accordance with the identification assigned to water column work under the contract. The numbering of the four water colums as Transect I, II, III, and IV was specified in the contract with Transect I located in the middle portion of the Western Florida Continental Shelf (off Tampa Bay) and Transect IV located off Horn Island on the Mississippi Continental Shelf. The data were collected by a consecutive occupation of Transects IV, III, II, and I; they have been discussed in the text and listed in that order. The rationale for the collection and discussion was based on the assumption that the major contaminants would occur from the Mississippi River System waters and the industrial complexes of Mississippi, Louisiana, and Alabama. By a collection of data in that order it was hoped that if the transport was into the pristine area connected with the Florida Middle Grounds and the Clearwater area, that is from west to east, that this method of collection would result in the following of the water movement from the Mississippi River System and Louisiana, Mississippi, and Alabama discharge area to allow some determination of the dispersion and dilution of these contaminants as it traveled to the east and south.

INTRODUCTION

Normally one thinks of physical oceanography as a means to examine the total transport within an area. This role, of course, would be critical in any OCS water area to predict the dispersion of materials either within the area or from the drilling and production operation connected with the oil leases.

Equally important, however, is the role of physical oceanography in its support of the other oceanographic disciplines. In an area where one must separate the baseline from possible contaminants data, it would be practically impossible to interpret the different biological, geological, and chemical responses in the ecosystem without an adequate knowledge of those factors that influence the total transport of the area as related to the water column and its environmental effect upon the bottom.

The mechanisms that can affect these objectives within the OCS lease areas and in this instance, MAFLA, are atmospheric disturbances, tides, river run-off, and the Loop Current. Each of these factors except perhaps the tides can have large variability from season to season and year to year. For this reason, before the commencement of monitoring the physical oceanographic parameters within the MAFLA area in support of the routine monitoring program, a special BLM study project was completed to assemble the historical and contemporary physical and associated meteorological data of the northeast Gulf of Mexico to construct a zero order synthesis of the oceanographic conditions and have them graphically displayed (SUSIO, 1975). Within this study was a recommended observational program for the general circulation of the MAFLA Continental Shelf which contained six major components: meteorology, hydrography, horizontal currents, sea level, bottom pressure, and river run-off. Within the hydrography sections were recommendations for future biological, geological, chemical, and physical oceanographic investigations.

BLM elected to cover only hydrographic components related to its water column study across the shelf in its routine monitoring program. Those hydrographic inputs required in such a study for the deep basin (Loop Current) were covered in a "special BLM numerical modeling project."

The recommendations for the hydrographic component included a monthly occupation of approximately ten standard stations on each of eight transect grid lines across the shelf and slope regions (Figure 1). At each of these stations a standard STD cast plus occasional water bottles for dissolved oxygen and nutrients should be taken so that the major features of the seasonal evolution of the hydrographic fields could be determined (SUSIO, 1975, page 81).

These recommended sampling grid transects were modified to insure that 1975-1976 water column transects cross through the five MAFLA lease block areas. They were further reduced to four transects in an attempt (1) to document the environmental conditions in selected hydro-biological areas on the shelf, (2) to describe the influence of the motion inducing forces on the general circulation, (3) to supply input to the numerical models, and (4) to connect where possible with the BLM Special Study Program. This would enable the interdisciplinary participants of the BLM program to draw on the existing MAFLA data bank, housed at NODC, and supplement physical measurements to be taken during the BLM special studies programs.

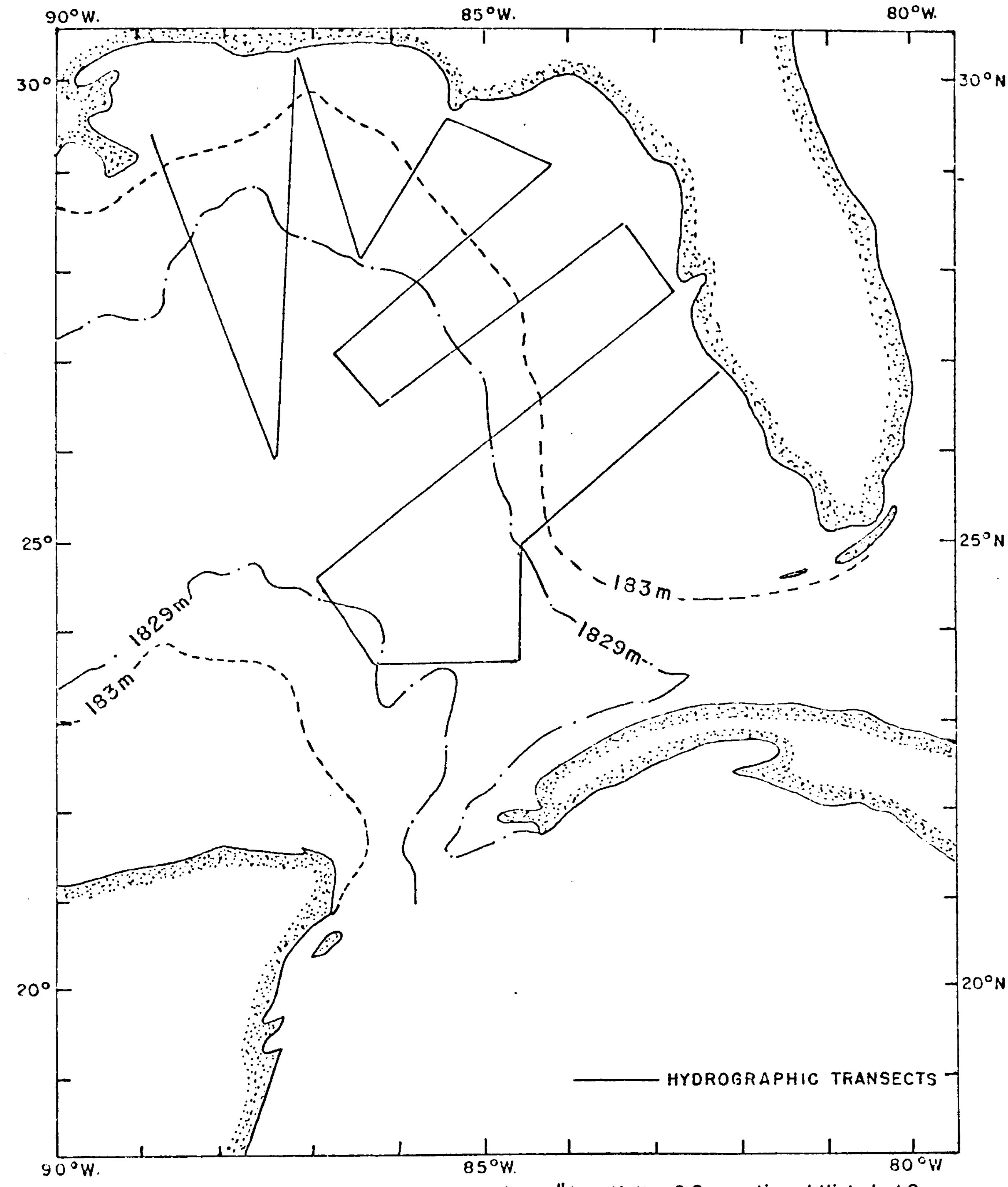


Figure 1. Recommended Hydrological Transects (From "Compilation & Summation of Historical & Existing Physical Oceanographic Data From the Eastern Gulf of Mexico - SUSIO, 1975)

The rationale for this change in numbers and locations of the sampling grid was related to five facts: (1) the existence of monthly or seasonal historical data files on which one could draw for a determination of the normality of the data being generated in any one year, (2) the four geographical sub-areas based on river discharge characteristics as defined by Schroeder (SUSIO, 1975, pages 9-15), (3) inshore and shelf hydro-biological zones (Figure 2), (4) limitations on the scientific capacity and resources to perform chemical analysis and supporting water column work, and (5) reduction in program cost whereby no attempt was made to collect synoptic data as this would have required multi-ship operations and collection systems.

This recommended sampling grid was not used during the pre-drilling (baseline) monitoring program since the compilation and summation of the historical data was being completed during the same time period. Starting with this contract, four standard grid transects were occupied on the shelf during June-July and September-October of 1975 and January-February of 1976.

Chart 1 shows the location of these transects and the relationship to long-time historical studies. On each of the transects are master stations at which STD lowerings were made along with appropriate chemical and biological measurements. Between each of these master stations and at the discretion of the chief scientist and if time permitted, either an XBT or STD lowering was made to further define the temperature and salinity fields.

At selected stations in the fall and winter sampling periods STD lowerings were made to supplement and support the transmissometer time series work with the data resulting in an STD time series station.

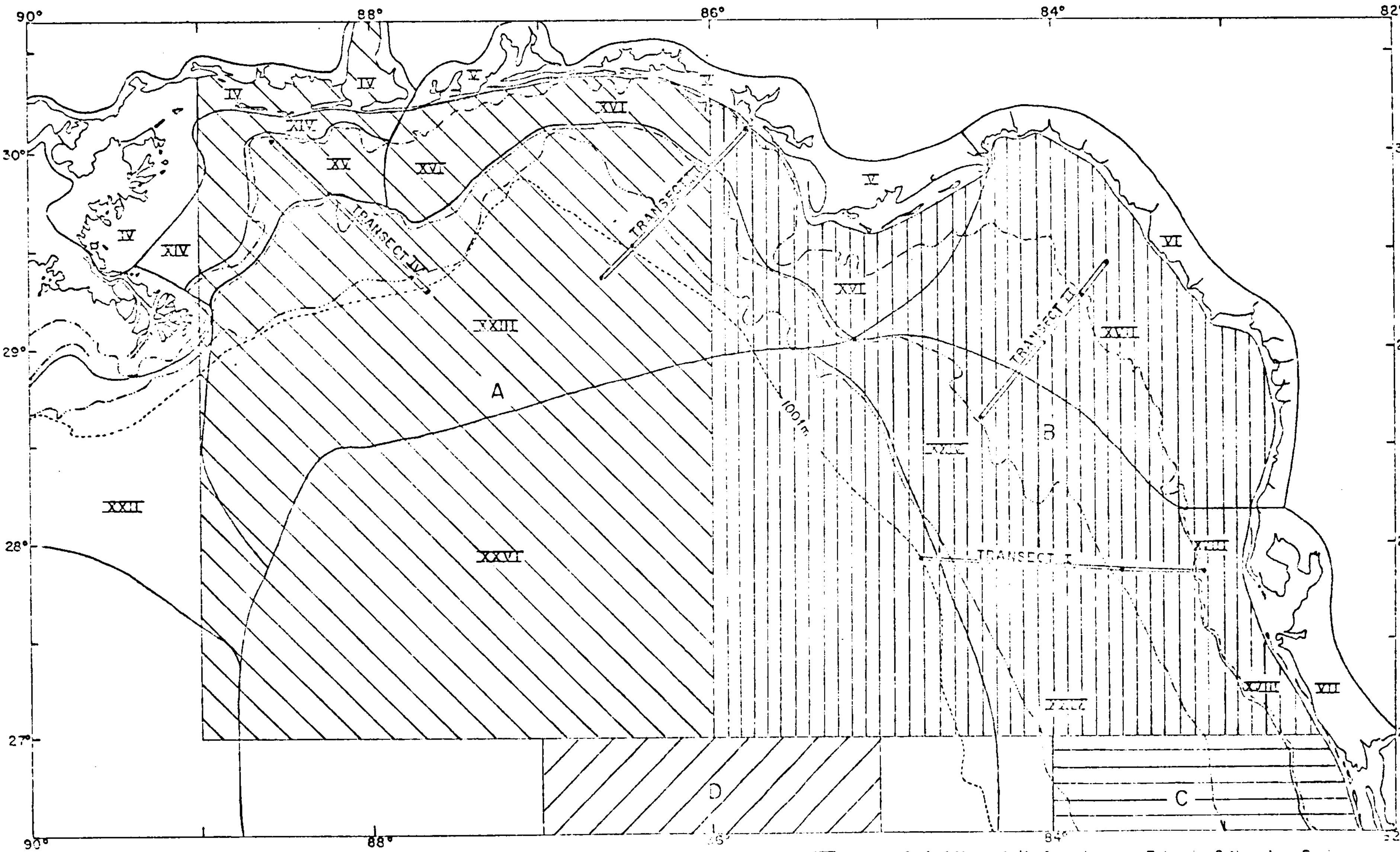


Figure 2 Delineation of Boundaries of Dissimilar Hydro-Biological Zones IV - VII, XIV - XVIII, XXIII - XXIV & XXVI Eastern Gulf of Mexico in the Bays, Lagoons, Estuaries & Nearshore Regions, the Intermediate Shelf Regions, & Oceanic Gulf Regions, Marine Meteorological Summary Areas A, B, C & D Indicated by Hatched Markings (From "A Report on the Hydro-Biological Zones on the Eastern Gulf of Mexico [Abridged]" - SUSIO, 1972)

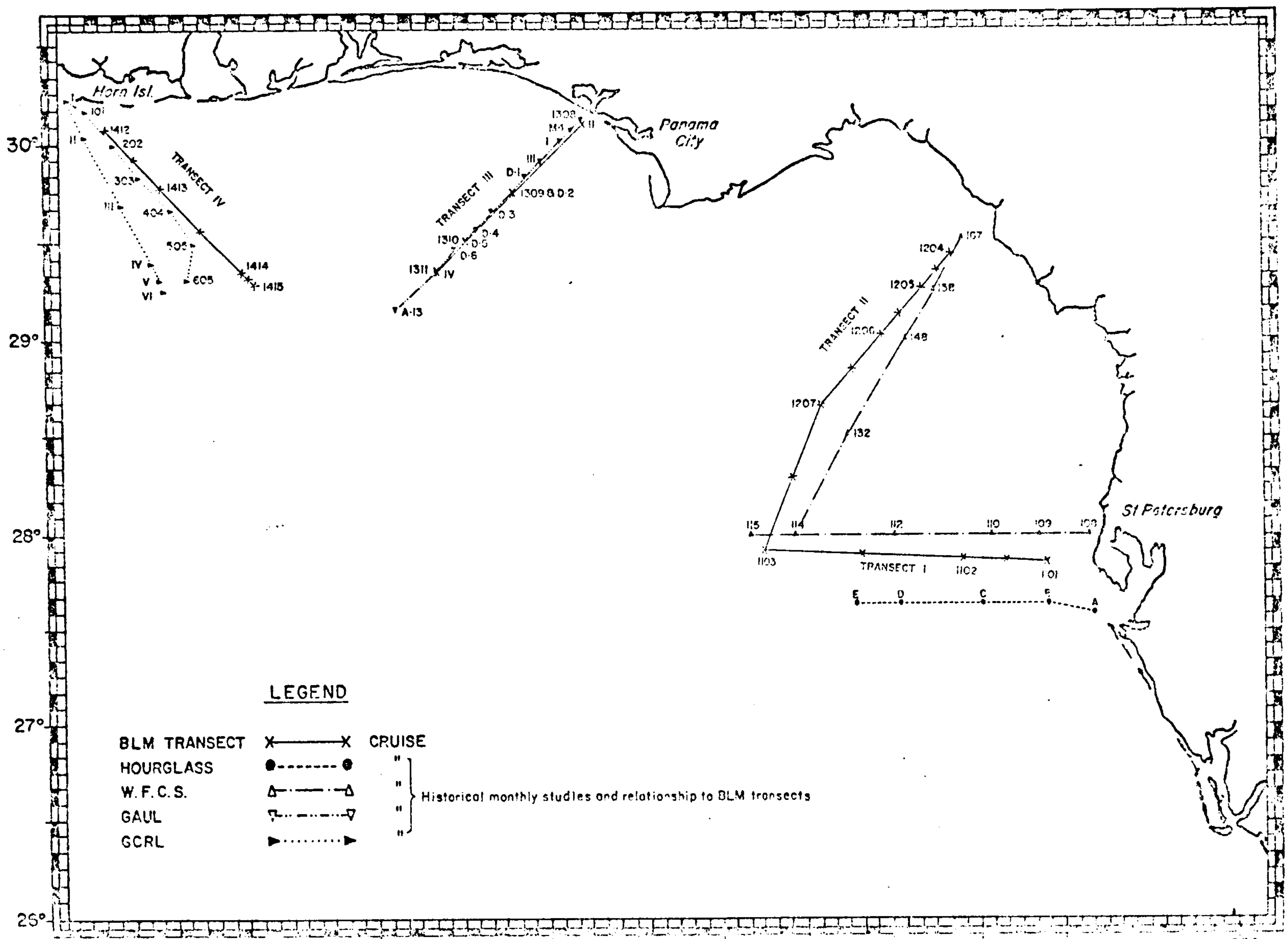


CHART 1. Location of BLM water column transects along with Master Station Numbers 1975-1976. On BLM transects, stations between Master Stations are indicated by "X".

Temperature, salinity, and sigma t values from these STD lowerings and/or XBT's would theoretically enable a definition of the water mass structure, give a general reference to the source of the water, and supply the biologist, chemist, and geologist with environmental background data for their use in analyzing their data. To insure the data could be used by other investigators in the future, the analog traces were digitized at whole degrees in temperature, 0.20 $^{o}/oo$ in salinity, and 0.20 sigma t values at standard depths and at inflection points of ±.05 in temperature and ±.05 $^{o}/oo$ salinity. This would allow each investigator to reconstruct the analogs of temperature and salinity to the accuracy of the collection system.

It should be understood that as part of the compromise, as stated above, these data are not synoptic. Because of the lack of these synoptic data which was due to the extensive sampling period between Transects I through IV of 25-32 days, it was recognized that the data could be examined only for gross features of the transportation system and not the study of the microstructure of the predictability of the effects on the transport from the forcing mechanisms of the Loop Current, wind stress, shelf circulation, tides, and run-off. The data, therefore, represent only general support information as required by an interdisciplinary study and do not represent the definitive study of the shelf circulation or the water mass characteristics. Although the discussion will contain reference to the general weather conditions, the Loop Current, and river run-off, the existing tide conditions will not be discussed in detail except in a general way.

Mooers (Molinari, 1976, page 8) notes that the diurnal tides in the Gulf of Mexico are dominant over the semi-diurnal tides in most localities of the MAFLA area; the range of the surface tides is on the order of 15 cm; there is very little tidal current data available and that numerical models for semi-diurnal tides and tidal currents in the Gulf of Mexico reveal tidal current patterns, which vary considerably throughout the Gulf; that internal tides can be expected to be more prevalent in the summer than in the winter; that tidal velocities of 5-20 cm/sec were observed in a study (Mooers and Price, 1974, and Mooers and Van Leer, 1975) at 26°N on the western Florida Continental Shelf with a diurnal ellipsis oriented north and south and a semi-diurnal ellipsis oriented east and west with both tidal species very baroclinic and irregular with their amplitudes and phases varying with depth and time due to modulation by transient circulations. The inertial motion has a period dependent upon latitude transient circulations with a period varying from about 28 hours at Key West to 24 hours at Mobile Bay which is near the diurnal tides and leads to irregular diurnal tidal behavior with observed horizontal velocities of 10 to 30 cm/sec on the west Florida shelf; and those who have studied the tides within the area state with some confidence that the tide inertia motions produce particle orbits with the range on the order of several kilometers and orbital periods of 12 to 28 hours in the Eastern Gulf of Mexico. As such, they would, of course, play an important part in horizontal dispersion of materials from a source area but would require the establishment of a tide study program for prediction of the actual dispersion patterns. A comprehensive review of the surface tides in the Gulf of Mexico has been given by Zetler and Hansen (1972).

SUMMER SAMPLING
June 19-July 17, 1975
(29 days)

During this summer sampling period a total of 23 STD lowerings and 14 XBT's were made. Each of the 15 master stations had an STD lowering on it. No truly STD time series was made although two STD lowerings were made on Master Station 1412, three on Master Station 1415, two on Master Station 1204, and three on Master Station 1101.

An examination of the vertical sections for temperature, salinity, and sigma t indicated that on Transects IV and III off Pascagoula, Mississippi, and Panama City, Florida, respectively, in run-off river characteristics areas WEST (Mississippi River System) and NORTHWEST (Mississippi Sound - St. Andrews Bay) as defined by Schroeder in Table I (SUSIO, 1975) and Marine Summary Zone A and Hydro-Biological Regions IV, V (Bays, Lagoons, Estuaries), XIV, XV, XVI (Nearshore), and XXIII (Intermediate Shelf) (Hydro-Biological Zones of the eastern Gulf of Mexico, 1972) (Figure 2) can be characterized by the presence of two distinct low salinity surface pockets (Figures 3 and 4) in the upper seven to eight meters which can be associated with run-off effects on Hydro-Biological Regions XIII and IV.

On both sections appeared eddy Locp Current water defined by Molinari (SUSIO, 1975, page 18) as water with salinity in excess of 36.55 $^{o}/oo$. On both transects such water appeared at approximately 100 m along the slope area of the shelf. Based on historical configuration and the location of the waters, the salinity values of the waters indicated that they were associated with break-off eddies from the main Loop Current

Table I. MAFLA Subareas Based on River Discharge Characteristics.

	Mean Discharge (c.f.s.)	
West		
Mississippi River		478,028
Northwest		
Mississippi Sound	33,321	
Mobile Bay System	73,076	
Perdido Bay	1,868	
Pensacola Bay System	12,602	
Choctawhatchee Bay	8,352	
St. Andrew Bay	6,367	
TOTAL		135,586
Northeast		
Apalachicola Bay	26,635	
Apalochee Bay	5,444	
Deadman Bay	745	
Suwannee Sound	11,428	
Waccasassa Bay	200	
TOTAL		44,452
East		
Tampa Bay System	1,814	
Charlotta Harbor	2,255	
San Carlos Bay	1,226	
Florida Bay	N.D.	
TOTAL		5,295
		663,361

(From "Compilation and Summation of Historical and Existing Physical Oceanographic Data from the Eastern Gulf of Mexico," SUSIO, 1975)

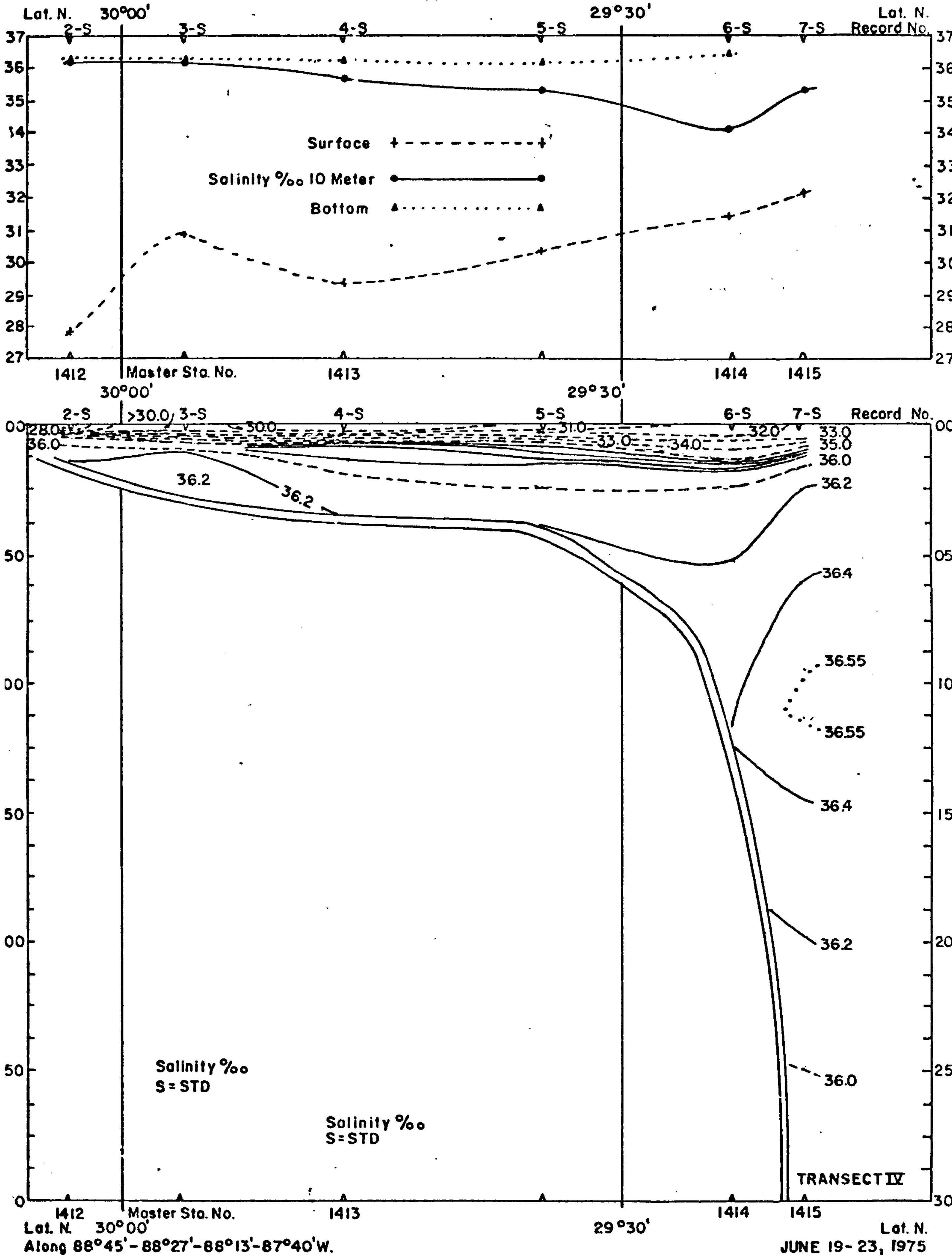


Figure 3. Vertical Distribution Salinity ‰ BLM-12

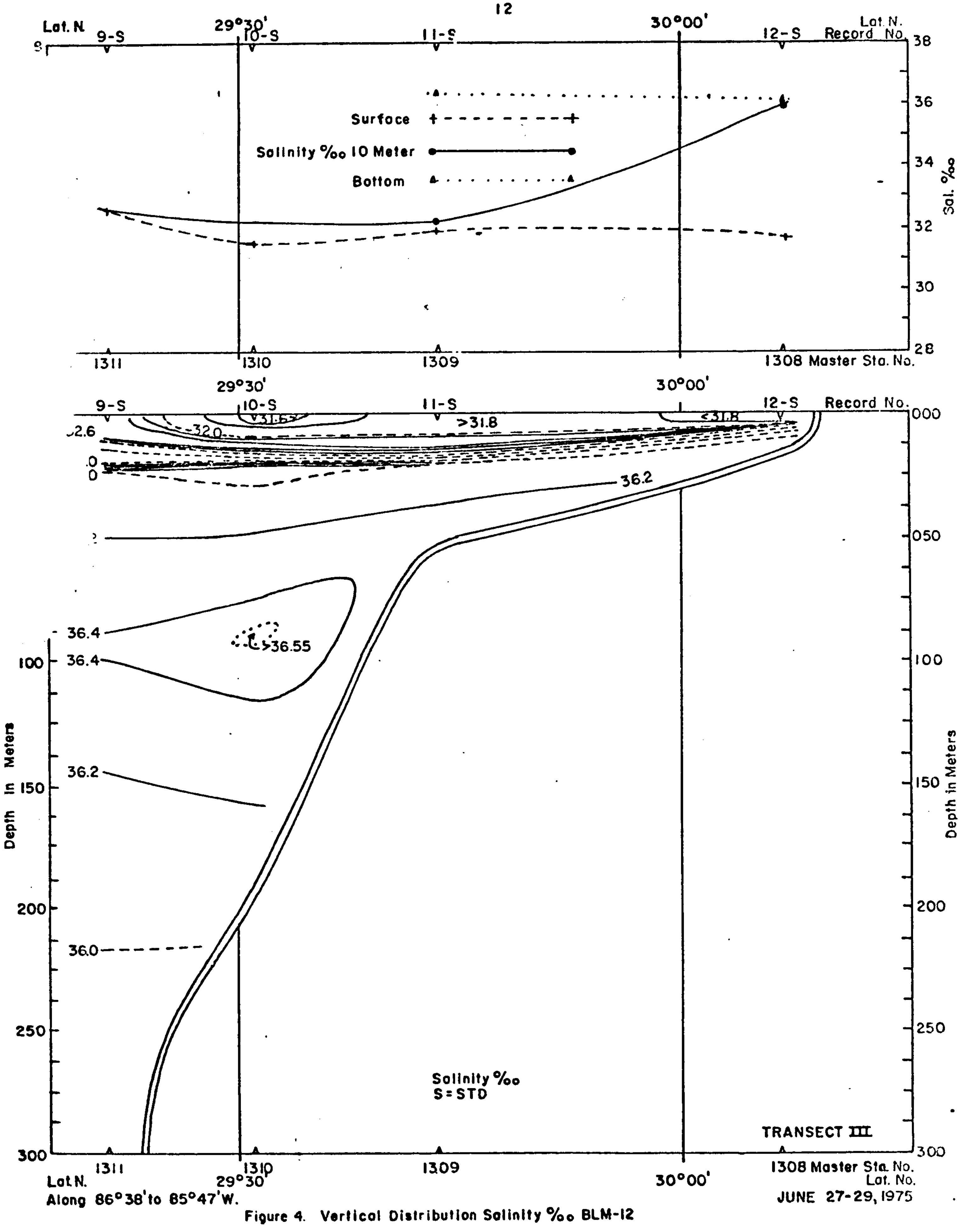


Figure 4. Vertical Distribution Salinity ‰ BLM-12

structure. Such break-offs are usually assoc..ated with a low surface salinity pocket located approximately in the middle of the slope on the Continental Shelf (Figures 3 and 4).

Figure 5 is the 22°C isotherm topographic depth in the eastern Gulf of Mexico during May-June, 1975, as furnished by Molinari (1976). This 20°C isotherm depth as well as the 22°C isotherm depth have been used in the past to determine the location of the Loop Current. Examination of this figure indicates the presence of two detached eddies located along the northwest Florida Continental Shelf near the Mississippi Delta and Panama City areas. These data established the existence of Loop Current water in the MAFLA area as shown in Transects III and IV and confirmed that they were break-off eddies.

Figures 6 and 7 are the temperature distribution for Transects IV and III. In general, the temperature values are uniform across the shelf except within the upper ten meters in the area of the low salinity surface pockets. The thermocline depth does not go below ten meters being shallower in areas of high and deeper in areas of low surface salinity values. (The thermocline depth in this presentation is defined as that depth in which an 0.1°C temperature change has occurred from the surface; it is, therefore, an isothermal layer and not the normal thermocline as defined by biologists.)

There were strong sigma t and temperature gradients at approximately 15 m with a similar salinity gradient located between five and ten meters.

As part of the environmental support data, which were furnished to the other disciplines as they were related to the location of their sampling areas, are the values of temperature and salinity at the surface, ten meters, and near the bottom as listed in Table II. These listings show the

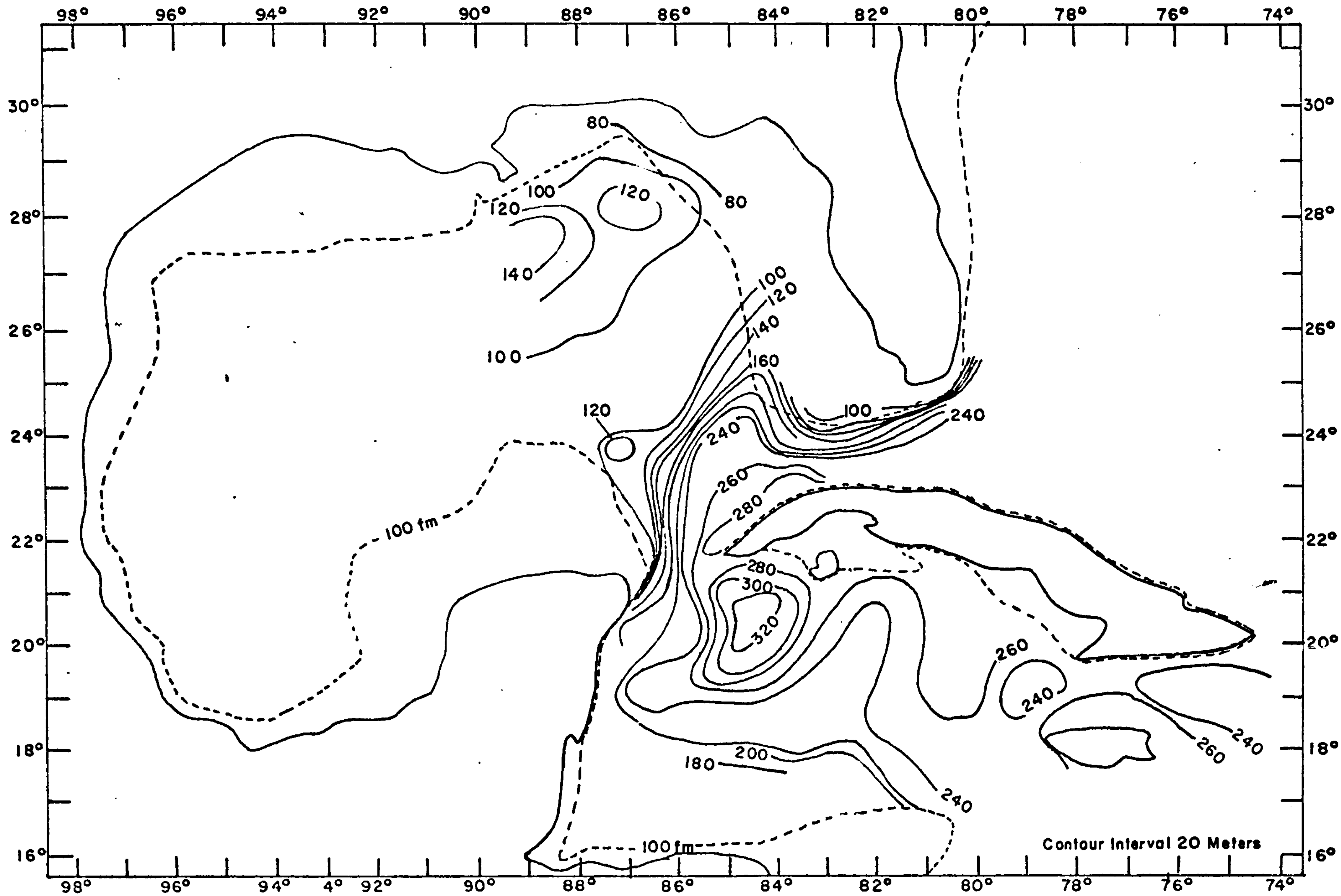


Figure 5. Depth of 20° Isotherm Levels in Eastern Gulf of Mexico and Caribbean Sea During May - June, 1975 From XBT and STD Lowering. Data From Molinari, 1976

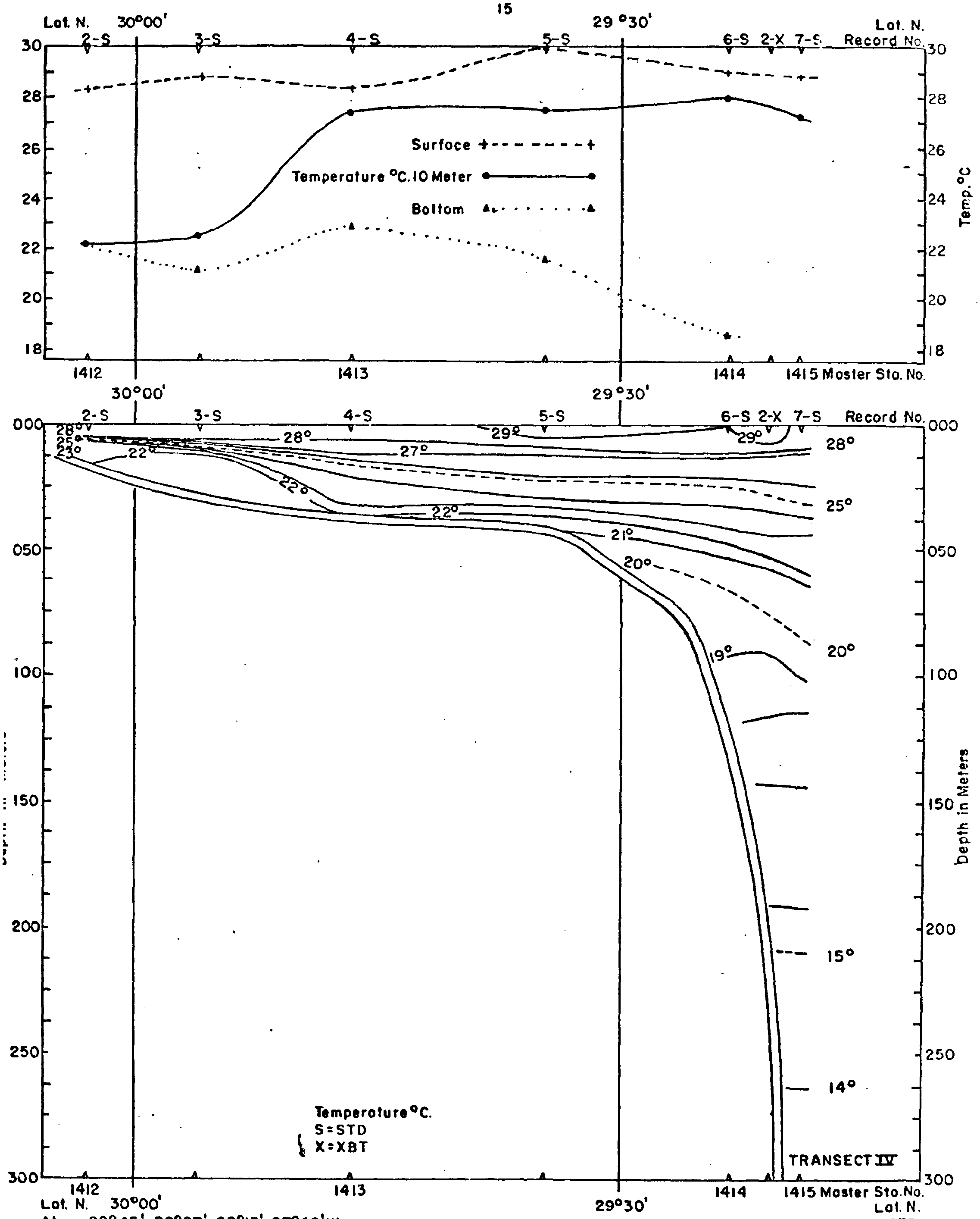


Figure 6. Vertical Distribution Temperature °C. BLM-12

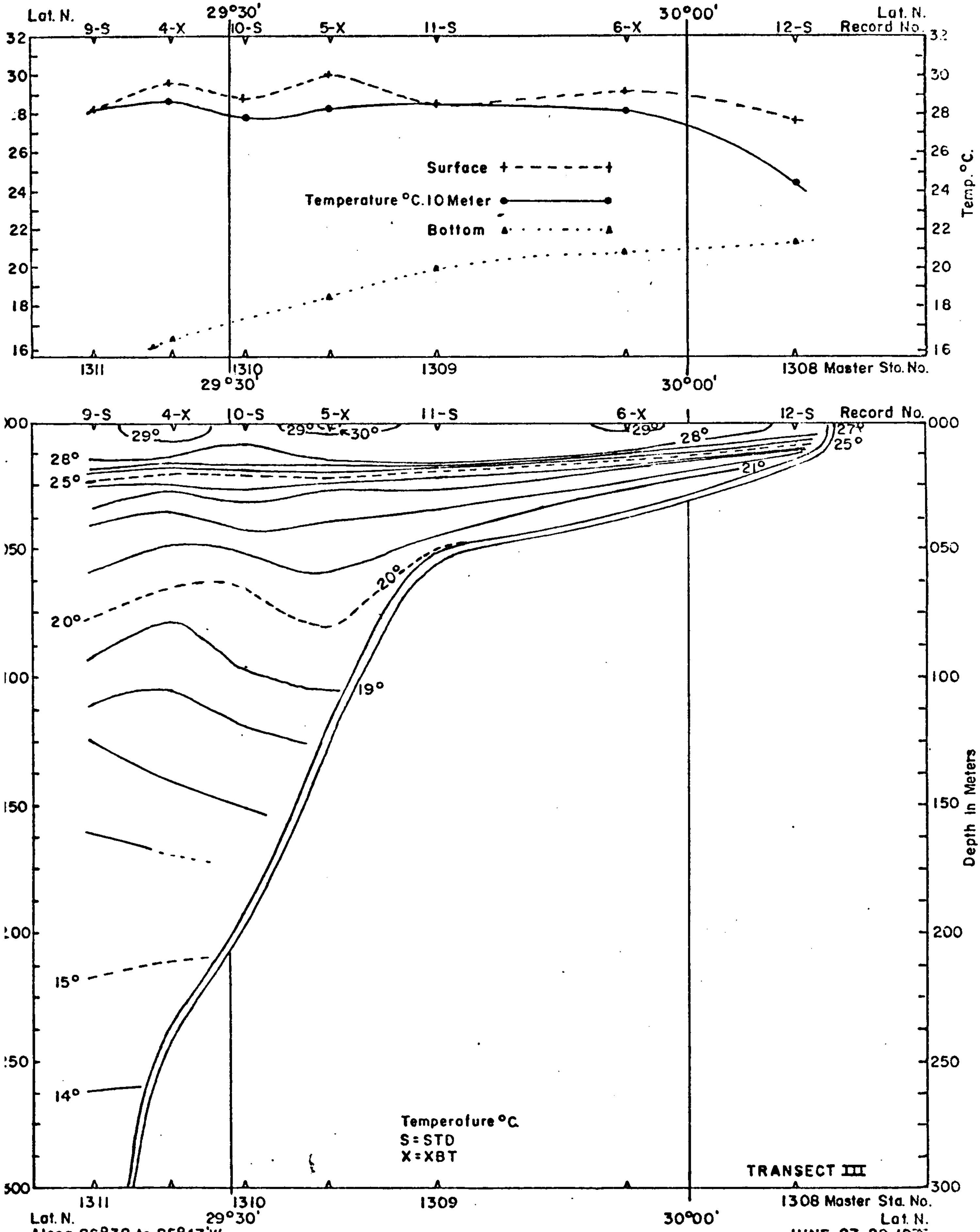


Figure 7. Vertical Distribution Temperature °C. BLM-12

Table II Temperature (°C) and Salinity (°/oo) Ranges Along Each Transect at the Surface, 10 m, and the Bottom During the Summer and Fall, 1975 and Winter, 1976.

	Surface Temperature	10 m Temperature	Bottom Temperature	Surface Salinity	10 m Salinity	Bottom Salinity
			Transect IV			
Summer	29.87-28.25	28.00-22.19	22.95-18.63	32.38-27.83	36.17-34.00	36.40-35.82
Fall	29.65-28.61	29.43-28.86	25.89-14.69	34.70-27.00	35.31-29.00	36.50-34.55
Winter	18.62-13.73	18.90-13.93	18.30-14.04	35.40-31.83	35.69-31.91	36.38-32.08
			Transect III			
Summer	30.00-27.74	28.62-24.50	21.34-16.60	32.56-31.52	35.92-32.20	36.29-36.12
Fall	29.49-28.20	29.55-28.00	-- --	35.76-31.69	35.83-34.80	-- --
Winter	19.84-13.24	19.84-13.46	19.09-12.44	36.30-34.88	36.30-34.95	36.16-35.14
			Transect II			
Summer	28.62-28.40	28.62-28.20	28.25-17.88	36.27-31.52	36.28-31.54	36.28-33.60
Fall	27.39-26.01	27.73-26.11	27.22-24.11	35.56-31.95	35.60-31.98	36.48-31.98
Winter	17.68-11.97	17.68-11.97	17.53-11.97	36.24-34.30	36.27-34.31	36.25-34.30
			Transect I			
Summer	29.30-27.80	28.62-27.50	28.58-17.88	36.27-33.50	36.28-33.50	36.36-35.13
Fall	27.40-26.15	27.40-26.35	26.10-16.85	35.92-33.71	35.92-34.00	36.52-35.19
Winter	20.2 -14.12	19.80-14.14	20.9 -14.16	36.21-35.17	36.28-35.16	36.16-35.15

variability of these parameters at those specific depths associated with discrete sampling across each of the four transects. In this report, the notation "bottom" represents the value taken either at the bottom or within five meters of it; this means that bottom temperature of certain outer stations on each transect cannot be included in this table.

The temperature ranges on Transects IV and III at the surface were 29.87 to 28.25°C and 30.00 to 27.74°C, respectively, with resulting ranges of 1.52 and 2.26°C with the highest range on Transect III; at ten meters, 28.00 to 22.19°C and 28.62 to 24.50°C, respectively, with ranges of 5.81 and 4.12°C with the highest range on Transect IV; and at the bottom, between 22.95 and 18.63°C and 21.34 and 16.60°C, respectively, with ranges of 4.32 and 4.68°C with the highest range on Transect III.

The salinity ranges on Transects IV and III at the surface were 32.38 to 27.83 °/oo and 32.56 and 31.52 °/oo, respectively, with ranges of 4.64 and 1.04 °/oo with the highest range on Transect IV; at ten meters, 36.17 to 34.00 °/oo and 35.92 to 32.20 °/oo, respectively, with ranges of 2.17 and 3.72 °/oo with the highest range on Transect III; at the bottom, 36.40 to 35.82 °/oo and 36.29 to 36.12 °/oo, respectively, with ranges of 0.58 and 0.17 °/oo with the highest range on Transect IV.

Transect II is in the NORTHEAST river discharge characteristic area (Table I) and Marine Summary Zone B and Hydro-Biological Regions VI (Bays, Lagoons, and Estuaries), XVII (Nearshore), and XXIV (Intermediate Shelf) (Figure 2). On this transect the average river run-off was one-tenth of that of Transect IV and one-third of that of Transect III. Because of the bottom topography to the west associated with Cape San Blas it is sheltered from bottom transport input generated from the area described by Transects IV and III for the inner one-half of the transect.

Figure 8 is the salinity and Figure 9 is the temperature distribution on Transect II. The predominant feature of these two sections was the appearance of two low salinity surface pockets (Figure 8); one of 32.06 °/oo located within what is known as the Horseshoe Bend area in approximately 17 m of water (Master Station 1205) and the other of 31.52 °/oo at the outer station of the transect (Master Station 1207) to the west of the Florida Middle Ground. There were no Loop Current or eastern Gulf of Mexico waters on this transect.

The thermocline depths ranged from 10 to 12 m with the deepest values under or near the low salinity pocket in Horseshoe Bend. The water was neither isothermal or isohaline from the surface to the bottom except on the inshore station (Master Station 1204). There were strong gradients in both temperature and salinity fields with the salinity gradients being either along the bottom or at 15 m and sigma t and temperature either at the bottom or along 25 m. The temperature on Transect II at the surface ranged between 28.62 and 28.20°C with a range of 0.42°C; at ten meters, 28.62 and 28.20°C with a range of 0.42°C; at at the bottom, 28.25 and 17.88°C with a range of 10.37°C. There was little variance in temperature with depth across the section except for a shallow depression associated at or near the Florida Middle Ground Master Stations 1206 and 1207 which may be associated with diurnal effect.

The salinity on Transect II at the surface ranged between 36.27 and 31.52 °/oo with a range of 4.75 °/oo; at ten meters, 36.28 and 31.54 °/oo with a range of 4.74 °/oo; at the bottom, 36.28 and 33.60 °/oo with a range of 2.68 °/oo.

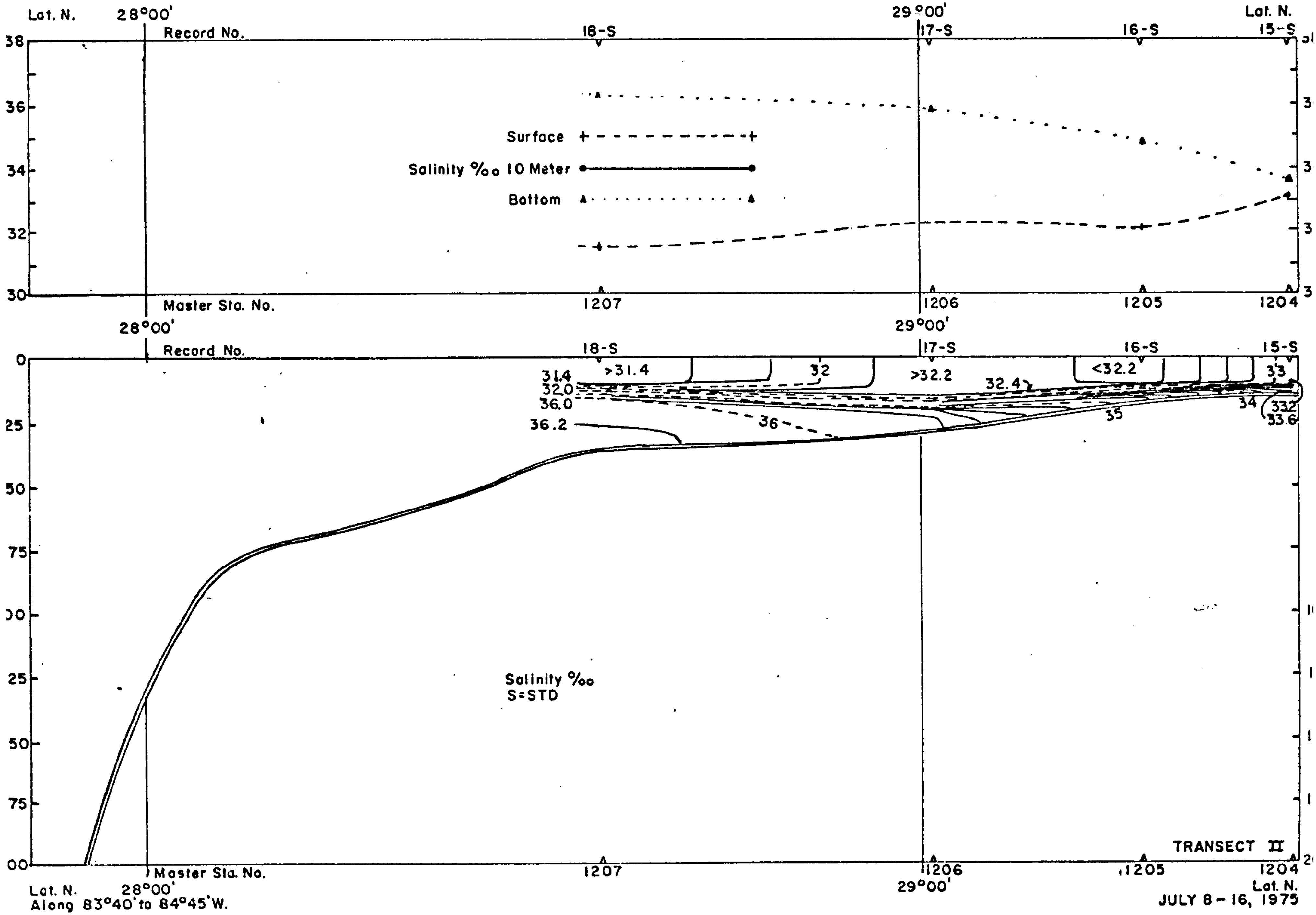


Figure 8. Vertical Distribution Salinity ‰ BLM-12

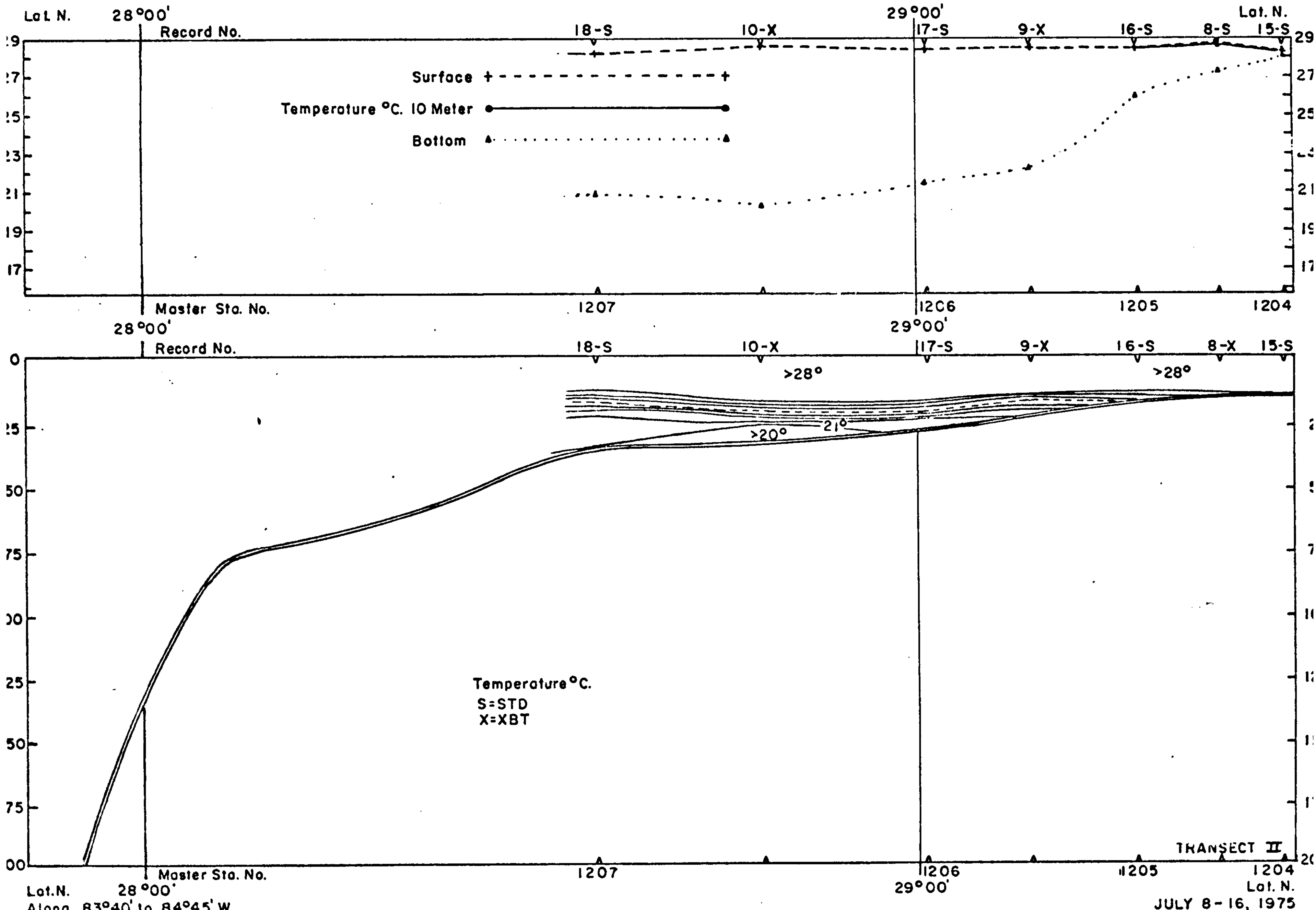


Figure 9. Vertical Distribution Temperature °C. BLM-12

The ranges in these parameters, in general, are markedly different than those associated with Transects III and IV.

Transect I is located west of Tampa, Florida, in the EAST river discharge characteristic area (Table I), Marine Summary Zone B, and Hydro-Biological Region VII (Bays, Lagoons, and Estuaries), Region XVIII (Nearshore), and Region XXIV (Intermediate Shelf) (Figure 2).

The river run-off in this area is on the average approximately one percent of that associated with Transect IV, three percent of Transect III, and nine percent of Transect II.

Figure 10 is the salinity and Figure 11 is the temperature distribution. This is the only transect on which a single low surface salinity pocket (33.50 °/oo) occurred. On the outer station (Master Station 1103) and up on the shelf to an approximate depth of 75 m Loop Current water was present. This water along with a very narrow band of the eastern Gulf of Mexico water intruded onto the shelf as a mid-water phenomenon located predominantly at a depth of 55-125 m. Unlike Loop Current water seen on Transects III and IV, this water was not only along the slope of the Continental Shelf but onto the shelf itself.

As can be seen by the examination of Figure 5, the depth of the 20°C isotherm indicates that this water was intruding onto the shelf as a continuous forcing mechanism rather than a detached eddy. Further, the salinity value of 36.78 °/oo and temperature of 22.12°C indicates that this was sub-tropical water (SUW) and was associated with the core of the Loop Current itself (Molinari, 1976, pages 17-18).

The temperature at the surface on Transect I ranged between 29.30 and 27.80°C with a range of 1.5°C; at ten meters, 28.62 and 27.50°C with a

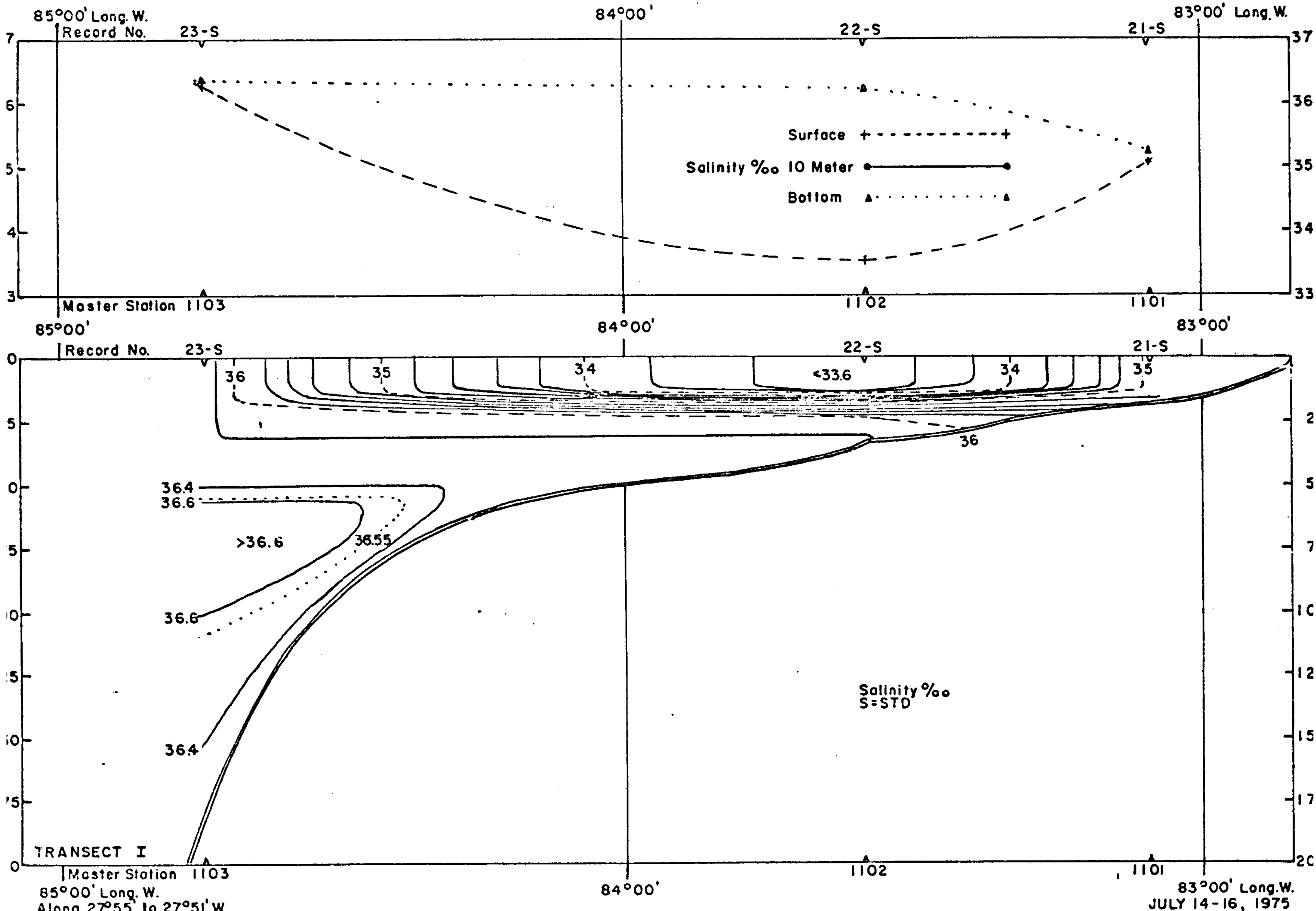


Figure 10. Vertical Distribution Salinity ‰ BLM-12

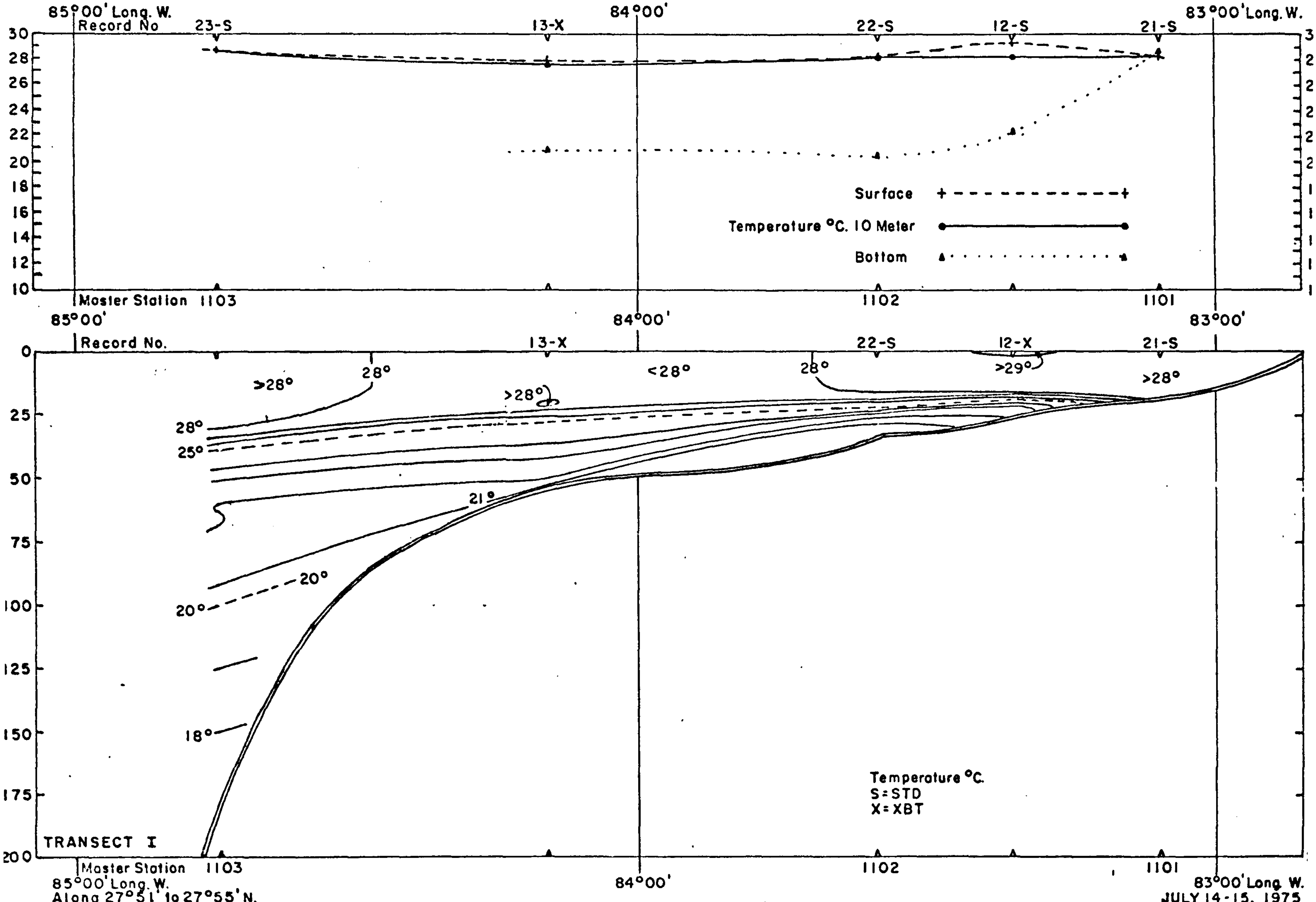


Figure 11. Vertical Distribution Temperature °C. BLM-12

range of 1.2°C; and at the bottom, 28.58 and 17.88°C with a range of 10.70°C. The thermocline depths ranged from 10 to 28 m with a steady increase in depth outward across the Continental Shelf. At no station except on the inshore Master Station 1101 was it isohaline or isothermal to the bottom.

There was a strong gradient at approximately 20 m in salinity out to the beginning of the slope of the Continental Shelf. In the temperature and sigma t fields strong gradients appeared between Stations 1102 and 1101 at approximately 20 m with weaker ones extending seaward from these and descending to approximately 45 m in depth.

The forcing mechanism associated with the river run-off and drainage areas appeared to influence Transects III and IV to a distance between 15 and 20 nautical miles (27.8 and 37.1 km) offshore. This influence is illustrated by the inshore low salinity pockets on Transects III and IV. If one considers the tidal oscillation effects on these pockets, the mean distance was about 17 nautical miles (31.5 km).

Since June and July represent times of extreme low run-offs (SUSIO, 1975, page 14) (Jones and Rinkel, 1973, page 199) and since the run-offs in Transect Areas I and II are extremely small, it is not surprising that no effects of run-off were noted in Transects I and II since inshore stations on each transect were 15 and 20 nautical miles (27.8 and 37.1 km) offshore.

While June-July might historically be times of low run-off discharge, only after the examination of the actual run-off discharge for June-July 1975 can one state with authority that the observed low inshore salinity pockets represent such a condition. A request, therefore, was made to the Department of Interior, U.S. Geological Survey, for all the historical data up through 1976 for the run-off discharge sources in the MAFLA area. This request specified the nearest Gulf run-off sources along with monthly mean maximum and minimum for each year for them.

Table III lists the location of the data sources, their names, the length of the data records, and the amount of data available for the time period October, 1974, through December, 1976, and Table IV lists the discharge volumes for the months of May, June, July (Summer); August, September, October (Fall); and December, January, February (Winter) for the years 1974, 1975, and 1976 as received from U.S.G.S. Since it is difficult to determine the time period of the processes connected with shelf circulation run-off discharge inter-reactions, this table includes data recorded one month before the start of each seasonal BLM study.

For selected stations, figures illustrating the yearly discharge distribution patterns have been prepared for the period July, 1973, through September, 1976. These figures appear in Appendix I along with a chart that shows the locations of the data sources and their relationship to the BLM transects. Before examination of Table IV and these figures, it is important to understand that the figures illustrate two different types of discharge information. One is the effect of large scale meteorological conditions on large drainage areas as represented by major river system discharges and the other, the local small scale effects on coastal areas. The latter can be seen in the creek discharge information.

It will be seen that these two types of influences can produce very different yearly discharge distribution patterns. In this study, the major river run-off discharge is the important factor, except when a local discharge source is discharging directly into a BLM transect. Unless so stated, the following discussion is related to the major river system information.

TABLE III

STATION NAME, LOCATION IN LATITUDE AND LONGITUDE, LENGTH OF DATA RECORD, AND DRAINAGE AREAS FOR RUN-OFF DISCHARGE VALUES
Modified from U. S. Geological Survey

STATION NAME	LATITUDE	LONGITUDE	OCT-DEC 1974	JAN-DEC 1975	JAN-1976	LENGTH OF RECORD	DRAINAGE AREA (SQ.MILES)
Red River	31°18'46"	92°26'34"	X	Jan-Sept	None	Oct. 28	67,500
Mississipi River Vicksburg	32 18 45	90 54 25	None	None	None	Oct. 31	1,144,500
Biloxi River	30 33 30	89 07 20	X	X	Jan-Sept.	Oct. 74	96
Red Creek	30 44 10	88 46 50	X	X	Jan-Sept	Oct. 74	416
Pascagoula	30 58 40	88 43 35	X	X	Jan-Sept	Oct. 74	6,600
1obile	30 39 03	88 07 28	X	Jan-Sept	None	June 62	9
,ig Coldwater Creek	30 42 30	86 58 20	X	Mar,April, Aug,Sept.	None	Dec. 38	237
ıggett Creek	30 43 40	86 39 35	X	X	Jan,Apr, June-Sept	Oct. 64	8
Shoal River	30 41 48	86 34 17	X	Oct-Sept	None	Aug. 37	474
Alaqua Creek	30 37 00	86 09 50	X	X	Jan-Sept	May 50	66
Choctawhatchee	30 27 03	85 53 54	X	X	Jan-March July	Oct. 30	4,384
Econfina Creek	30 23 04	85 33 24	X	X	Jan-Sept	Oct. 35	122
Steinhatchee River	29 47 11	83 19 18	X	X	Jan-Sept		350
Suwannee River	29 35 22	82 56 12	X	X	Jan-Feb	Oct. 30	9,640
Waccasassa River	29 12 14	82 46 09	X	Jan-Sept	None	Oct. 63	480
Pithlachascotee River	28 15 19	82 39 37	X	X	Jan-Sept	April 63	182
Anclote River	28 12 50	82 40 00	X	X	Jan-Sept	June 46	72
Brooker Creek Tarpon Springs	28 05 45	82 41 15	X	X	Jan-Sept	Sept. 50	30
Sweetwater Creek	28 02 33	82 30 44	X	X	Jan-Sept.	Oct. 51	7
Rocky Creek	28 02 23	82 34 31	X	X	Jan-Sept	June 53	35
Alligator Creek	27 58 45	82 41 45	None	None	None	Oct. 49 Sept. 74	9

TABLE III contd.

	LATITUDE	LONGITUDE	OCT-DEC 1974	JAN-DEC 1975	JAN-1976	LENGTH OF RECORD	DRAINAGE AREA (SQ.MILES)
Seminole Lake Largo, Florida	27°50'20"	82°46'50"	None	None	None	Aug. 50 Sept. 71	14
Hillsborough River Tampa, Florida	28 01 25	82 25 40	X	Sept.75	None	Oct. 38 Sept. 74	650
Alafia River Tampa Bay	27 52 19	82 12 41	X	X	Jan-Sept.	Oct. 33	335
Little Manatee River	27 40 45	82 21 10	X	X	Jan-Sept.	Oct 39	149
Manatee River	27 28 30	82 18 05	None	None	None	Oct. 39 Sept. 66	80

Table IV. Discharge volume for selected stations within the MAFLA are for May, June, August, September, October, December, January, and February for 1974, 1975, and 1976

	MAY			JUNE			JULY			AUGUST		
	1974	1975	1976	1974	1975	1976	1974	1975	1976	1974	1975	1976
Pascagoula River	----	24,850	9,850	----	10,900	5,070	----	7,020	2,950	----	11,500	1,870
Red Creek	----	1,920	977	----	1,170	624	----	282	449	----	1,910	221
Biloxi River	----	444	224	----	271	90	----	186	89	----	436	16
Mobile	----	22	24	----	12	28	----	25	25	----	27	21
Big Coldwater Creek; Milton, FL	366	657	----	318	661	----	297	1,160	----	419	2,480	382
Milligan FL	17	26	----	17	23	26	15	43	23	23	65	21
Shoal River, FL	627	1,100	2,240	554	1,430	1,680	522	1,310	934	1,030	4,390	913
Alaqua Creek DeFuniak Springs FL	84	185	250	73	236	265	61	1,080	200	129	949	198
Choctawhatchee River	4,380	7,390	----	3,790	8,940	----	2,600	6,850	5,290	3,550	21,900	----
Econfina Creek	612	67	55	431	179	107	424	179	150	501	669	56
Steinhatchee Rv.	64	67	55	68	179	107	94	669	150	1,030	440	56
Suwannee River	8,720	20,900		6,980	11,600		6,460	9,630	----	8,030	12,800	----
Waccasassa Rv.	62	88		98	47		209	309	----	392	288	651
Pithlachascotee River	0.86	1.2	38	126	1.1	64	151	13	23	191	27	34
Anclote River	2.3	2.4	75	245	3.4	215	233	96	49	318	104	110
Brooker Creek Tarpon Springs	0	0	7.8	93	0.17	21	79	27	21	88	12	29
Rocky Creek Sulphur Springs	4.0	1.5	20	122	2.9	59	122	15	35	79	28	71
Hillsborough Rv. Tampa	0.06	0	----	390	0.10	----	2,160	217	----	1,410	1,480	----
Alafia River Tampa Bay	116	101	335	337	185	753	1,100	383	402	900	570	449
Little Manatee River	29	22	39	195	105	105	607	357	36	317	164	102

	SEPTEMBER			OCTOBER			DECEMBER			JANUARY			FEBRUARY		
	1974	1975	1976	1974	1975	1976	1974	1975	1976	1974	1975	1976	1974	1975	1976
Pascagoula River	----	6,290	1,040	3,620	12,400	----	14,100	8,130	----	----	34,100	14,400	----	25,275	8,950
Red Creek	----	1,050	268	----	1,780	----	835	784	----	----	1,390	891	----	709	1,040
Biloxi River	----	111	49	----	219	----	255	98	----	----	251	148	----	164	158
Mobile	----	22	27	----	40	----	15	28	----	----	18	22	----	16	15
Big Coldwater Creek; Milton, FL	616	1,170	442	281	----	----	376	----	----	652	555		494	548	----
Milligan FL	30	56	20	19	93	----	17	62	----	27	21	51	31	21	----
Shoal River, FL	1,470	3,970	808		2,660	----	816	1,780	----	2,340	1,040	1,660	2,750	1,250	1,420
Alaqua Creek DeFuniak Springs FL	277	525	159	88	668	----	127	252	----	260	182	313	260	162	203
Choctawhatchee River	3,570	8,470	----	2,630	----	----	4,580	10,300	----	13,700	7,940	8,240	19,500	11,275	7,390
Econfina Creek	500	440	161	116	522	----	100	49	----	552	435	245	540	572	544
Steinhatchee Rv.	738	522	161	116	229	----	100	49	----	65	485	245	89	705	266
Suwannee River	13,400	1,020	----	10,600	7,730	----	6,610	6,490	----	7,420	10,400	9,730	9,870	17,900	11,900
Waccasassa Rv.	289	----	----	93	----	----	134	----	----	131	170	----	117	114	----
Pithlachascotee River	122	72	16	18	83	----	7.1	6.1	----	11	8.4	8.0	4.5	27	5.8
Anclote River	215	147	28	11	150	----	3.3	6.4	----	28	4.4	7.8	5.9	5.8	5.4
Brooker Creek Tarpon Springs	67	55	24	7.3	58	----	0.19	0.80	----	4.6	0.76	1.90	0.89	0.80	1.10
Rocky Creek Sulphur Springs	85	76	36	11	92	----	4.4	5.5	----	19	5.7	5.3	9.5	5.4	3.7
Hillsborough Rv. Tampa	996	764	----	208	----	----	30	----	----	319	18	----	78	29	----
Alafia River Tampa Bay	321	478	336	147	434	165	146	166	----	177	138	166	150	155	206
Little Manatee River	66	210	39	22	120	----	27	36	----	25	25	33	24	30	32

In Transects IV and III the river systems, as documented in the Biloxi, Pascagoula, and Big Coldwater Creek areas (Table IV), could discharge into Transect IV. Figures 1 and 3 (Appendix I) show low June-July, 1975, discharge values at Biloxi and Pascagoula. Big Coldwater Creek (Figure 5), on the other hand, has near-maximum values. Historically, during June-July the river run-off values for Mississippi Sound and Mobile Bay Systems (Transect IV) have five times the flow rates of the Perdido, Pensacola, Choctawhatchee, and St. Andrew Bay Systems (Transect III) as seen in Table I. Despite the large discharge values associated with Big Coldwater Creek, the other run-off areas associated with Transect III (Shoal River, Alaqua Creek, and Choctawhatchee River) run-off sources have low discharge values in May, June, and July of 1975.

Considering the accumulated effect of the run-off, it should be expected that the influence of the discharge would be less pronounced on Transect III than on Transect IV. Examinations of Figures 3 and 4 show that this is the case with the run-off effects being seen 17 nautical miles (31.5 km) offshore on Transect IV and 13 nautical miles (24 km) offshore on Transect III.

On Transect II the major discharges influencing the salinity distribution patterns are represented by the Steinhatchee and Suwanee River systems (Figures 11 and 12, Appendix I). These figures indicate that there are either low, or extremely low, discharge values during the summer period. Although a marked increase in flow is recorded on the Steinhatchee River during July, the BLM sampling had been completed by the first two weeks of July, and this discharge rate probably had not influenced the salinity distribution patterns. The influence of this discharge cannot be seen on Transect II on which the inshore station was 17 nautical miles (31.5 km) offshore.

Unlike the run-off discharges on Transects II, III, and IV, those connected with Transect I show maximum flow rates during June and July. The data source consists of a number of small creeks discharging to the north of the transect and a number of rivers emptying into Tampa Bay with a resulting discharge to the south of the transect.

Unlike the northern Gulf data, there is not a major difference in the discharge characteristics between the localized drainage areas and the major river system areas. This can be seen by examination of Figures 14-22 in Appendix I.

Since the summer sampling occurred during the maximum discharge, it is surprising that no evidence of this flow can be seen on Figures 10 and 11 on the inshore station, which is 17 nautical miles (31.5 km) offshore. Historically, there has been an inshore northerly transport inside of the ten fathom line which would tend to move the discharge to the north. However, the intrusion on the shelf in the vicinity of Transect II might be entraining this water to the south.

There was another run-off effect that appeared on all transects. This was the low salinity pocket situated either on the shelf on Transects I, II, and IV or along the slope of the Continental Shelf on Transect III which is associated with the Mississippi River system drainage (WEST). This was a separate run-off than that of the NORTHWEST drainage associated with the inshore low salinity pockets on Transects III and IV. Figure 12 is a horizontal distribution of surface salinity which may be used to illustrate the feature of the transport of these drainage areas. The Mississippi River System drainage is to the east and appeared to have been influenced by the two broken-off Loop Current eddies (Figure 5), which caused the movement of the water onto the shelf on Transect IV and outward to the Continental Shelf

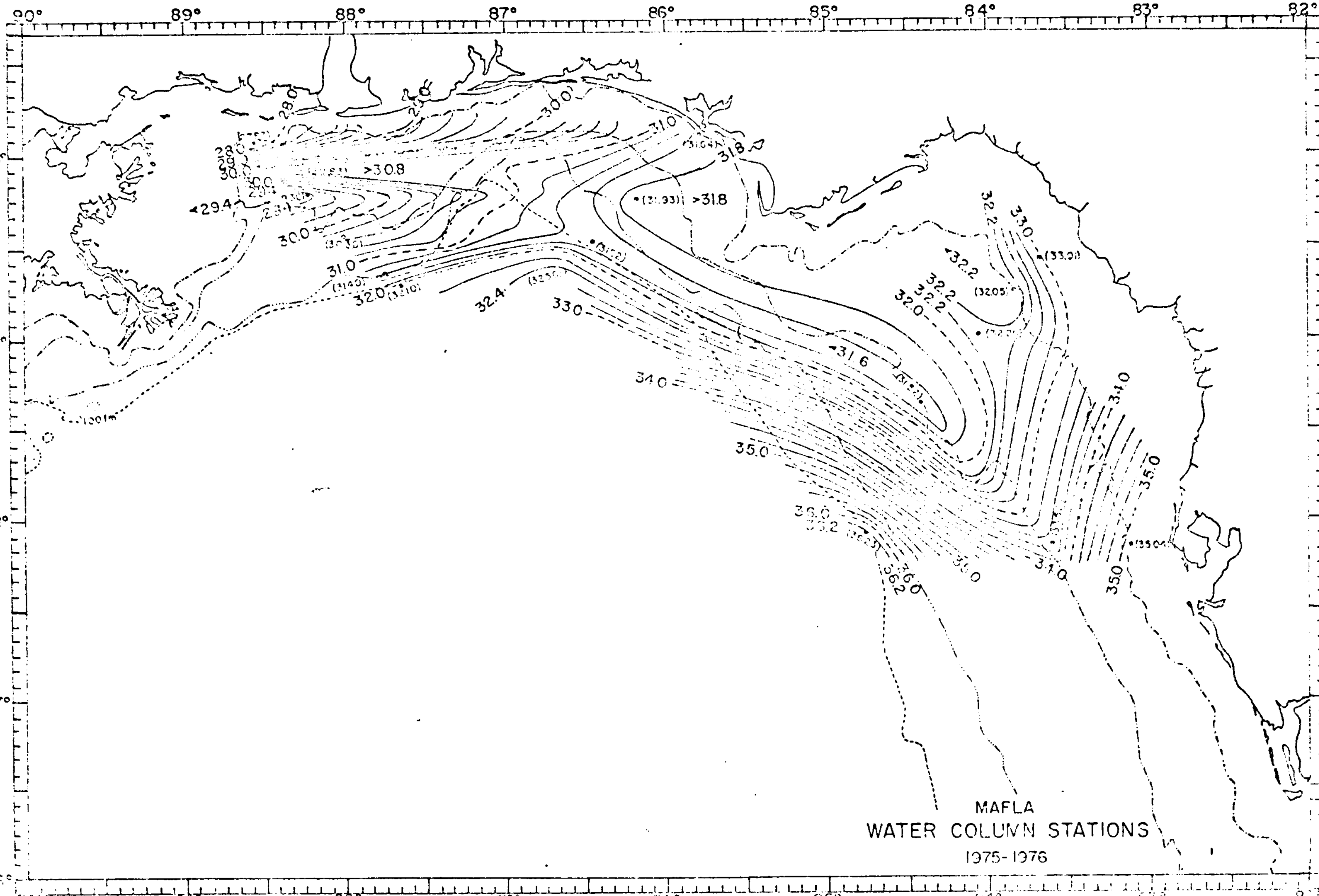


Figure 12 Surface Distribution of Salinity ‰ BLM-12 JUNE 10-JULY, 1975

slope on Transect III. As it moved southward, it was further influenced by the intrusion onto the shelf itself of core Loop Current water near Tampa Bay forcing this run-off water up onto the middle area of the shelf on Transects I and II.

The run-off data received from the U. S. Geological Survey for the Mississippi River System discharges did not contain any information past September, 1974. It is, therefore, impossible at this time to determine the actual yearly distribution of discharge flow during this BLM sampling program. Historically, June and July were low discharge periods as reported by Schroeder (SUSIO, 1975, page 14).

The NORTHWEST drainage flow as described by the nearshore low surface salinity on Transects III and IV apparently was moving to the east and was forced to the south and east after Transect III by the geographical nature of the Cape San Blas area.

Although it is very dangerous to use non-synoptic data to infer transport features by the use of salinity distribution particularly with the presence of broken-off Loop Current eddies, such as were occurring at this time on the shelf, the offshore low salinity distribution might reflect the transport of a Mississippi River System discharge over 270 nautical miles (500.4 km) within 24 days as it was slowly eroded away by other shelf forcing mechanisms. The salinity distribution pattern associated with the major flooding (once in 100 years feature) from the Mississippi River System discharge in 1973, in the presence of Loop Current waters near Transects III and IV, showed a similar flow with a 30-day period (average speed 24 cm/sec). Further, according to Mooers and Price (SUSIO, 1975, page 45) the mean current velocities over an approximate five-week period near 26°00'N at an outer and middle shelf location at a depth of 25-27 m by direct current measurement were between 10 and 17 cm/sec. The mean flow in the summer of 1975 would have been approximately 24.37 cm/sec, which is near those reported by Mooers and Price and observed in 1973.

It is believed that the low salinity pocket observed in Transect II in the Horseshoe Bend area (Master Station 1205) with a minimum salinity of 32.96 $^{o}/_{oo}$ was not connected or associated with either the WEST (Mississippi River System) or NORTHWEST drainage areas. The results of drift bottle studies conducted in May, 1970, and August, 1971, by Brucks (SUSIO, 1975, pages 33 and 34), who used the sigma t values in determining the movement of the bottles, and the presence of a high salinity ridge between the low salinity surface pockets on Transect II indicate that this salinity was the center of an eddy in the Horseshoe Bend area.

As stated by Fernandez Partages (SUSIO, 1975, pages 5-7, and Appendix II), the summer atmospheric circulation over the eastern Gulf is primarily controlled by a quasi-permanent feature; i.e., the east-west oriented high pressure ridge, which elongates westward from the Bermuda Azores high. The summer disturbances in the eastern Gulf of Mexico are basically of a tropical origin and consist of either tropical waves or tropical cyclones. The tropical waves tend to be quite weak especially near the sea surface.

As stated by Jordan (SUSIO, 1972, pages 5-18), a detailed description of the climate of each individual hydro-biological zone in the eastern Gulf of Mexico cannot be provided ... since the available marine data have been summarized only for fairly large areas (such as Zones A and B on Figure 2);

the probability of a tropical storm or hurricane influencing the eastern Gulf of Mexico during any given year is about fifty percent, and the probability of two hurricanes or tropical storms occurring during the year is fifteen percent; hurricanes and tropical cyclones are capable of producing effects, which might be present in the area for a period of days or weeks; the heavy rains associated with these storms might lead to abnormally large river discharges, which might affect the coastal areas for a period of days or longer; in a 1954-1969 study the frequency of extratropical cyclones moving into coastal areas is 0.7 (in occurrence per year) for the summer months in Marine Summary Zone A in the eastern Gulf of Mexico (Table V); thunderstorms through June and September average between 42 and 55 across the shore weather stations within the inshore portion of Zone A; although large scale circulation patterns, which suggest that winds with a northerly component (October to February) and a southerly component (March through September), the wind directions vary considerably from day to day; during the period March through September, when the tropical air masses dominate the area, the percentage of wind with a southerly component is only slightly greater than those with a northerly component; that the mean annual speeds from coastal stations, in general, show appreciably lower speeds occurring during the winter or early spring and the lowest mean speeds occurring in January or August; for Marine Summary Zones A and B, the mean speed shows small month to month differences with appropriate lower values during the months of May through August (Table VI); that the concentrations of rainfall in the summer in northern and western Florida leads to the highest river discharge in the late summer and early fall (which would

Table V. Mean Seasonal Frequency (in occurrences per year) of low pressure center which move inland in the indicated coastal sectors. Hurricane and tropical cyclones have been excluded.

	90°W to Apalachicola (Zone A)	Apalachicola to 28.5°N (Zone B)	28.5°N to Ft. Myers (Zone B)	Ft. Meyers to 25°N (Zone C)	All Sectors
Winter	1.6	2.2	0.2	0.4	4.4
Spring	0.7	1.0	0.3	0.2	2.2
Summer	0.7	0.6	0.2	0.1	1.6
Fall	1.6	0.6	0.2	0.1	2.9
TOTAL	4.6	0.6	0.2	0.1	11.1

From Table, page 10 Hydro-Biological Zones of the Eastern Gulf of Mexico, 1972. For location of areas see Figure 2.

Table VI. Wind Statistics for Marine Areas

	Area A		Area B	
	Sept.-Apr.	May-Aug.	Sept.-Apr.	May-Aug.
Mean Speed (knots)	13.2(679.5)*	9.0(463.3)*	12.6(648.6)*	8.4(432.4)*
Less than 7 knots(359.8)*	16%	37%	19%	38%
7 - 16 knots(359.8 to 822.4)*	58%	56%	59%	56%
Greater than 16 knots (822.4)*	26%	7%	22%	6%

* cm/sec

Modified from Table VI, page 14, Hydro-biological Zones of the eastern Gulf of Mexico, 1972 not affect the June-July salinity distribution pattern); and the quality of ship reports at most of the areas would probably prove inadequate for reliable climatological values.

The R/V BELLOWS, which was anchored at diving stations on Transect II during a period from June 1 through July 1, 1975, will be used as an example of open shelf surface weather conditions with regard to possible strength of wind stress forcing mechanisms on shelf circulation. Also presented on Figure 13 are the actual wind conditions from the water column cruise of the R/V TURSIOPS as it moved from Transect IV to Transect I.

Figure 13 shows that the R/V BELLOWS' wind speed ranged from approximately five (257 cm/sec) to twenty knots (1028 cm/sec) with the mean speed being approximately twelve knots (6168 cm/sec). The wind flow ranges indicated the presence of both easterlies and westerlies. In a period of thirty days it also showed that there were four reversals in the flow regime which is lower than the average number of fronts as indicated by Fernandez-Partagas and Mooers (SUSIO, 1975, Appendix II).

In an attempt to relate the R/V BELLOWS' essentially anchored location with the rest of the data taken from the R/V TURSIOPS during the water column cruise from June 19 to July 17, 1975, the wind speed and wind direction from that vessel have been plotted on Figure 13. It should be remembered that in meteorology the wind direction is defined as the direction from which the wind blows which is just the reverse of the way current direction is recorded by the oceanographers. For example, a southwest wind is a forcing mechanism towards the northeast which would generate northerly surface currents. Both in direction and speed the data from the R/V TURSIOPS were near

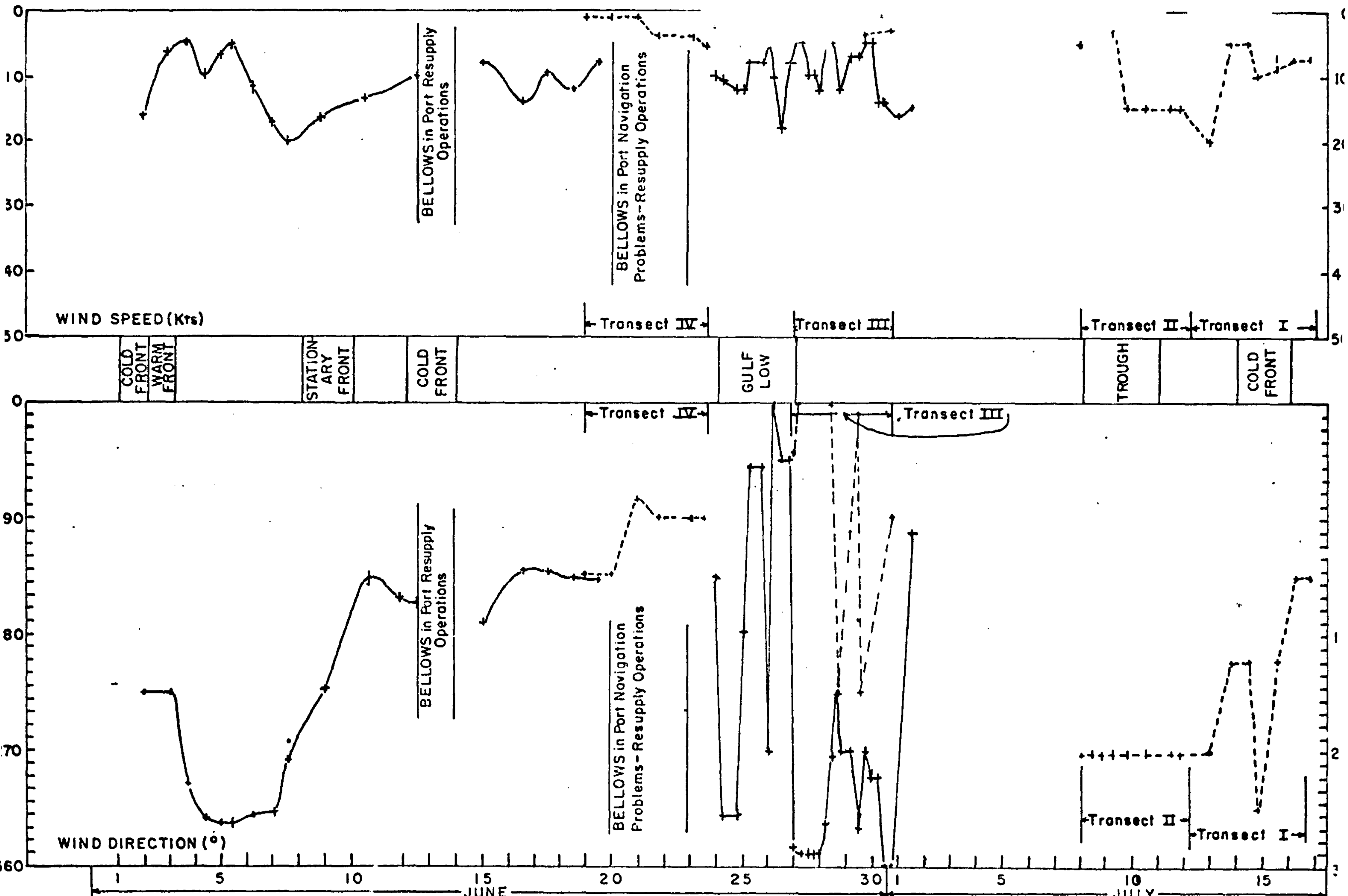


Figure 13. Wind Speed and Direction from R/V BELLOWS and TURSIOPS – June and July, 1975 in MAFLA Area. BELLOWS on Transect II + —— + TURSIOPS on all Transects + - - - - - +

those collected by the R/V BELLOWS except that the wind speed in the northern portion appears to be lower than those in the southern areas which agrees with Jordan (SUSIO, 1972).

In examination of daily series synoptic weather maps at 1200 GMT (NOAA, 1975) the surface chart indicates that during the summer sampling season a total of three cold fronts and one warm front moved through the area The first of these phenomena was a cold front from June 1st through June 2nd which was followed by a warm front on June 3rd. This can be seen rather clearly in Figure 13 with not only a change in wind direction but wind speed. Another disturbance, which influenced the area, was a stationary front from June 8th through the 10th located in the lower portions of Mississippi, Alabama, Florida, and Georgia which is also signified by a change in wind direction and speed (Figure 13). On June 12th through the 14th a cold front moved across Transects IV, III, and the northern part of Transect II extending down to 29°N. It then moved northward and out of the area. This is not reflected in Figure 13 since the vessels were in port.

On June 26th a low developed in southern Florida the effects of which can be seen on the 24th through the 27th on Transect II but not on Transect III (Figure 13).

On July 8th through the 11th a trough developed across southern Louisiana, Alabama, Georgia, and Florida and along western Florida followed on July 13th by a cold front over land. The effects of this cold front can be seen on Figure 13 on July 14th and 16th.

Based on vessel weather observations and this cursory examination of the daily weather charts, it would appear the meteorological observations fall into the average conditions as indicated in Tables V and VI; further, that the predominantly easterly winds would set up a circulation pattern in which the effects of the Ekman spiral would tend to establish an eddy in the Horseshoe Bend area and further confirms the existence of a separate water mass in that area as indicated by the temperature and salinity fields.

The Loop Current is one of the forcing mechanisms that can influence the transport on the shelf. In reviewing the summer sampling, Loop Current water was present at Master Stations 1415, 1311, and 1103. On Master Stations 1415 on Transect IV and 1311 on Transect III, which are at the outer end of each transect and located on the slope of the Continental Shelf rather than on the shelf itself, the Loop Current was present at approximately 100 m. While this water was from two detached eddies on Master Station 1103 on Transect I, it appeared as a mid-water intrusion extending inward to approximately a location at a 75-meter depth on the shelf. For this reason, only the plankton tows would be under the effect of the Loop Current since no such water was present at the surface, ten meters or along the bottom. Further, while the Loop Current forcing mechanism was influencing the shelf circulation on Transects III and IV, its major effect was on Transect I which would result in a rapid transport of contaminants from that area to the southeast and then south and southwest off the shelf and into the Straits of Florida.

There were strong temperature, salinity, and sigma t gradients on each transect. However, except for Transect I the salinity was separated from the temperature and sigma t with the gradients being of deeper depths the farther south you went.

In planning the water column sampling program, it was assumed that the major source of chemical contamination on the shelf would be associated with the low salinity surface pockets resulting from drainage run-off. Measurements for chemical samples were set at ten meters since historical chemical data indicated that a sampling depth of five to ten meters would be required to remove possible contamination from the vessel, and physical data indicated that these low salinity surface pockets in the MAFLA area were usually 15 m deep. It should be noted that on Transects III and IV the salinity gradient structure indicated that these pockets extended only to a depth of five-ten meters. The chemical samples, therefore, might not represent measurement for these run-off sources. The water was isothermal and isohaline only on the inshore stations on all the transects. Further, the mixed layer was not very deep on the remaining stations on the transects. There was a small but significant increase in the depth of the thermoclines as you went further to the south where the effects of the westerlies were more predominant on the surface water structure.

Figure 14 is the horizontal salinity distribution (°/oo) at ten meters. Unlike the surface salinity distribution, this figure does not show the continuous flow of Mississippi River System water (WEST) on Transect IV. The reason for this has been discussed above. However, on Transect II this was probably Mississippi River System water resulting from the mixing as that water mass moved to the east and south.

Figure 15 is the bottom distribution of salinity. By and large, this indicated that except for the outermost station on Transect IV, which is along the slope of the Continental Shelf, the entire shelf area was covered with outer shelf water (36.2 °/oo) except in the area of Horseshoe Bend and in the inner portion of Transect I. This is another indication of the separation of the water mass structure in the Horseshoe Bend area and its

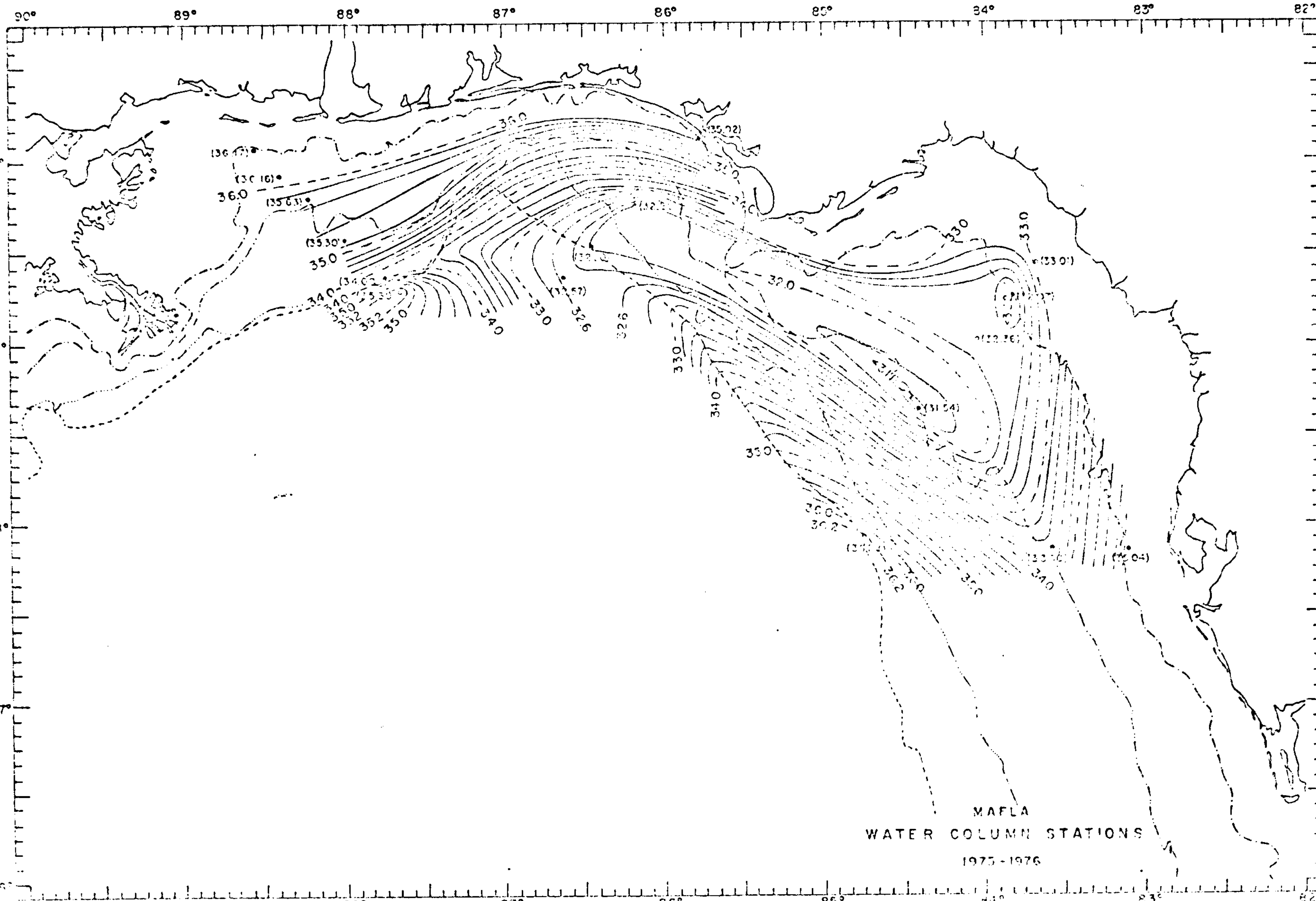


Figure 14 10 Meter Distribution Salinity ‰ BLM-12 JUNE 19,-JULY 15, 1975

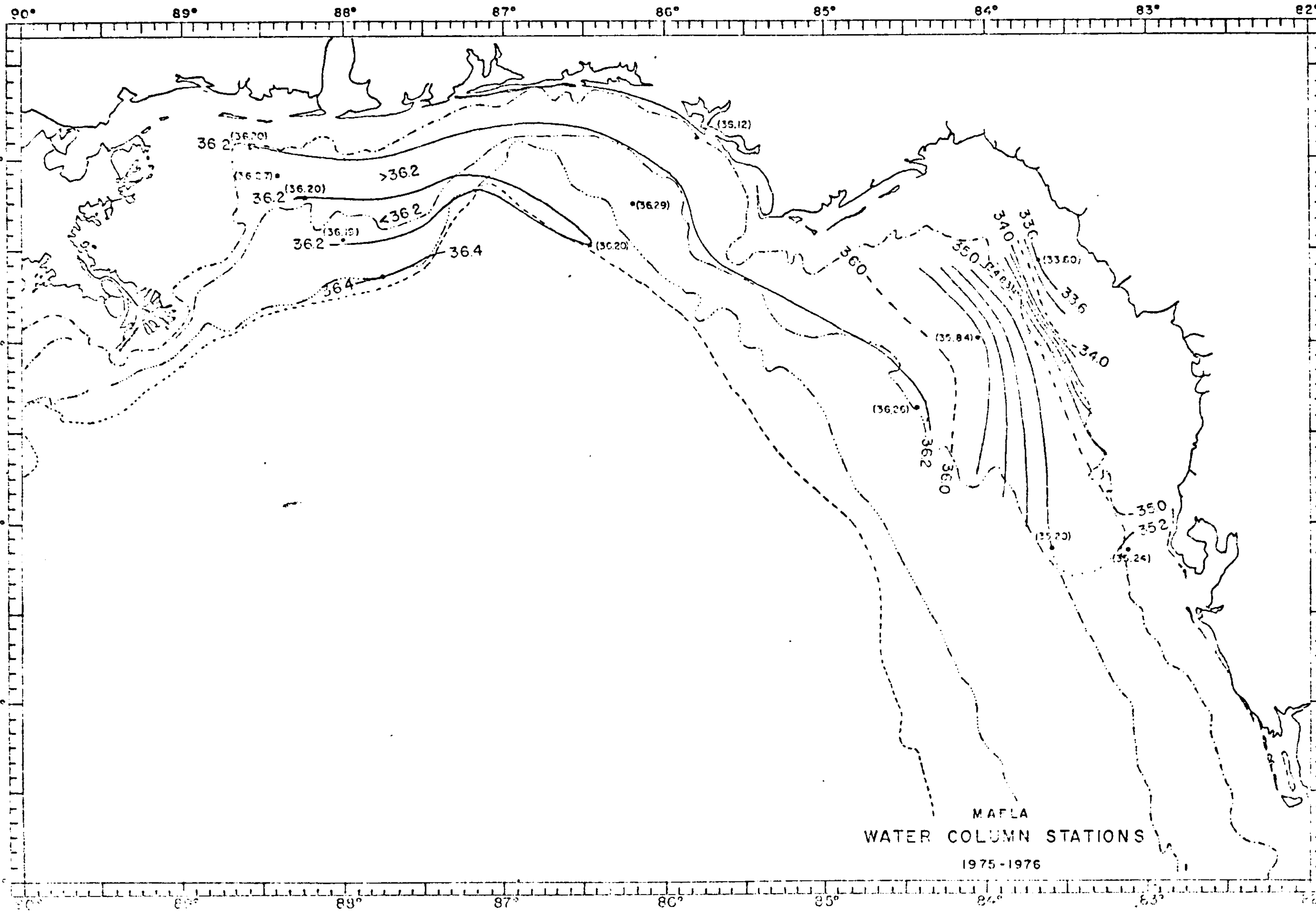


Figure 15 Bottom Distribution of Salinity ‰ BLM-12 JUNE 19-JULY 15, 1975

possible relationship to the inshore areas and drainage from the Tampa Bay complex. More important, the salinity contours follow, by and large, the bottom isobath and further indicate that the bottom waters were flowing parallel to the bottom topography. This agrees with the current meters installed between 26°31'N, 25°30'W as reported by Price and Mooers (1974 and 1975), who state that the mean current average over periods a month or more long tend to flow parallel to the isobaths (SUSIO, 1975, pages 44 and 45).

Environmentally, the effects of salinity could be more important than temperature. Across the entire area surface temperature ranged between 30 and 27.8°C, with a range of 2.2°C, while the salinity ranged between 31.52 and 36.27 °/oo with the largest range occurring on Transects IV and III. The lack of major variability in the surface temperature would be precluded using satellite data to determine the surface location of the Loop Current structure so that such monitoring would have to be based on the results of color changes resulting from either chemical or biological phenomena.

At ten meters, the temperatures ranged between 28.62 to 22.19°C, with a range of 6.43°C while the salinity values were between 36.28 and 32.20 °/oo for a range of 4.08 °/oo.

The location of the outer transect stations and the slope of the Continental Shelf and the resulting difficulty of securing measurement near the bottom without the loss of equipment made it difficult to record bottom temperatures and salinity data. Without such data it is not possible to make comparisons of bottom conditions completely over each transect or between seasons.

Perhaps the most important phenomenon observed during this season's study and which will become more apparent and important in the time series stations, which were occupied in the fall and winter seasons, is the variability both on a short and long time period of the parameters of salinity and temperature at the various stations. Although no time series were taken during this season, there were duplicate STD lowerings on Master Stations 1412, 1415, 1308, 1204, and 1101. Master Stations 1412, 1308, 1204, and 1101 on Transects IV, III, II, and I, respectively, were all inshore stations which were affected by river run-offs. Under these conditions and depending upon the time of the year, strong horizontal gradients of temperature or salinity can be present in the distribution patterns.

Table VII is the difference in the values observed during all three seasons of the year in the salinity and temperature data at which two or more STD's and/or XBT's were taken at a station location.

These inshore stations fall under the particle movement of the tidal oscillation and current patterns. These can move a particle on and off shore in an orbital pattern of two to five nautical miles (3.7 to 9.3 km) and perpendicular to the coastline from one and a half to two and a half nautical miles (2.8 to 4.6 km) as has been previously discussed under tides. These motions can result in rapid changes in temperatures and salinity values with time.

Master Station 1204 appears to be an example of this phenomenon in which in approximately a one-hour time period a change of nearly 1.00 $^{o}/oo$ of the two STD lowerings were taken a pocket of high salinity would appear or not appear on the inshore station. This could lead to the interpretation of the water mass relationships as either the lack of run-off on Master

Table VII The range of temperature (°C) and salinity (°/oo) at the surface, ten meter and bottom on master stations at which either a time series study or two or more STD's or XBT's were taken.

Summer - BLM 12

Master Station	Depth Meter	Surface Temp.	Surface Salinity	Ten Meters Temp.	Ten Meters Salinity	Bottom Temp.	Bottom Salinity	Time Interval
1412	15	28.32	---	22.40	36.20	22.18	36.21	18 Hours
1412	15	28.25	27.83	22.19	36.17	22.19	36.20	
Range		0.07		0.21	0.03	0.01	0.01	
1308	17	27.74	31.64	24.50	35.92	21.34	36.12	1 Hour
1308	17	27.62	31.66	23.00	35.94	21.22	36.00	
Range		0.12	0.02	1.50	0.02	0.12	0.12	
1204	14	28.42	32.06	28.42	32.06	28.19	33.60	1 Hour
1204	14	28.38	33.01	28.38	33.01	28.25	32.60	
Range		0.04	0.95	0.04	0.95	0.06	1.00	
1101	21	28.37	34.95	28.50	35.20	28.52	35.20	
1101	21	28.39	35.00	28.39	35.01	28.58	35.13	13 Hours
1101	21	28.28	35.04	28.28	35.04	28.54	35.24	
Range		0.11	0.09	0.22	0.19	0.06	0.11	
1415	380	28.80	32.10	27.25	35.30	---	---	9 Hours
1415	380	28.51	32.38	27.90	35.00	---	---	
Range		0.29	0.28	0.65	0.30			

Fall - BLm 20

Master Station	Depth Meter	Surface Temp.	Surface Salinity	Ten Meters Temp.	Ten Meters Salinity	Bottom Temp.	Bottom Salinity	Time Interval
1412	17	29.65	27.00	29.45	30.00	25.45	35.04	24 Hours
1412	17	28.84	26.63	29.00	29.00	24.84	34.62	
Range		0.81	0.37	0.45	1.00	0.61	0.42	
1414	110	29.33	35.07	29.21	35.16	---	---	7 Hours
1414	110	28.67	34.70	29.06	35.15	---	---	
Range		0.66	0.37	0.15	0.01			
1309	55	28.91	35.76	29.54	35.00	---	---	1 Hour
1302	55	28.86	35.76	29.00	33.80	---	---	
Range		0.05	0.00	0.54	1.20			
1204	13	28.26	31.93	28.52	32.40	28.52	32.43	30 Min.
1204	13	28.20	31.90	28.41	32.28	28.44	32.42	
Range		* 0.06	0.03	0.11	0.12	0.08	0.01	
1204	13	26.88	31.95	26.82	31.98	26.82	31.98	120 Hours
Range		** 1.38	.05	1.70	0.42	1.70	0.42	

* Difference before Hurricane ELOISE

** Difference after Hurricane ELOISE

Table VII (continued)

Master Station	Depth Meter	Surface Temp.	Surface Salinity	Ten Meters Temp.	Ten Meters Salinity	Bottom Temp.	Bottom Salinity	Time Interval
				Fall - BLM 20				
1205	18	28.24	32.74	28.24	32.75	28.41	33.40	120 Hours
1205	18	26.89	32.98	26.91	32.98	26.92	32.98	
Range		** 1.35	0.24	1.33	0.23	1.49	0.42	
1207	35	26.43	34.91	26.41	35.10	---	---	24 Hours
1207	35	25.94	34.19	26.00	34.78	---	---	
Range		0.49	0.72	0.41	0.32			
				Winter - BLM 28				
1412	14	13.74	31.92	15.22	33.60	15.87	33.81	24 Hours
1412	14	13.50	30.37	13.90	31.91	14.04	32.08	
Range		.24	1.55	1.32	1.69	1.83	1.73	
1310	167	19.82	---	19.78	---	15.33	---	5 1/2 Hours
1310	167	19.29	---	19.29	---	14.86	---	
Range		.53		.49		.46		
1413	30	16.76	34.01	18.00	35.45	19.64	36.40	12 Days
1413	30	16.64	33.60	17.50	34.40	18.30	35.62	
Range		0.12	0.41	0.50	1.05	1.34	0.78	
1414	80	19.79	35.77	19.79	35.78	20.53	36.41	10 Days
1414	80	18.62	35.40	18.90	35.69	19.20	36.25	
Range		1.17	0.37	0.89	0.09	1.33	0.16	
1415	332	20.33	36.19	20.33	36.19	---	---	9 Days
1415	332	17.60	33.90	18.19	34.60	---	---	
Range		2.73	2.29	2.14	1.59			
1205	16	14.30	35.60	14.30	35.60	14.30	35.60	12 Hours
1205	16	14.15	35.54	14.15	35.54	14.15	35.54	
Range		0.15	0.06	0.15	0.06	0.15	0.06	
1207	36	17.79	36.28	17.70	36.28	17.62	36.29	24 Hours
1207	36	17.61	36.22	17.60	36.25	17.53	36.26	
Range		0.19	0.06	0.10	0.03	0.09	0.03	
1102	32	16.85	36.18	16.95	36.18	16.30	36.16	66 Hours
1102	32	36.17	36.17	15.89	36.17	15.24	36.10	
Range		0.96	0.01	1.06	0.01	1.06	0.06	
1101	18	14.12	35.17	14.14	35.16	14.16	35.15	38 Hours
1101	18	13.98	35.44	14.06	34.98	14.04	35.08	
Range		0.14	0.73	0.08	0.18	0.12	0.07	

** Difference after Hurricane ELOISE

Station 1204 or a considerable surface pocket of low salinity run-off water extending out to Master Station 1205.

Based on the above discussion and the surface salinity distribution patterns shown in Figure 13, the high salinity values at Master Station 1204 could be the result of the tidal oscillation as the strong horizontal gradients associated with the Horseshoe Bend water mass form a boundary condition at or near this location.

In Appendix II, T-S curves have been plotted for the stations on the four transects. They are presented as individual figures for each transect (Figures 1-4). In examining them, there is a similarity in the water mass structures between Transects III and IV. Transect I shows no similarity of the water masses across the transect, and except for the outer station, is different from Transects II, III, and IV.

FALL SAMPLING
September 7-October 2, 1975
(26 days)

During the fall sampling period, a total of 44 STD's and 14 XBT's were made. An STD lowering was made on each of 15 master stations.

On Transect IV at the inshore station (Master Station 1412) eight STD's and on the outer station (Master Station 1207) on Transect II six STD's were taken over 24 hours as physical support for the transmissometer time series studies. This resulted in two (2) STD time series studies. On the Continental Slope station on Transect IV (Master Station 1414) three STD's were taken over an eight-hour period; on Transect III at the thirty fathom line (Master Station 1309) two STD's were taken; and on Transect II before and after the passage of Hurricane Eloise three STD's were taken at Master Station 1204 (the innermost station of Transect II) and two were taken on Master Station 1205.

Following the grouping of the transects established previously in the summer sampling period and the relationship to the run-off river characteristic areas, hydro-biological and marine summary zones, an examination of the vertical sections for temperature and salinity (Figures 16 and 18 for salinity and Figures 17 and 19 for temperature) indicate the presence of one low surface salinity pocket on Transect IV and two on Transect III. This inshore low salinity pocket on Transect IV has a surface salinity of 27.00 $^{o}/oo$, the thickness of which is indicated by the strong salinity gradient at approximately twelve meters depth. The two low salinity surface pockets on Transect III, on the other hand, consist of an inshore pocket with a surface

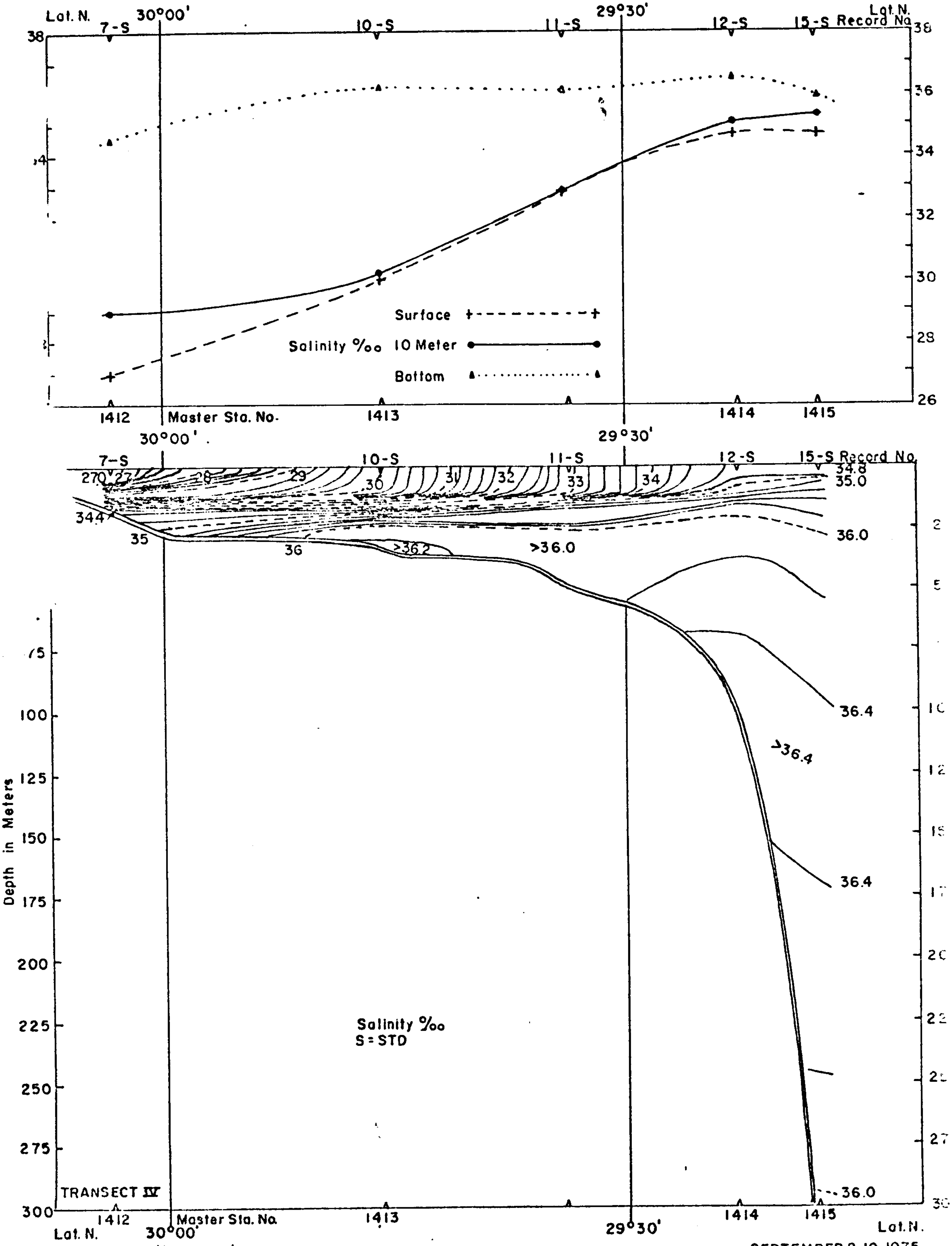


Figure 16 Vertical Distribution Salinity ‰ BLM-20

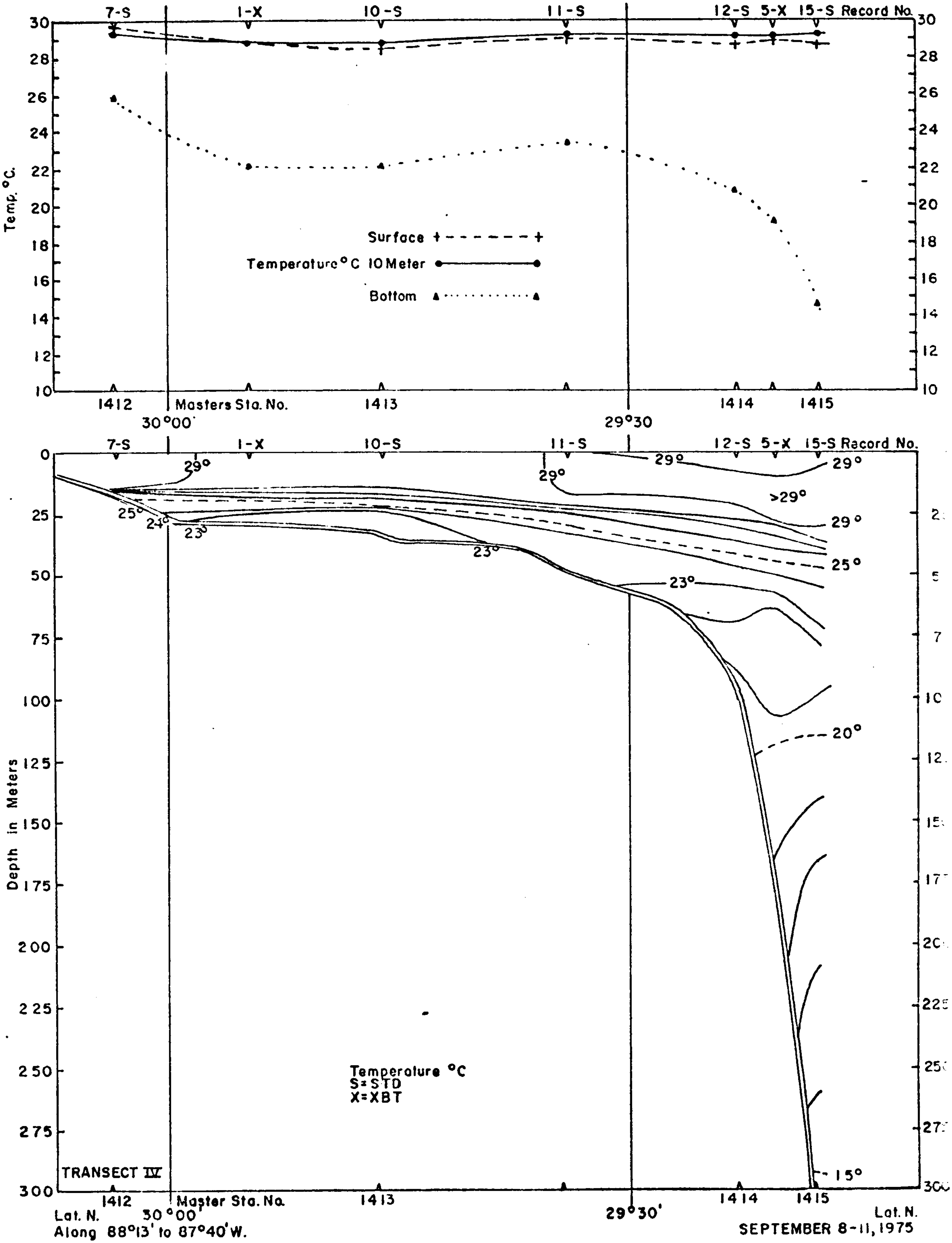


Figure 17. Vertical Distribution Temperature °C BLM-20

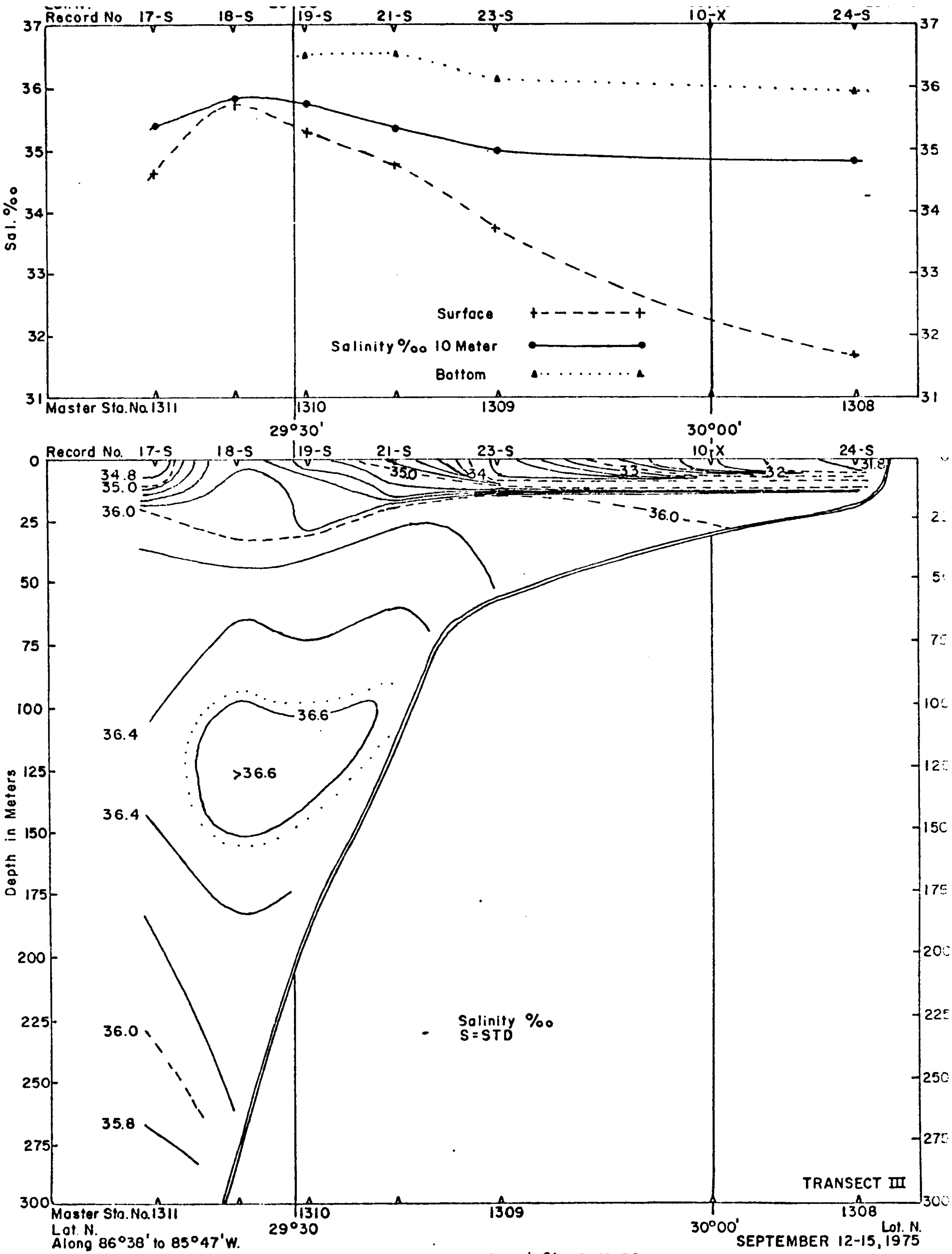


Figure 18. Vertical Distribution Salinity ‰ BLM-20

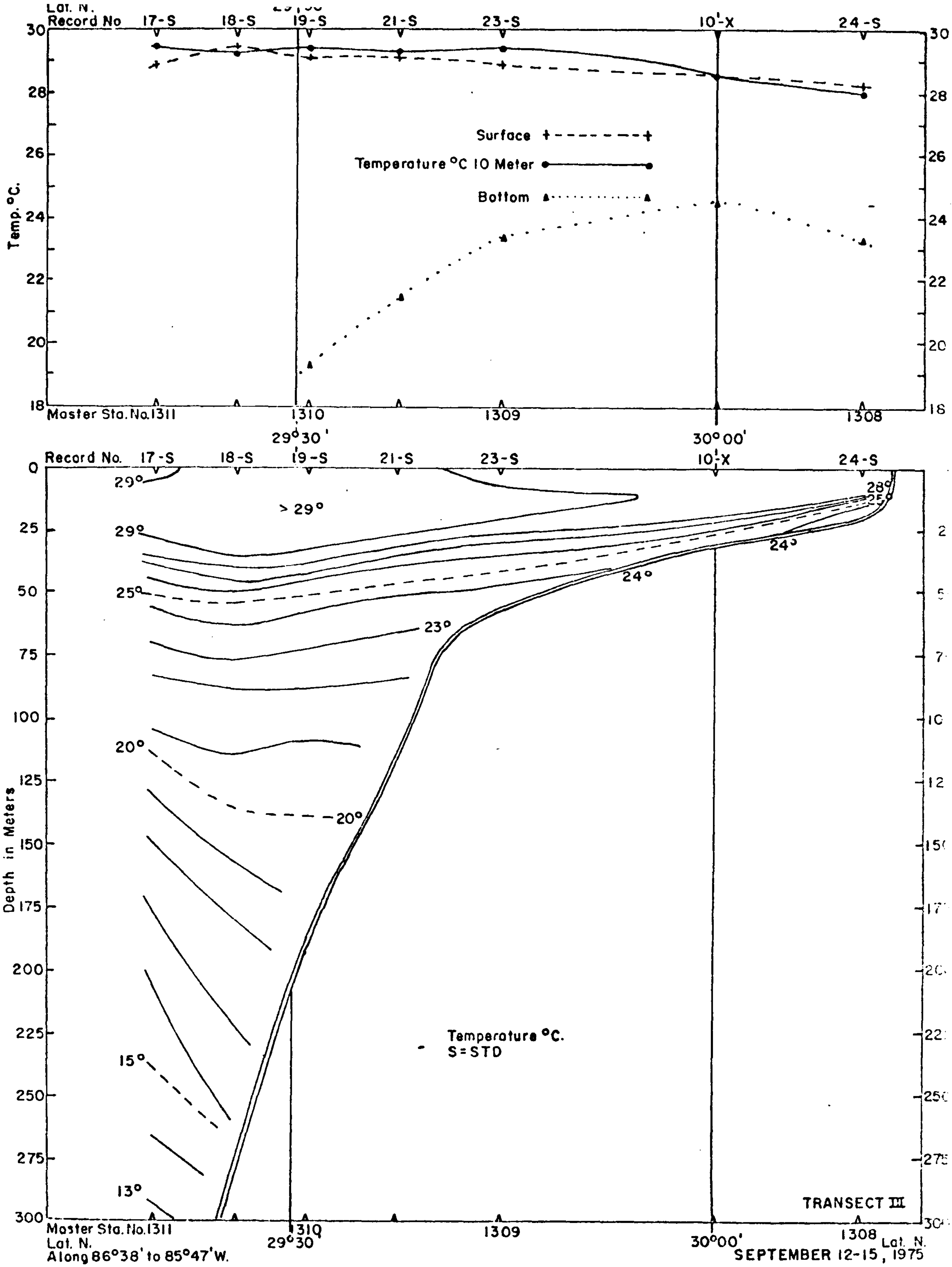


Figure 19. Vertical Distribution Temperature °C. BLM-20

salinity of 31.69 $^{o}/oo$ and another on the Continental Slope with a surface salinity of 34.63 $^{o}/oo$. As on Transect IV the thickness of these pockets is approximately twelve meters with the inshore pockets appearing to be associated with a run-off from the NORTHWEST river characteristic run-off areas (Transects III and IV) while the outer pocket (Transect III) is probably associated with the Mississippi River System run-off area (WEST). It should be noted that this WEST pocket has increased from 29.36 to 34.69 $^{o}/oo$ from the summer sampling to the fall which would be in accordance with continued low run-off (SUSIO, 1975, page 14) (Jones and Rinkel, 1973, page 199).

Eastern Gulf of Mexico water (36.4 $^{o}/oo$) was present on Transect IV at the upper edge of the Continental Slope between a depth of about 80 and 170 m. It was similarly located on Transect III; however, associated with it was a broken off ring of water the maximum salinity of which was 36.62 $^{o}/oo$ with temperature ranges between 23.23 and 18.62°C. This was Loop Current water defined by its salinity as a spin-off eddy from the Loop Current (SUSIO, 1975, page 18).

On both transects there was a tongue of warm water entering onto the shelf to approximately a depth of 35 to 25 m with temperatures in excess of 29°C. There was low temperature water, with temperatures less than 29°C, associated with the low salinity pocket on Transect III and the outer station on Transect IV which apparently were associated with the Mississippi River System run-off waters (WEST). On Transect IV the inshore low surface salinity pocket had water less than 29°C associated with it.

At no stations on either of the transects was the water either isothermal or isohaline to the bottom. There were well mixed waters on both sections as indicated by thermocline depths.

On Transect IV this appeared as two pockets; one associated with the NORTHWEST waters extending from Master Stations 1412 to 1413 and the other associated with the Mississippi River System run-off waters with the thermocline depths between 8-10 m. On Transect III, however, there was a thermocline existing across the entire section which, in general, increased with depth from the outer stations (10 to 30m). Superimposed and associated with the surface Mississippi River System water (WEST) on Master Station 1311 and between Master Stations 1310 and 1309 on the inshore side of the salinity ridge, which separated that water from the NORTHWEST waters, were two shallow depth thermoclines. These shallow depth thermoclines superimposed on deep thermoclines are called a "stair step" phenomenon and in the equatorial areas is an indication of the modification of deep mixed layers, which have been transported into a location by local conditions or modified by local weather conditions. These can be present on recent modifications, which produce either a small surface or sub-surface inversion. Figure 20 shows the temperature STD traces that illustrate this phenomenon and indicate the structure of the superimposed shallow thermoclines. STD Lowering 17 (Master Station 1311) was a surface and Lowering 18 was a sub-surface temperature inversion.

There were strong gradients associated with the salinity field at approximately 15 m on Transect IV and 12 m on Transect III out to the edge of the Continental Shelf. There were similar gradients for temperature and sigma t which increased in their depth from the shore toward open Gulf between 15 to 20 m and continued completely across each transect. This separation in the strong gradient field of temperature and sigma t versus salinity was similar to the conditions noted in the summer sampling period.

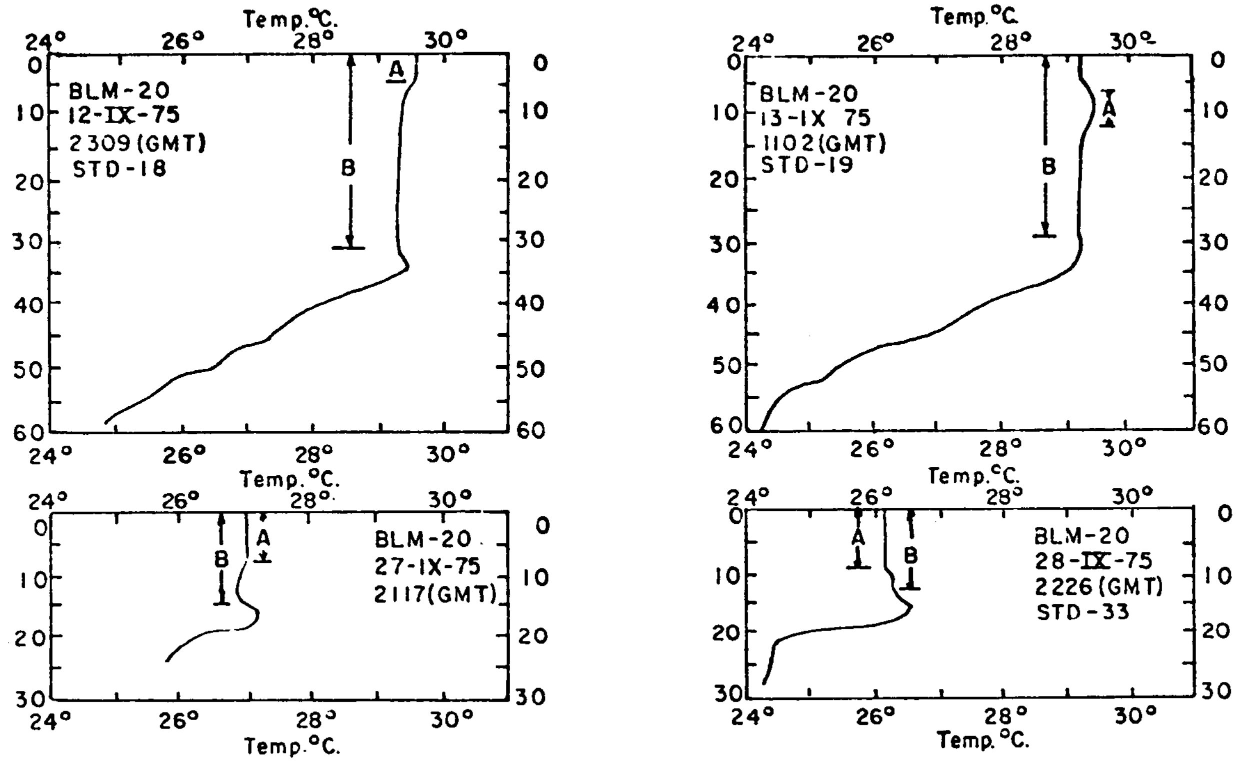


Figure 20. Temperature Trace from STD Analog Traces from BLM-12. A is Shallow and B is Deep Thermocline.

Figure 21 is the topographic depth in meters of the 20°C isotherm in the eastern Gulf of Mexico during October and November of 1975 as furnished by Molinari (1976). Using this as an indicator of the Loop Current, it would appear that detached eddies were present in the northern areas of the eastern Gulf of Mexico. Further, this water appeared as two eddies; one to the west of the Mississippi River System drain-off area (WEST) and the other in the vicinity of Transect III. This would explain the appearance of Loop Current water on Transect III and lack of it on Transect IV where Loop Current was to the west of the Mississippi Delta transect. Furthermore, it probably explains the presence of the Mississippi River System water (WEST) on the outermost stations on Transect IV and III since the Loop Current forcing mechanisms were not transporting water onto the shelf. This is further confirmed in the temperature field where there was very little indication of colder water coming onto the shelf. It would appear that if the Loop Current eddy were affecting the shelf circulation, it would be to the south and east of Transect III. The temperature on Transects IV and III at the surface were 29.65 to 28.61°C and 29.49 to 28.20°C, respectively, with ranges of 1.04 and 1.29°C with the largest range on Transect III; at ten meters, 29.43 to 28.86°C and 29.55 to 28.00°C, respectively, with ranges of 0.57 and 1.55°C with the largest range on Transect III; at the bottom on Transect IV it was between 25.89 and 14.69°C with a range of 11.20°C. There was not enough data available on Transect III to determine the variability of the bottom temperatures.

The salinity values on Transects IV and III at the surface were between 34.70 and 27.00 °/oo and 35.76 and 31.69 °/oo, respectively, with ranges of 7.20 and 4.07 with the largest range on Transect IV; at ten meters,

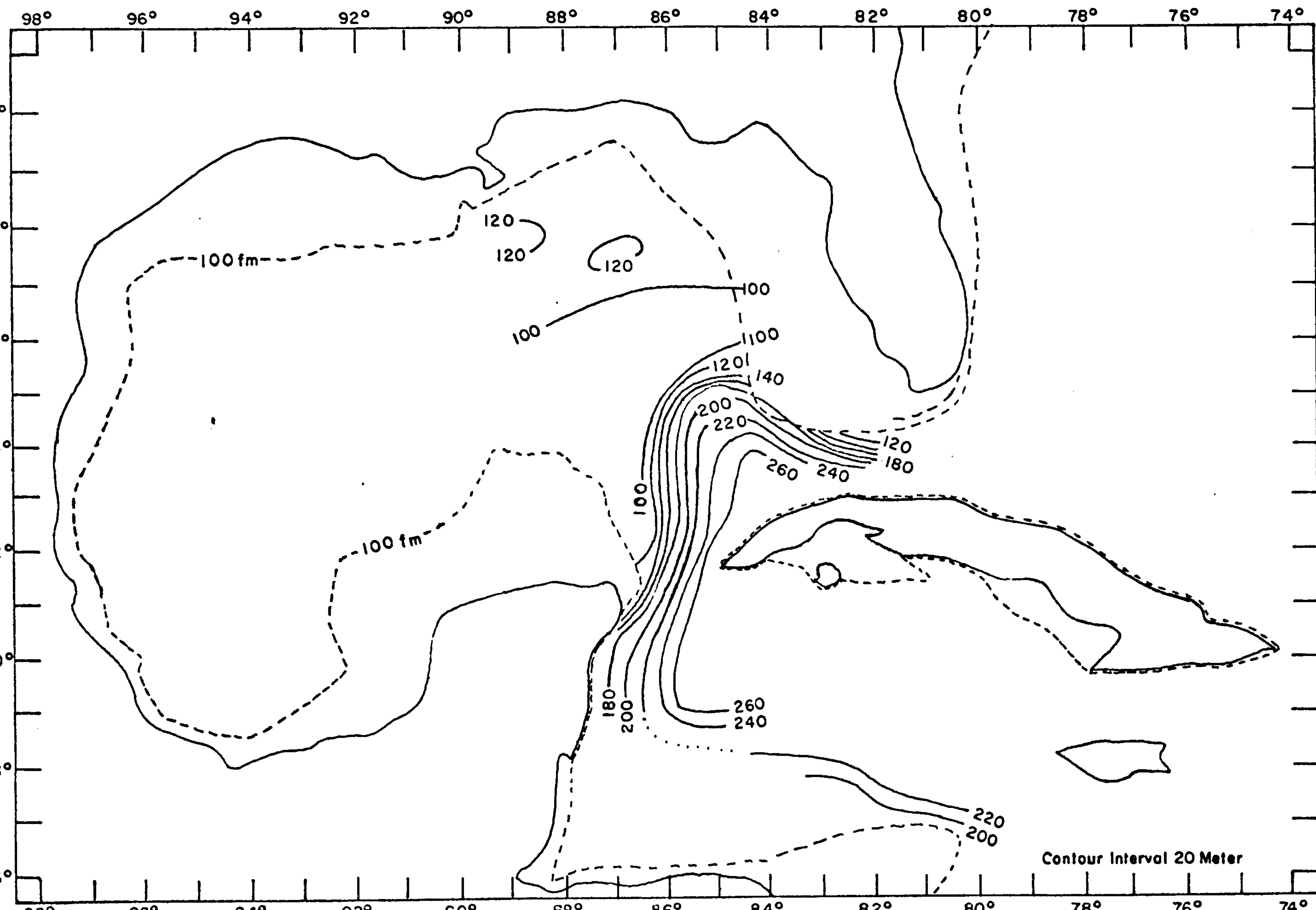


Figure 21. Depth of 20° C. Isotherm Levels in Eastern Gulf of Mexico and Caribbean Sea During October and November, 1975 From XTB and STD Lowerings (From Molinari, 1976)

35.31 and 29.00 °/oo and 35.83 and 34.84 °/oo, respectively, with ranges of 6.31 and 1.03 °/oo with the highest range on Transect IV; at the bottom on Transect IV the salinity values were 36.50 to 34.59 with a range of 1.95 °/oo. There was not enough bottom data available on Transect III to determine the variability.

On Transect II the vertical distribution is shown for salinity (Figure 22) and temperature (Figure 23). In these figures there are three dominating features. The first of these is the isothermal and isohaline structure on the inshore portion of the transect extending to a distance of approximately thirty nautical miles (55.6 km) offshore (Master Station 1205). The second is the lack of any surface salinity pockets with a gradual increase of salinity from shore to the basin area. The third is the appearance of bottom pockets of water between Master Stations 1206 and 1207 which have a maximum salinity value of 36.33 °/oo and a minimum temperature value of 24.62°C.

Starting from the inshore station and running across the shelf, the thermocline depths were along the bottom from Master Stations 1204 through 1205 and then slowly decreased in depth until they reached the surface at STD Record No. 39. Superimposed on this structure was a shallow thermocline stair-step effect between Master Stations 1205 and 1206 to between 1206 and 1207 (Figure 20).

There were no continuous strong temperature gradients across the transect. However, at the depth (20 m) at which the isothermal-isohaline conditions ceased there was a strong gradient of salinity and sigma t along 20 m. The only strong temperature gradient was associated with the pocket (lens) of high salinity low temperature water on the bottom between Master Stations 1206 and 1207.

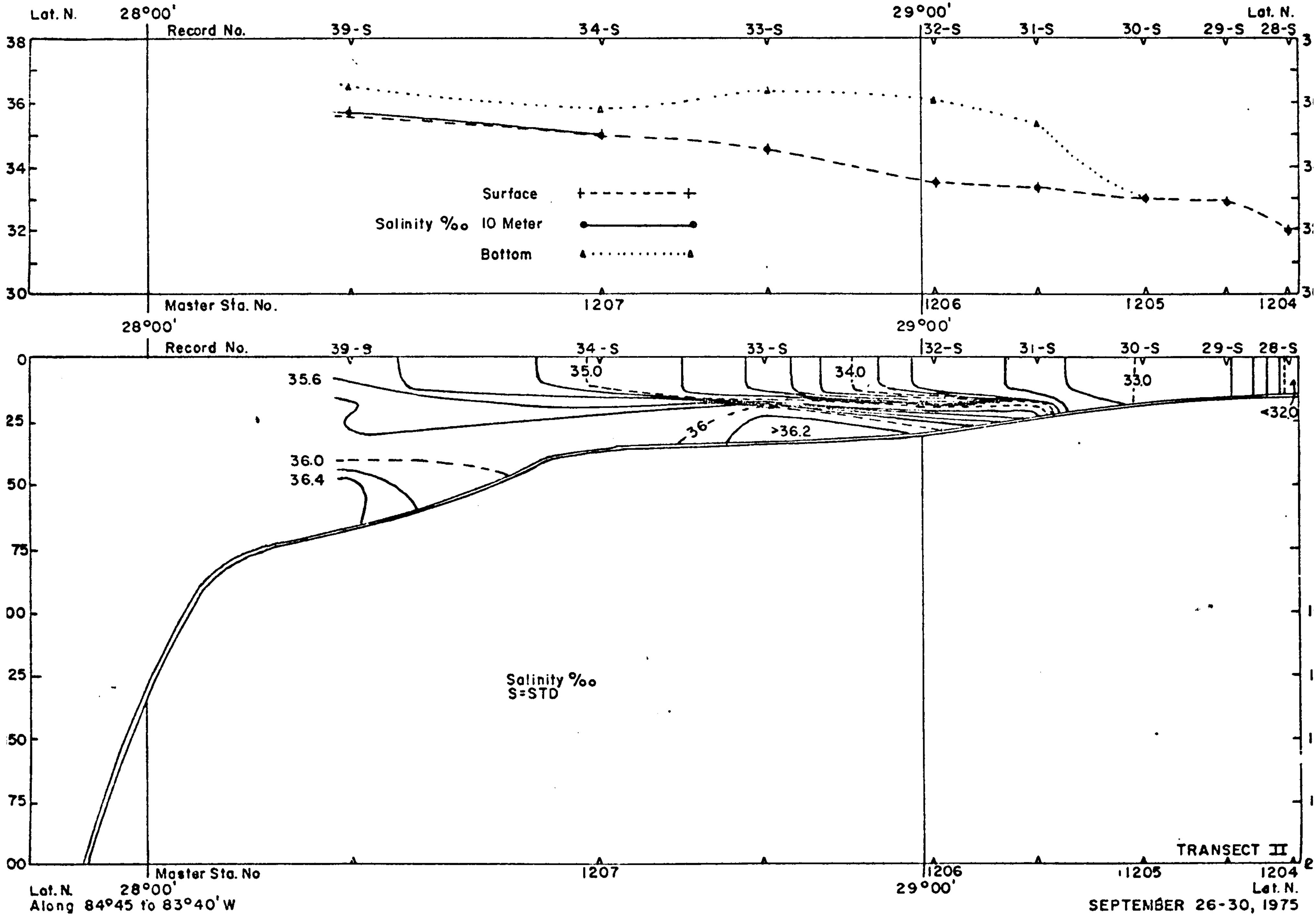


Figure 22. Vertical Distribution Salinity ‰ -BLM-20

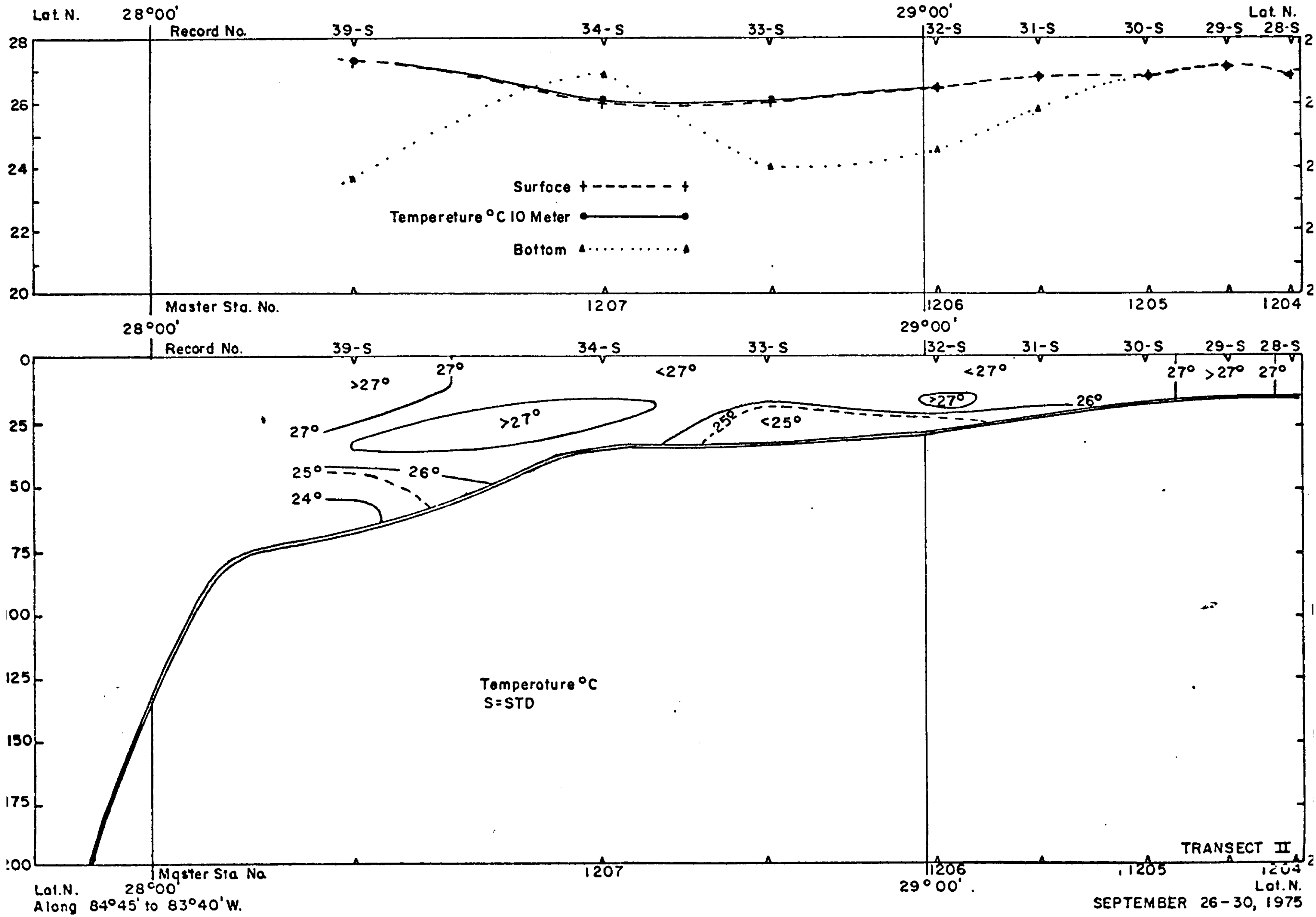


Figure 23. Vertical Distribution Temperature °C BLM-20

The temperatures on Transect II at the surface were between 27.39 and 26.01°C with a range of 1.38°C; at ten meters, 27.73 and 26.11°C with a range of 1.62°C; and at the bottom, 27.22 and 24.11°C with a range of 3.11°C.

The salinity of Transect II at the surface was between 35.56 and 31.95 °/oo with a range of 3.61 °/oo; at ten meters, 35.60 and 31.98 °/oo with a range of 1.62 °/oo; and at the bottom, 36.48 and 31.98 °/oo with a range of 5.50 °/oo.

On Transect I the vertical distribution is shown for salinity (Figure 24) and for temperature (Figure 25).

The ranges in temperature and salinity parameters, in general, were markedly different from those associated with Transects III and IV.

The salinity distribution had three dominating features. The first of these was a low salinity surface pocket located at or near Master Station 1101 with a surface salinity of 33.71 °/oo. The second was a low salinity surface pocket located between Master Stations 1102 and 1103 in a depth of approximately 60 m with a minimum value of 34.94 °/oo. The third was the appearance of eastern Gulf of Mexico water protruding up onto the shelf to 84°W. The eastern Gulf of Mexico water extended inward across the shelf to approximately 60 m. Accompanying this water was an intrusion of Loop Current water extending upward from 189 to 125 m to 75 m on the outer edge of the Western Florida Continental Shelf. The Loop Current water had a maximum surface salinity of 36.64 °/oo with a temperature of 21.49°C.

The temperature, on the other hand, had very little change in its values across the shelf except for the appearance of two warm temperature areas; one associated with Master Station 1102 at approximately ten meters with an increase of 0.18°C and the other at the extreme outer station on the section (27.56°C).

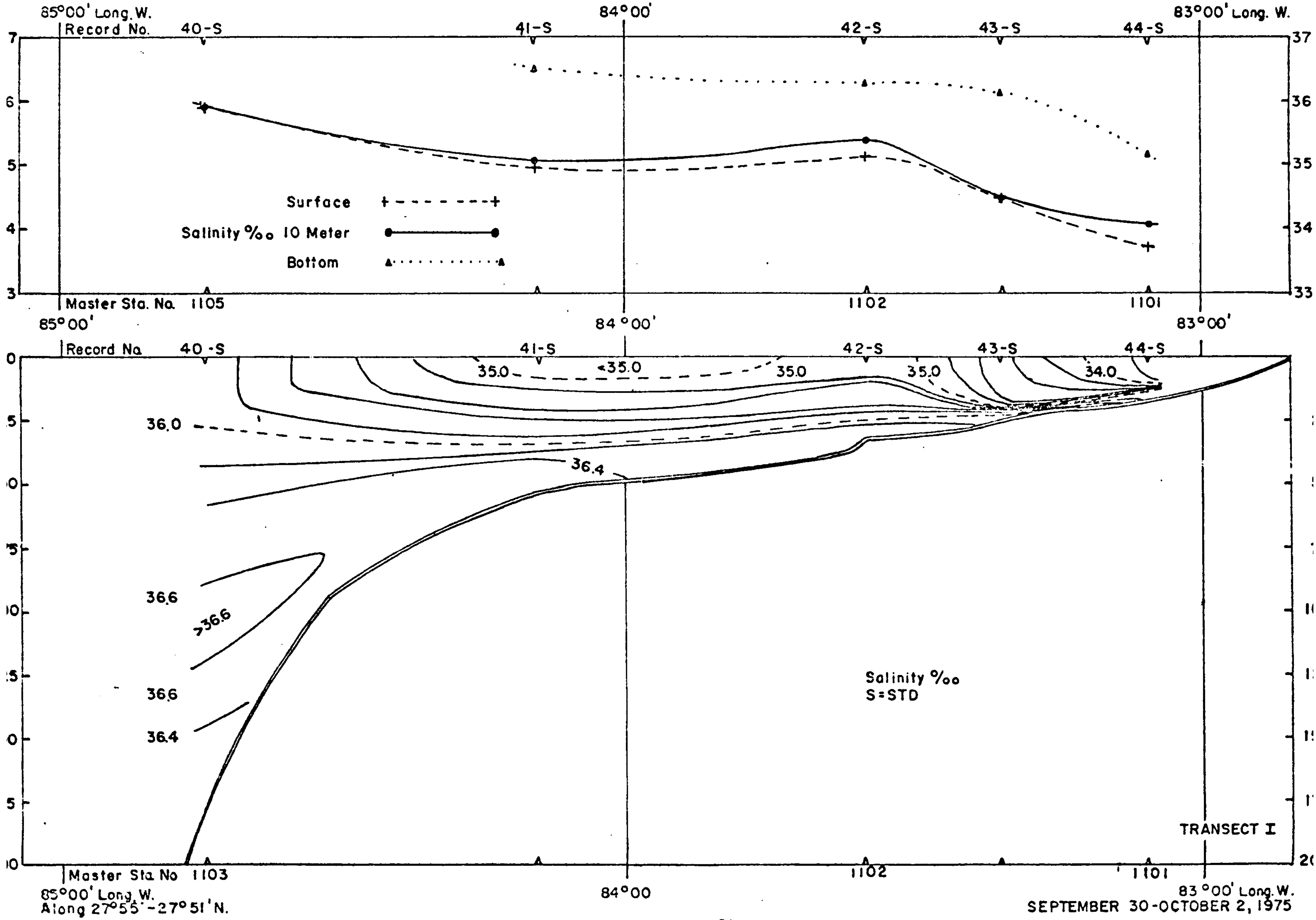


Figure 24. Vertical Distribution Salinity ‰ BLM-20

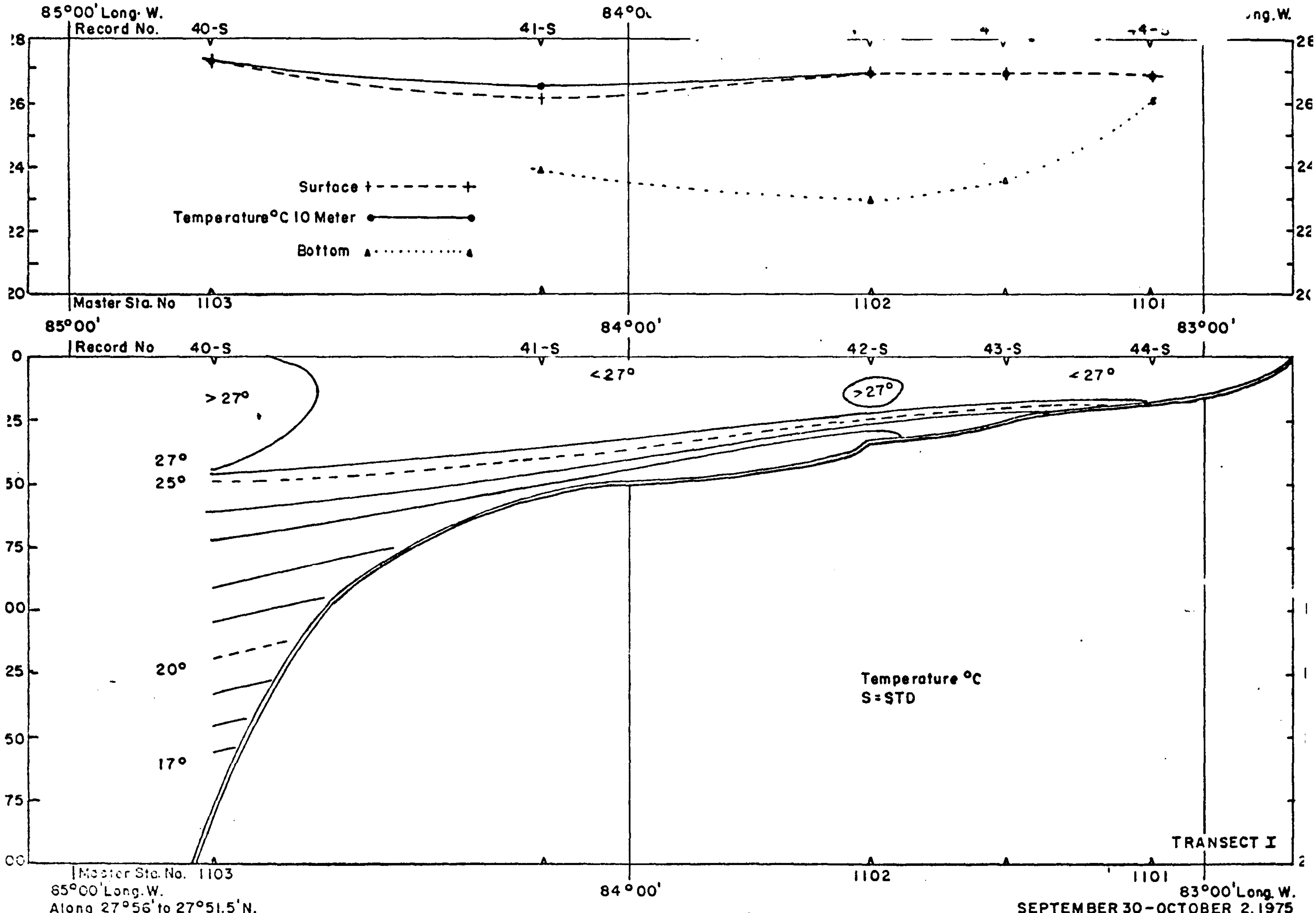


Figure 25. Vertical Distribution Temperature °C BLM-20

As can be seen by examining Figure 21, the topographical data in meters for the 20°C isotherm, there is an indication that to the south or very near to Transect I itself Loop Current water was over onto the shelf as an east-west flow. This flow would eventually turn to the south, and it could be seen discharging down through the Dry Tortugas area. This means that a major transport of water would be occurring in close proximity to Transect I which would be influencing the shelf circulation. The temperature on Transect I at the surface was between 27.40 and 26.16°C with a range of 1.25°C; at ten meters, 27.40 and 26.35°C with a range of 1.05°C; and at the bottom, 26.10 and 22.80°C with a range of 9.25°C. There were no isothermal stations, and the thermoclines were composed of stair-step features such as were present on Transect III and II. The deep thermocline extended across the shelf from 10 m to 40 m to the edge of the Continental Slope. Connected with Master Station 1101 and out to the break in the Continental Shelf was a shallow thermocline, which reached a maximum depth of approximately ten meters midway between Master Stations 1102 and 1103 and at a depth of about sixty meters. This shallow thermocline was associated with the low surface salinity pocket previously noted in Figure 24.

The salinity values on Transect I at the surface were between 35.92 and 33.71 °/oo with a range of 2.21 °/oo; at ten meters, 35.92 and 34.00 °/oo with a range of 1.92 °/oo; and at the bottom, 36.52 and 35.19 °/oo with a range of 1.33 °/oo, In general, these values are in agreement with those on Transect I but show some difference in those related to Transects III and IV.

In the summer sampling program previously discussed an attempt was made to review those items that acted as forcing mechanisms on the shelf circulation patterns. It was the intent that this procedure would be followed for the remaining sampling seasons throughout the three-year study. However, there is one of these forcing mechanisms that could cause major effects not only in the water column but on the other interdisciplinary studies if it should occur during any of the sampling periods. This, of course, is a hurricane.

During the fall season such a hurricane occurred (ELOISE) moving through the eastern Gulf of Mexico starting on September 21 and going ashore in the vicinity of Panama City, Florida, on September 23, 1975. The track of this hurricane and its relationship to the water column transect is shown in Figure 26.

Hurricane ELOISE caused the interruption of the water sampling after the completion of sampling on Master Stations 1204 and 1205 on Transect II. It interrupted the box coring cruise while it was on Transect IV (the Horseshoe Bend transect, which corresponded to the water column Transect II) and the diving program in the Clearwater, Florida, area. Further it occurred before the start of the dredge and trawl cruises.

It is important, therefore, to understand what effects a hurricane of this nature can have on the various hydro-biological zones in the MAFLA area. Perhaps even more important than these differences is the realization by the various investigators and by BLM the effect that such a hurricane might have on the seasonal sampling aspects of a three-year MAFLA study.

Between 1899 and 1971 approximately 600 tropical cyclones have been recorded over the North Atlantic (Brower, et al, 1972). A tropical cyclone is an atmospheric cyclonic circulation, which originates over the tropical oceans, with speed ranging from 34 to 63 knots (1750 to 3243 cm/sec). When an intensity of 64 knots (3295 cm/sec) or higher is reached, it is classified

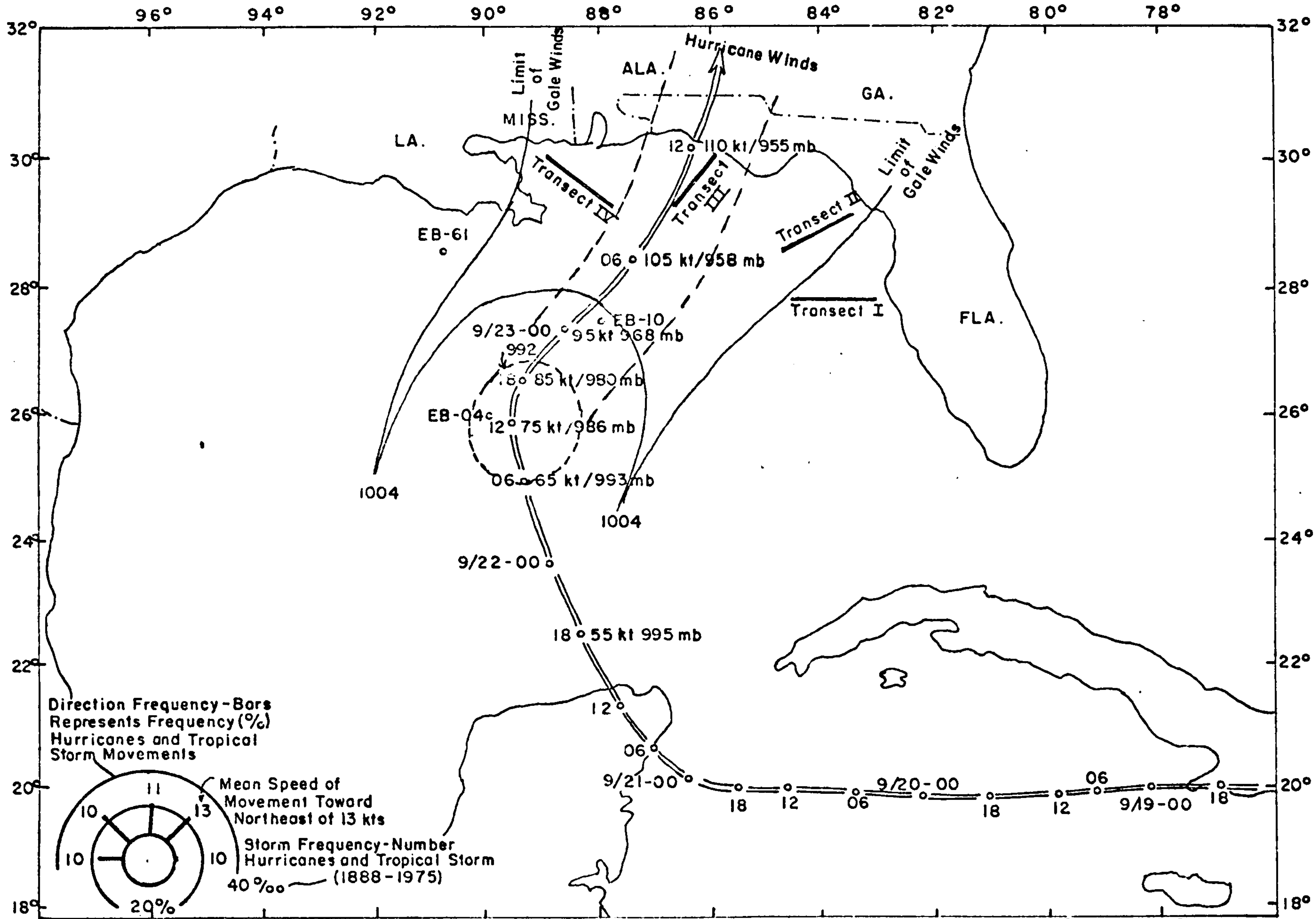


Figure 26. Official NHC Storm Track of Hurricane ELOISE with Significant Events and NDBO Buoy Positions Denoted

as a hurricane. The effects of hurricanes on the outer Continental Shelf in the eastern Gulf of Mexico occur most frequently in the extreme southerly portion of Peninsula Florida and in the Panhandle section (Dunn and Miller, 1906). In the MAFLA area the maximum possibility for either tropical cyclones or hurricanes is in the Panama City, Florida, area (Transect III). Table VIII shows the frequency of tropical cyclones and hurricanes in the area between the Mississippi Delta and Cape San Blas for the years 1899 to 1971 which includes the above mentioned area. This table indicates that once in every 3.8 years a hurricane could affect the area. It would be possible, therefore, for a three-year study not to record the effects of a hurricane.

A tropical cyclone-hurricane rose is shown in the lower left-hand corner of Figure 26 for September on data derived from the "Climatological and Oceanographic Atlas for Marine Areas, U. S. Department of Commerce and Navy, 1959," based on storm frequency from 1886 to 1957. The direction of movement of these hurricanes and tropical cyclones as shown by this rose indicates that Hurricane ELOISE impacted on the shelf in a direction similar to 22% of the historical tropical cyclones and hurricanes.

Before examining the water column sections, it is important to understand the characteristics of the hurricanes and how they affect the hydro-biological zones in the area. The material that follows has been extracted from eleven sources, and no attempt will be made to reference each individual statement to its source; rather, it is suggested that those who are interested review these particular source materials for themselves. The source materials are Dunn and Miller "Atlantic Hurricanes, 1960"; Brower et al, Environmental Guide for the U. S. Gulf Coast, November, 1972"; the "Daily Synoptic Weather Charts"

Table VIII. Frequency of Tropical Cyclones and Hurricanes in the area between Mississippi Delta and Cape San Blas for the years 1899-1971

Storm Type	Southwest Pass: Total No. 1899-1971	Southwest Pass: Average No. of Yrs. Between Occurrences	Mobile-Pascagoula: Total No. 1899-1971	Mobile-Pascagoula: Average No. of Yrs. Between Occurrences	Panama City: Total No. 1899-1971	Panama City: Average No. of Yrs. Between Occurrences
Tropical Cyclones (Winds ≥ 34 knots) (1750 cm/sec)	49	1.5	41	1.8	52	1.4
Hurricanes (Winds ≥ 64 knots) (3295 cm/sec)	18	4	15	4.9	19	3.8

Compiled from Brower, et al (1972, pages 92, 110, and 129) put out by NOAA for September and October of 1975; "Data Report: Buoy Observations During Hurricane ELOISE (September 19-October 11, 1975)"; "Marine Environmental Data Package ELOISE, 1975"; "Natural Disaster Survey Report 75-1 Hurricane ELOISE: The Gulf Coast. A Report to the Administrator, December 1975"; "NODC Hydrographic Vertical Sections"; "Tide and Storm Surge Data"; "Tide and Storm Surge Curves"; "AXBT Log (Flight 750922A)"; and Stage I and Stage II Data Environmental Division, Naval Coastal Systems Laboratory."

The location of maximum winds vary with the development stage of the hurricane. For instance, intense immature storms seem to have more symmetrical wind fields with the strongest wind located in the wall cloud around the eye while, on the other hand, in mature decadent storms the maximum winds can be found far from the center; and in poorly defined storms hurricane winds might be observed only in one quarter. Further the location and angle of inflow seems to vary considerably with individual storms - their size, their latitude, and other meteorological situations.

It is appropriate, therefore, to review the meteorological history of Hurricane ELOISE. This disturbance was spawned on the west coast of Africa on September 6, 1975, and by the 13th was a complete depression. By the 16th it had reached tropical storm strength and as a minimal hurricane struck the northeast coast of the Dominican Republic late on the 16th. Here it lost its intensity as it was circulating over land until it passed into the northwest Caribbean Sea as a minimal tropical storm with a marked decrease in associated rainfall. Even though the center was over the open warm waters of the Caribbean Sea, it remained poorly organized until it approached the northeast coast of Yucatan late on the 20th. And during its trip through the Caribbean, its size was 40 to 60 nautical (74.1 km to 111.2 km) in diameter. The existence of an upper level trough in the westerlies caused ELOISE to turn to the north, crossing the Yucatan Peninsula, and reaching the eastern Gulf of Mexico. ELOISE began a steady strengthening north of the Yucatan Peninsula gaining hurricane force in the central Gulf of Mexico about 350 nautical miles (648.6 km) south of New Orleans, Louisiana, on the morning of the 22nd. The hurricane continued to strengthen until it reached landfall about midway between Fort Walton Beach and Panama City, Florida, shortly after 1200 GMT on the 23rd. In short, during the last 350 nautical miles (648.6 km) of its travel across the eastern Gulf of Mexico, it was an intensifying-immature hurricane, the maximum velocity of which had increased from 65 knots (3295 cm/sec) at approximately 25°N to 110 knots (5662.2 cm/sec) with a steady instensification of the low pressure from 993 to 995 mbs until it struck land. Preliminary examination of the data indicated that gusts as high as 135 knots (6949.1 cm/sec) were measured as it crossed the Continental Shelf areas of Transect III (water column) in the MAFLA area.

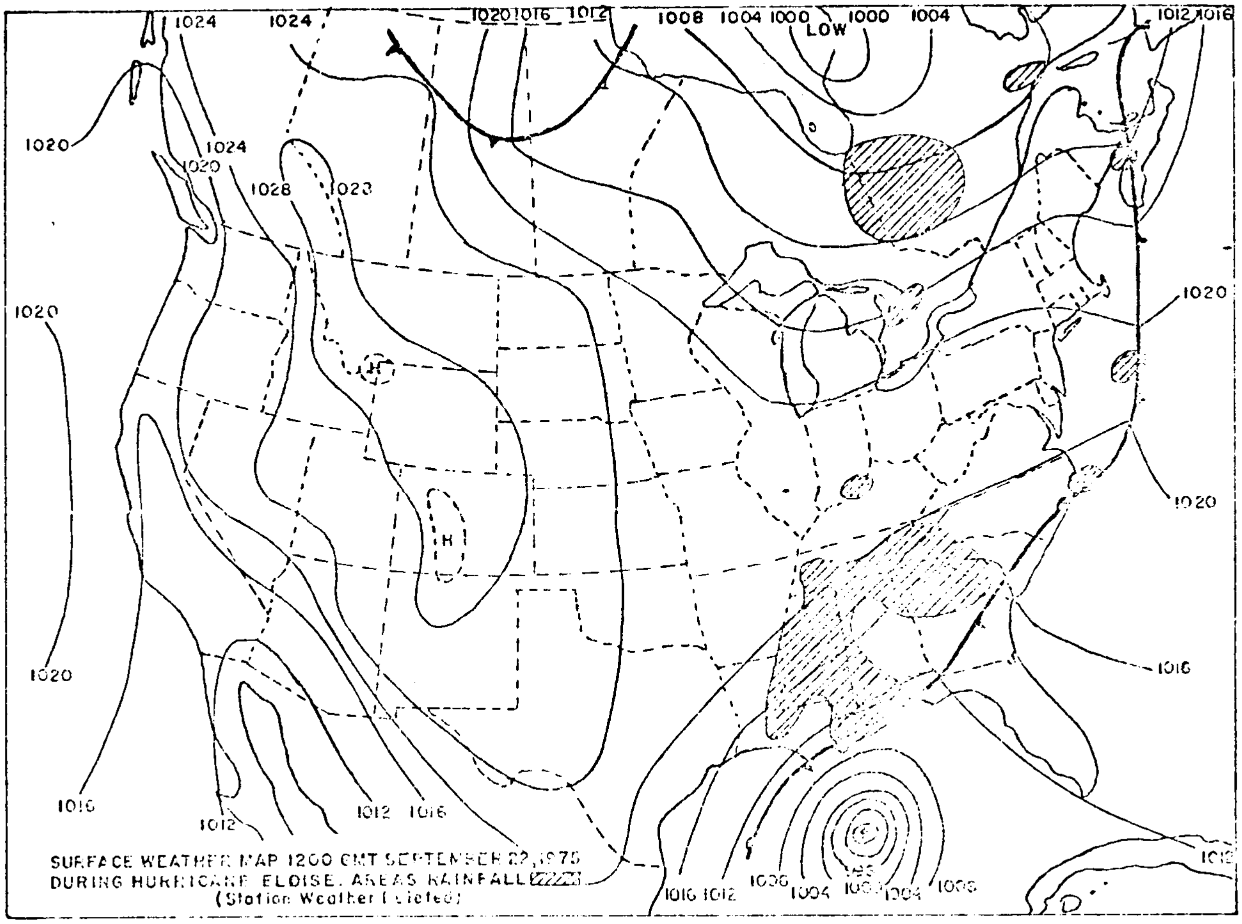
Although not an absolute measurement, the barometric pressure in the center of a hurricane can be used as a measure of its intensity. Since readings as low as 915 mbs in the western Caribbean and 935 mbs off Miami have been recorded, ELOISE did not have an extremely intense pressure pattern (955 mbs). As it was a developing hurricane having reintensified after crossing the Yucatan Peninsula, its strongest winds should have been located in the wall cloud around the eye with the winds inclining inward toward the center. The strongest winds will occur to the right and, therefore, would be along that side of the hurricane in the closest proximity to the Western Florida Continental Shelf.

The size of a hurricane can be expressed in two additional ways. One is by the diameter of the hurricane and gale winds and the other by the diameter of the outer closed (roughly circular or elliptical) isobars. Figure 27 is the surface maps from the "Daily Synoptic Weather Chart Series" for September 22 and 23, 1975. If one compares the limits of gale force and hurricane winds as reported from the southwest Louisiana Delta to Cedar Key, Florida, with the isobar patterns from these two maps, it can be seen that the 1004 isobar defines the gale force or greater winds and the 992 isobar the hurricane or greater winds. This would indicate that during the hurricane passage onto the Continental Shelf that gale winds were extending to 130 to 150 nautical miles (240.9 to 278.0 km) and hurricane winds were extending 25 to 30 nautical miles (46.3 to 55.6 km) on either side of the center of the hurricane. It also indicates that all of Transect III was under hurricane wind conditions while all parts of Transects IV and II and the outer portion of Transect I were under gale conditions.

The diameter of the eye of the hurricane was forty nautical miles (74.1 km) when it crossed the southwest Florida Panhandle. This is considerably larger than the average diameter of hurricane eyes of about fourteen nautical miles (25.9 km).

The track of Hurricane ELOISE took it past four instrument buoys or towers of which two (buoys) were in deep water and two (towers) were on the Continental Shelf. It is possible by use of data from these instrument locations to discuss, in some detail, the characteristics of the hurricane.

In recent years the National Data Buoy Office (NDBO) of the National Oceanic and Atmospheric Administration (NOAA) has been operating deep ocean data buoys in the Gulf of Mexico. Two of these buoys were in operation in



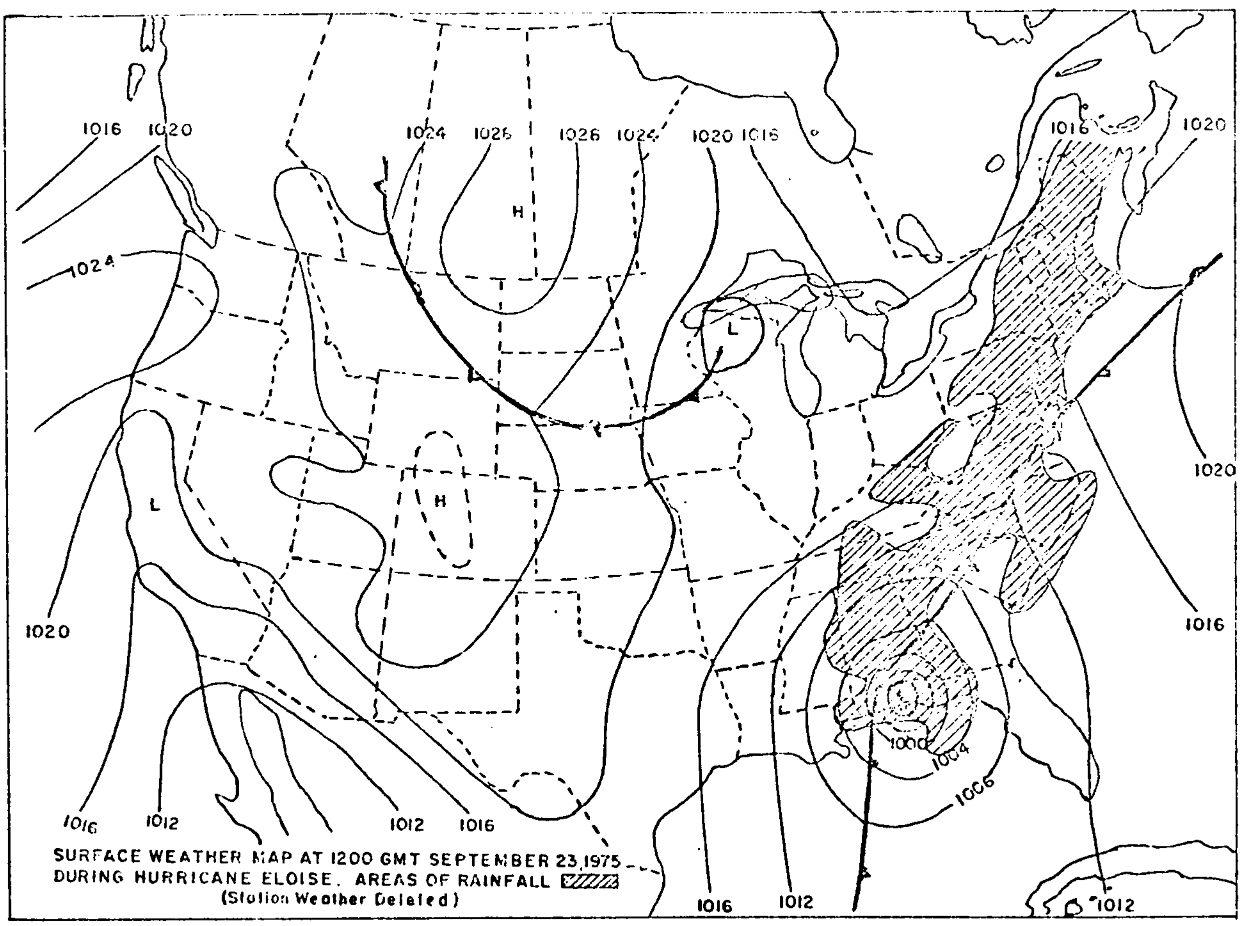


Figure 27. Surface Weather Map at 1200 GMT September 22, 1975 During ELOISE from Daily Synoptic Surface Weather Maps (NOAA)

the eastern Gulf of Meixco during the passage of Hurricane ELOISE. These buoys were EB-04 and EB-10 located at 26°00'N, 90°00W and 27°47'N, 88°02'W. Since it is unusual to have open ocean wind wave height, precipitation, current speed, current direction, surface and at depth salinity and temperature values in connection with the passage of a hurricane, this set of data is of a unique nature. These buoys measured atmospheric pressure, wind speed and direction, air temperature, dew point, precipitation, shortwave solar radiation, longwave solar radiation, wave spectrum, wave period significant heights, pressure, current direction and speed, temperature, and salinity. Depending upon the buoy, some or all of these parameters were measured.

The Environmental Science Division of the Naval Coastal System Laboratory at Panama City, Florida, in recent years, has instrumented two towers along Transect III which have produced tidal wave heights, wind speed, and wind direction data for the period 0550 GMT hours, September 22, through 1127 GMT hours, September 23, 1975. These towers are identified as Stage I at 30°00.6'N, 85°54.2'W (approximately 12 natuical miles (222 km) offshore). These towers produced data until ELOISE caused a power failure on shore preventing the transmittal of data. These towers feed their data to a computer that computes statistical values at approximately 30-minute intervals based on 1160 sampling points.

The hurricane passed within 17 nautical miles (31.5 km) of Buoy EB-04 with the western fringe of the eye passing over it between 1300 and 1400 hours GMT on September 22, 1975. As the storm passed this buoy, it intensified to hurricane strength. At 0300 GMT on September 23, 1975, it appears that the storm center came within 10 nautical miles (18.km) of Buoy EB-10. This would mean that the eye of the hurricane passed directly over the buoy.

On Buoy EB-04 gale force winds were not reached until 0900 GMT on September 22 and terminated by 0200 GMT on September 23 while on Buoy EB-10 gale force winds were reached by 1400 GMT on September 22 and were over by 0900 GMT on September 23, 1975. This would mean that gale force winds or greater occurred at EB-04 for 17 hours and on EB-10 for 19 hours. Since we do not have any data after the hurricane on Stages I and II, it is difficult to determine the extent of gale force or greater winds at sea on the Continental Shelf. However, because of the speed of the hurricane, it seems reasonable to assume that the time period would not be greater than 22 hours.

Data are given for Buoy EB-04 from 1200 GMT on September 19 through 1200 GMT on September 25, 1975, and for Buoy EB-10 from 1200 GMT on September 20 through 1200 GMT on September 26 for wind speed and direction. At 1100 GMT, September 22, a maximum speed of 237.3 cm/sec (46 knots) was recorded as the northwest portion of the eye passed over Buoy EB-04. At 1500 GMT on September 22 the southwest portion of the eye passed over Buoy EB-04, and by 1700 GMT the wind speed had reached its maximum value of 270.1 cm/sec (52 knots). The wind speeds and wind direction are given in Figure 28 (wind speed recording units m/sec).

On Buoy EB-10 at 0100 GMT on September 23 the maximum wind speed of 351.8 cm/sec (68.2 knots) was recorded as the eye of the hurricane moved across the buoy. By 0400 GMT on September 23 the eye had crossed the buoy, and the wind increased to 348.3 cm/sec (67.6 knots). The wind direction and wind speeds for this buoy are shown in Figure 29 (Wind speed recording units were m/sec.).

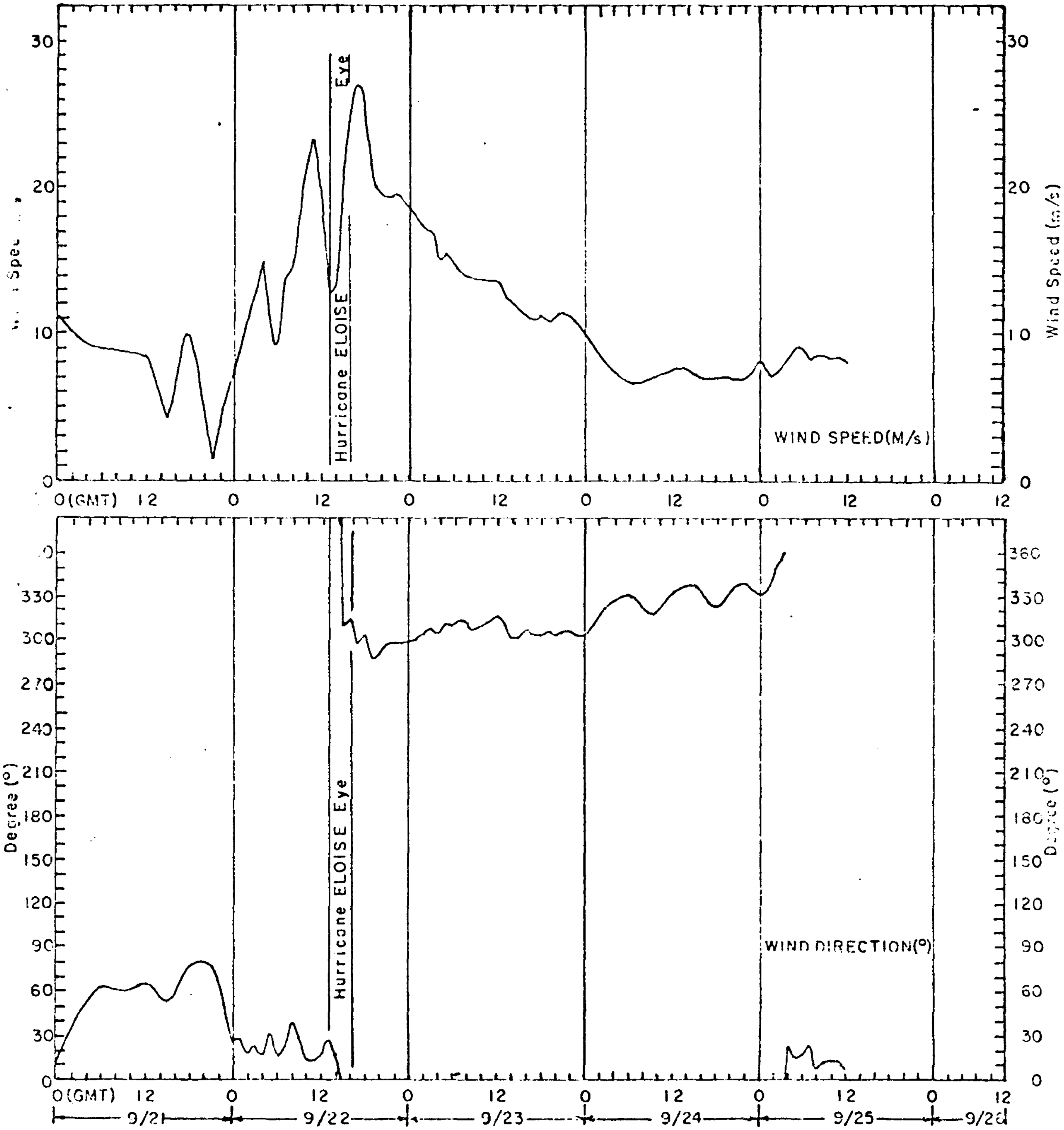


Figure 28. Wind Speed and Direction from NDBO Buoy EB-04 26°00'N., 90°00'W. September 21-26, 1975

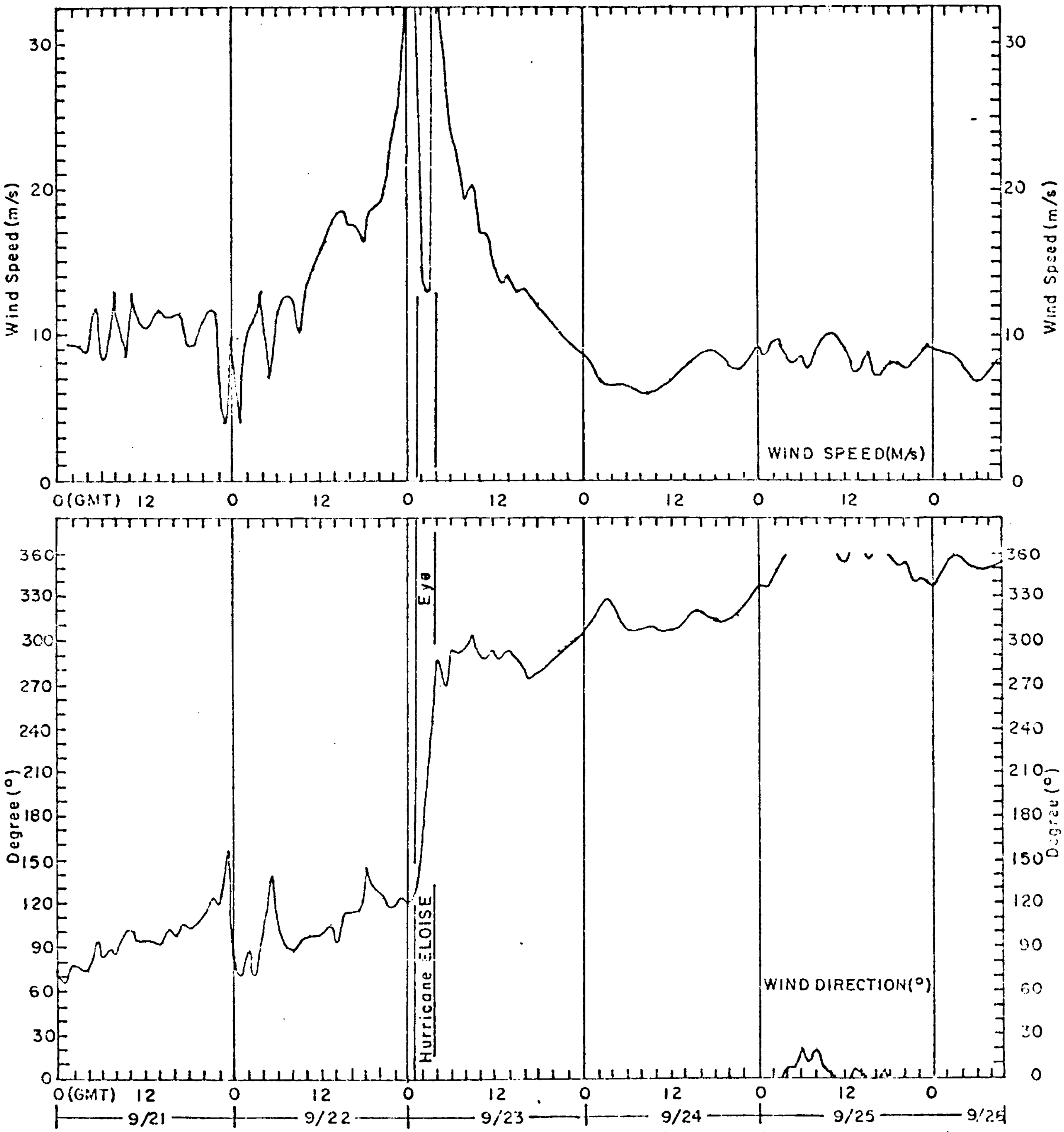


Figure 29. Wind Speed and Direction from NDBO Buoy EB-10 27°47'N., 88°02'W. September 21-26, 1975

On the Florida Continental Shelf at Stage I gale force winds began to occur at 0554 GMT on September 23 reaching hurricane force at 1127 GMT on September 23. On Stage II gale force winds were reached at 0622 GMT on September 23 and had not reached hurricane force by the time power failure occurred after 1127 GMT on September 23. The wind direction and wind speeds are shown in Figure 30 (Wind speed recording units were knots.).

Because of the track of ELOISE, the full hurricane wind effects could be expected along Transect III, which is nearly parallel to the course of the eye in the right quadrant of the hurricane. The effects of the wind should have been felt strongly on the outer portion of this transect from Master Station 1310 to Master Station 1311. On Transect II, which is also nearly parallel to the track of the hurricane, gale force wind of between 35 and 42 knots (1801.7 cm/sec and 2162.1 cm/sec) should have occurred along the entire transect. On the other hand, Transects IV and I were nearly perpendicular to the track of the hurricane, and there would have been steadily decreasing wind effects from outer stations towards shore.

Some of the world's heaviest rainfalls have occurred in connection with hurricanes. The rainfall is always heavy, probably three to six inches (7.6 cm to 15.2 cm) on the average - frequently much more. The total accumulation of rain at a given locality is greatly dependent upon the forward speed of the hurricane simply because in slower moving storms the rain lasts a longer time. Although distribution of rain patterns around hurricanes are still in the stage of development, in general, it has been found that the amount and areas of rainfall distributions are quite astrosymmetrical around the storms along the Gulf Coast when the hurricane center is moving. The

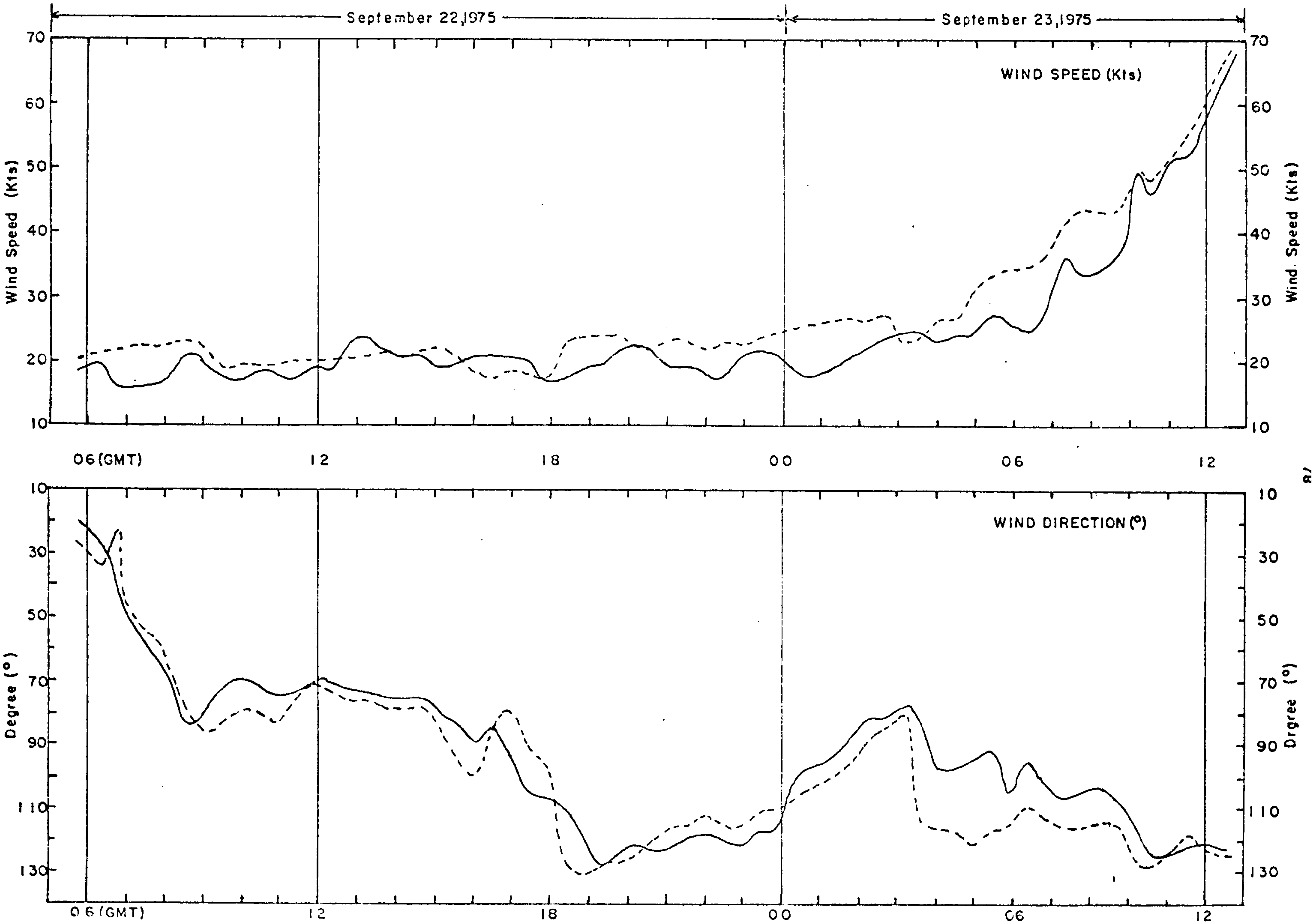


Figure 30. Wind Speed and Direction from Stage I 30° 00.6' N., 85°54.2' W. and Stage II 30°07.23' N., 85°46.5' W. September 22-23, 1975

areas of greatest intensity are 60 to 80 nautical miles (111.2 to 148.3 km) in front of the cyclone center and mostly to the right of the line along which the cyclone is advancing. However, such conclusions can be altered not only by the stages of development, but by the speed of motion and degree of curvature that occurs with each individual hurricane. In the case of Hurricane ELOISE, which was a very "wet hurricane", rainfall amounts ranged in general from four to eight inches (10.2 cm to 19.2 cm) from extreme southeast Louisiana to west of the Panama City, Florida, area. The greatest rainfall was 14.9 (37.8 cm) at Eglin Air Force Base, Florida. Unlike the normal hurricanes, the heaviest rainfalls occurred west and north of the storm tract as the moist warm airs associated with ELOISE overran the colder air behind the stagnant frontal zone extending from northern Alabama southward into the Gulf of Mexico (Figure 27). From the eastern side of the eye wall (from Panama City, Florida) most stations had less than one inch (2.5 cm) of rainfall as a tongue of dry air behind the frontal zone was drawn into the area of ELOISE circulation. This means that heavy rainfall was experienced on Transect IV only. However, because of the rapid movement of the hurricane, excessive rainfall (that is above the average of three to six inches (7.6 to 15.2 cm)) did not occur on Transect IV. The speed of advance of the hurricane and the meteorological conditions associated with the frontal conditions caused very little rain to fall on Transects II and III, and little or no flooding was noted in the area. The rainfall associated with this hurricane is given in the following tables.

TABLE IX

Rainfall Associated with Hurricane ELOISE
September 22-23, 1975

Station	Rainfall Storm Total in Inches*	Dates
Boothville, La.	4.72	21-23
Bay St. Louis, Miss.	8.72	No Date
Dauphin Island, Ala.	5.22	22-23
Mobile, Ala.	1.74	22-23
Pensacola, Fla.	5.62	20-23
Crestview, Fla.	9.48	22-24
Valparaiso, Fla.	14.90	21-23
Panama City, Fla.	0.74	23
Apalachicola, Fla.	0.12	22-23
Tallahassee, Fla.	0.91	23

*One inch = 2.54 cm.

TABLE X

	Precipitation - September				Hurricane Eloise	
Station	Normal Total*	Maximum Monthly Total*	Minimum Monthly Total*	Maximum in 24 hrs.*	Storm Total	September Dates
New Orleans, La.	5.03	16.74	0.24	6.50	4.72	21-23
Mobile, Ala.	6.25	13.61	0.58	6.58	1.74	22-23
Pensacola, Fla.	7.69	10.28	2.38	10.02	5.62	20-23
Apalachicola, Fla.	8.53	22.50	0.78	11.71	0.12	22-23

*One inch = 2.54 cm.

Table X gives the September precipitation from several of the meteorological stations in the area of the hurricane. This table records the normal total, the maximum monthly, the minimum monthly and the maximum in 24 hours of rainfall in inches for September. Included as part of this table are the actual observed rainfall amounts in inches for Hurricane ELOISE.

These data would indicate that the hurricane created rainfall amounts equal to about 90% of the normal rainfall for those areas west of the hurricane center except for Mobile, Alabama. Looking at Table IX, it can be seen that at Dauphin Island, Alabama, on the coast straight south of Mobile, Alabama, 5.22 inches (13.3 cm) of rain occurred, which would be approximately 90% of the normal rainfall at Mobile.

To the east of the hurricane, values represented by Apalachicola, Florida, indicate that only a nominal amount of rain fell in relation to the normal monthly rainfall.

Of particular interest at this time in the report is the precipitation record from Buoy EB-10 during the passage of the hurricane. Figure 31 shows the hourly rate and the accumulated precipitation in centimeters during this time period at a height of ten meters above the surface. The hourly rates are shown as dashed lines, and the accumulated amounts as a solid line. These data, along with variations in wind speed and wind direction, indicate possible bands of activity which are associated with the spiral effect noted in the structure of hurricanes. These can be seen by periods of rainfall on the 21st and 22nd of September which are separated by either no precipitation, or very little, and the increasing amount in the hourly rate as the hurricane approached the buoy. The maximum amount of rainfall per hour occurred just before the passage of the eye because of the extratropical characteristics of the meteorological events that occurred as the hurricane passed the buoy (See page 78 of this report.).

An important characteristic of any hurricane is the influence of the abnormal tides and storm surges associated with the passage of a hurricane. In this discussion the storm surge resulting from the hurricane will be

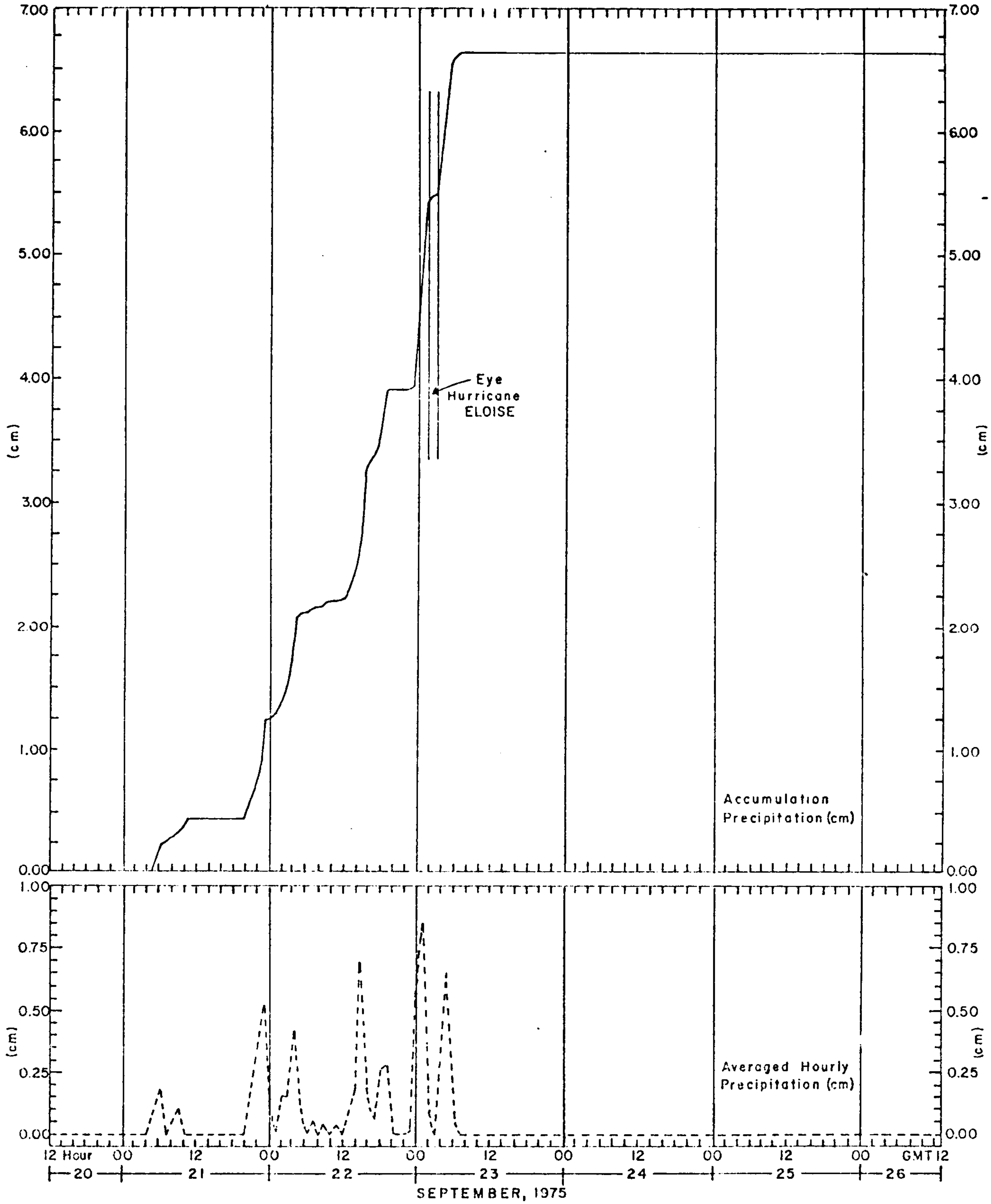


Figure 31. NDBO Buoy EB 10 Precipitation (cm) 1200 GMT, 20 September to 1200 GMT, 26 September, 1975.

defined to include a rise above normal water level on the open coast due to the action of wind stress on the water surface and the rise in level due to the atmospheric pressure reduction.

The highest waves are usually produced just at the right of the hurricane center when the observer faces the direction toward which the center is moving. Examining Figure 26, it can be seen that the inner part of Transect III would have received the highest waves. It can also be shown that the ocean waves travel with a speed somewhat slower than the winds which generate them, and normally they will precede the hurricane since the average movement of a hurricane is about twelve nautical miles (22.2 km) per hour, and the average movement of the waves is between thirty and fifty nautical miles (55.6 km and 92.7 km) per hour. This hurricane, however, was not an average one in its rate of movement. By 0600 GMT on September 23rd its speed was approaching 16 knots (823.7 cm/sec), and by the time it reached land it was moving at 20 knots (1029.6 cm/sec).

Through the courtesy of NOAA/Marine Climatological Services Branch, graphs of the observed tide and storm surges from three NOS tide gages located at Pensacola, Panama City, and Apalachicola, Florida, are shown in Figure 32. These curves are based on hourly values. The storm surge was determined by subtracting values of the astronomical tides from the observed tides. The recording units are feet.

As can be seen from Figure 32, the storm surge west of the hurricane center, as indicated by Pensacola, Florida, was between one and two feet (0.3 and 0.6 m), while the values at Panama City and Apalachicola, Florida, to the east of the hurricane center ranged from one to five feet (0.3 to 1.5 m). The influence of the hurricane on the water level can be noted

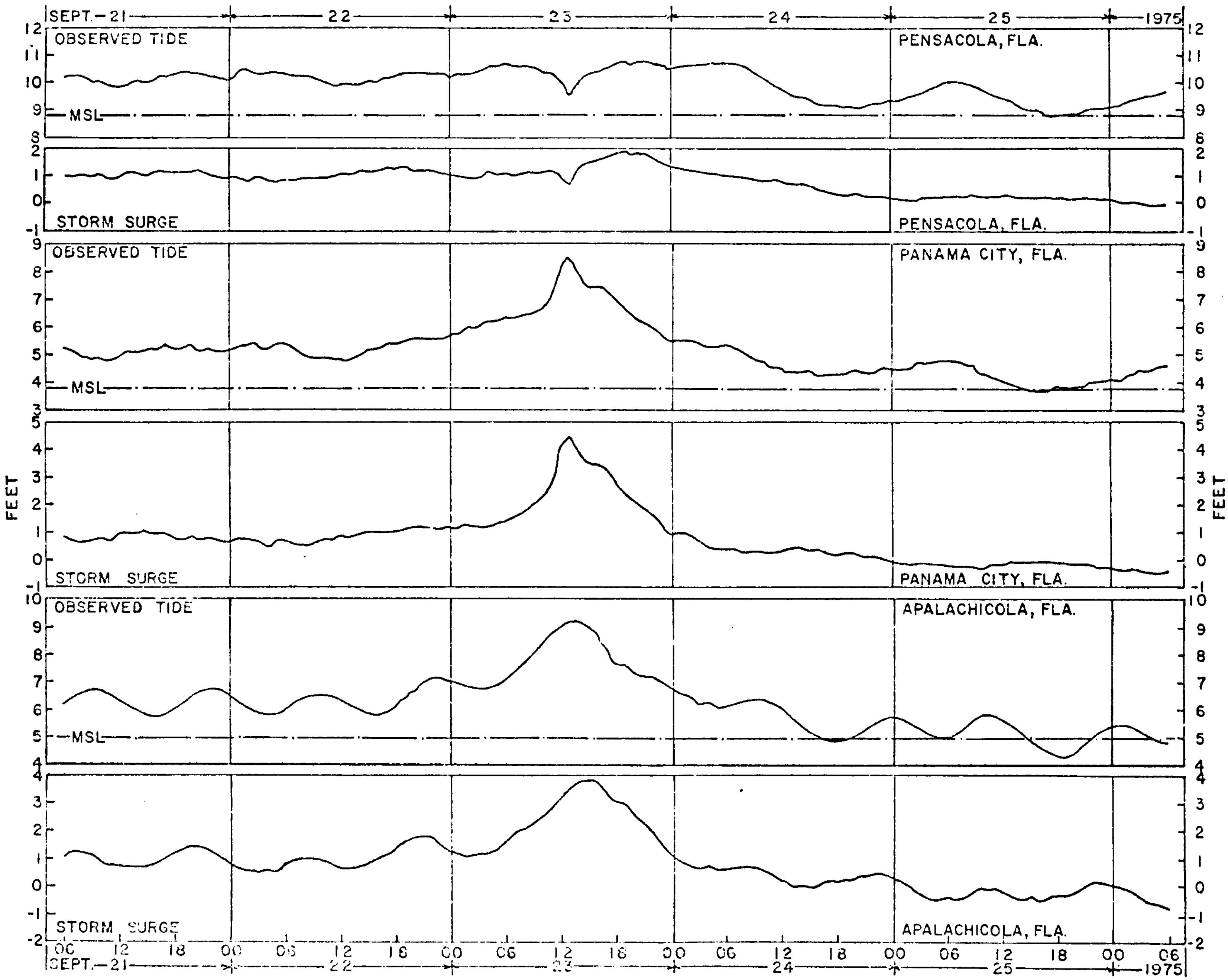


Figure 32. Observed Tide and Storm Surge from NOS Tide Gages at Pensacola, Panama City, and Apalachicola Florida During Hurricane ELOISE September 21-26, 1975 Based on Hourly Values. The Storm Surge is Determined by Subtracting Values of the Astronomical Tide from the Observed Tide. (Supplied by NOAA/Marine Climatological Services Branch)

starting on the 21st of September and subsiding by the end of the 24th. Figure 32 graphically illustrates the location of the highest increase in water level to the right of the hurricane.

Preliminary measurements indicated that the storm surges were from 12 to 16 feet (3.7 to 4.9 m) above mean sea level (MSL) just east of Fort Walton Beach, Florida; 6 to 12 feet (1.8 to 3.7 m) eastward to Port St. Joe, Florida, from 3 to 5 feet (0.9 to 1.5 m) elsewhere in the gale wind area (Figure 26); and 2 to 3 feet (0.6 to 0.9 m) southward from Cedar Key to Naples, Florida.

The extent of maximum wave heights was a much more difficult problem to determine. The highest inside high water mark of 18.2 feet (5.5 m) above MSL occurred near Dune Allen Beach, Florida. The data from the towers indicated that at Stage II the maximum high was 9.5 feet (2.9 m) and at Stage I 10.5 feet (3.2 m) representing conditions between Master Stations 1308 and 1309. The maximum observed wave height value on Buoy EB-10 was 8.1 m (26.5 feet) just before the passage of the eye of the hurricane and 8.8 m (28.2 feet) after its passage. If one removed the normal recorded wave action before and after the hurricane of approximately two meters (6.6 feet) from these values, one has wave heights of 20 to 22 feet (6.1 to 6.7 m), respectively. The position of the sensor and the buoy transfer function indicated that the estimate of the total system accuracy is approximately 50% depending upon the statistical confidence required. Taking this figure, the highest observed wave height would have been about 11 feet (3 m), which agrees rather well with the figures recorded at Stages I and II.

Subsurface oceanographic measurements were made at both Buoys EB-04 and EB-10. These measurements consisted of temperature, salinity, pressure, and current direction. At 50 m on Buoy EB-10 current speed was taken. The depth of these sensors is listed below:

Depth	Buoy EB-04	Buoy EB-10
2 m	Temp., Salinity, Current Dir.	Temp., Salinity, Current Dir.
50 m		Temp., Salinity, Current Sp. & Dir., and Pressure
200 m		Temp., Salinity, Current Dir., Press.
500		Temp., Salinity, Current Dir., Press.

Historically, there are a number of incidents in which physical data have been collected before and after a hurricane, but this is the first case in the eastern Gulf of Mexico in which recordings have been made in a time series mode at or near the center of a hurricane and before, during, and after a hurricane. For this reason, it can be anticipated that a number of papers will appear which will analyze these data in regard to the energy input into the hurricane and in relation to the wind speed drop, dew point rise, and wave height decrease during the passage of the eye. These types of meteorological presentations along with subsurface oscillation patterns, current direct (Manheim, et al, 1976), and pressure represent special studies and are beyond the objectives of the physical environmental support program due to cost. Therefore, they will be referred to only in general terms.

The data does allow the interpretation and speculation in another aspect that pertains to the MAFLA routine monitoring conception and that is in the variability of the parameters with respect to time and the extent of their gradients. These data records have been examined for temperature and salinity at the 2, 50, and 200 m levels and are given as time series data in Figures 33, 34, 35, and 36.

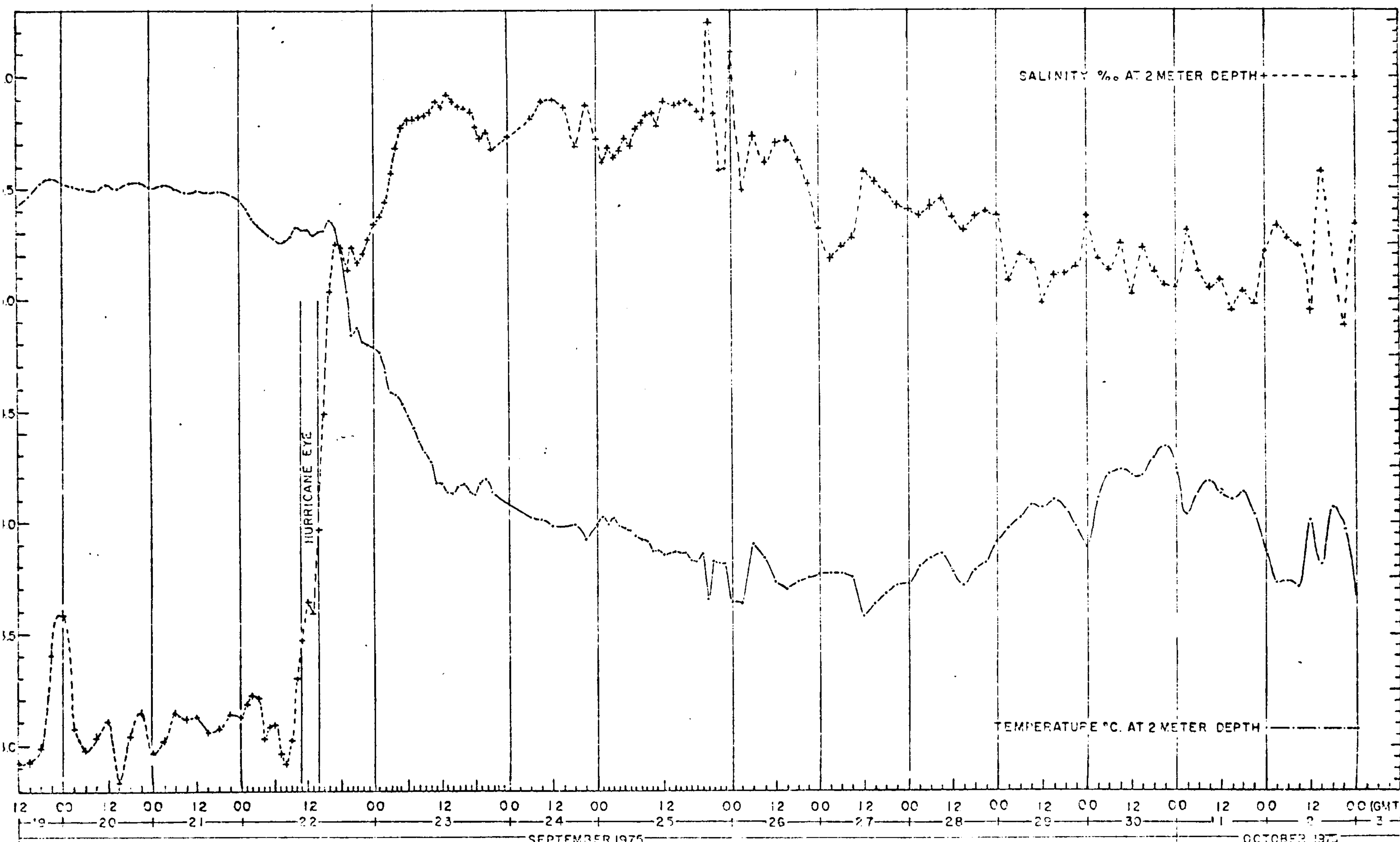


Figure 33 Environmental Measurements of Temperature and Salinity taken by EB-04 26°00'N, 90°00'W at 2 Meter Depth During "ELOISE"

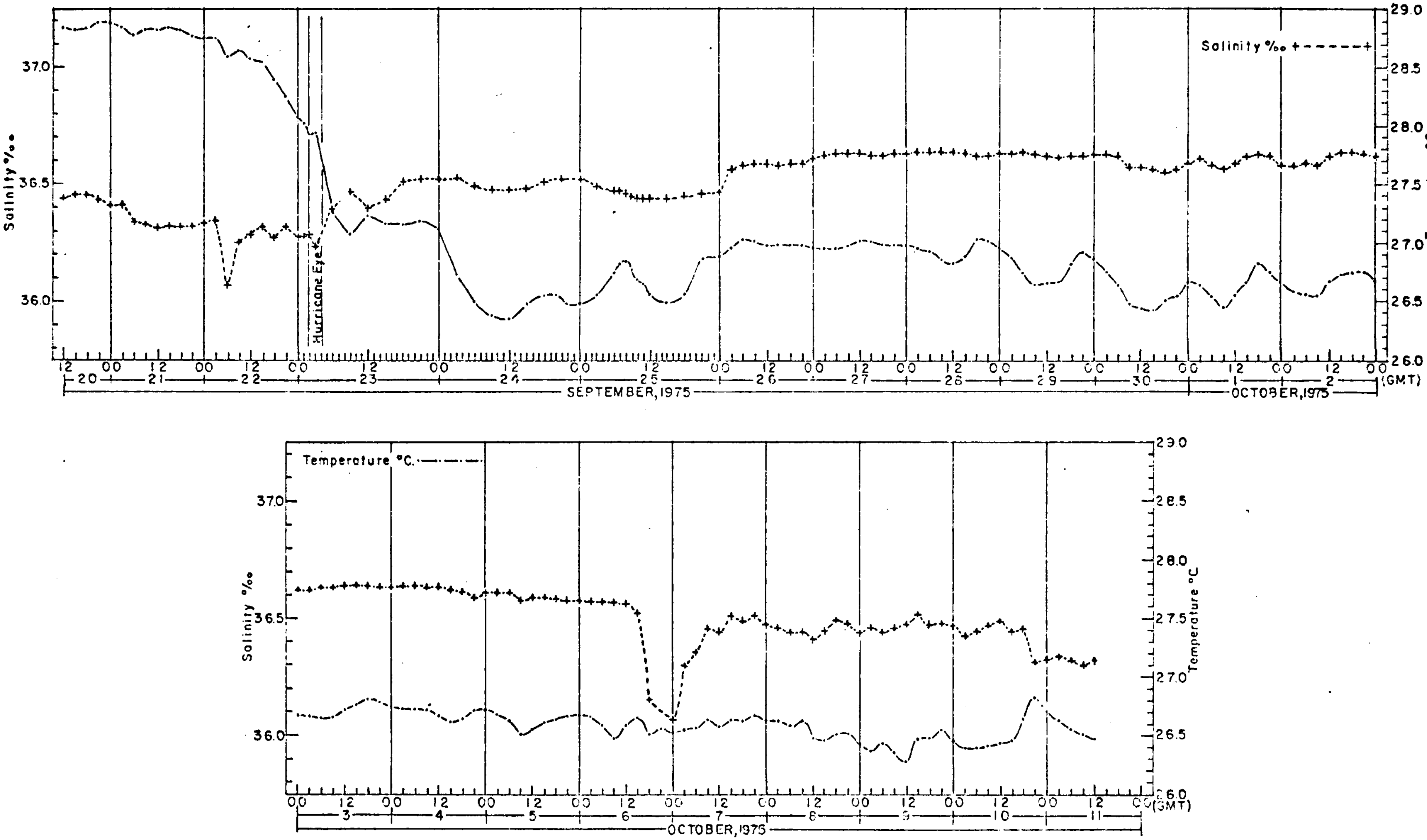


Figure 34. Environmental Measurements of Temperature and Salinity taken by EB-10 27°47'N, 88°02'W at 2 Meter Depth During "ELOISE"

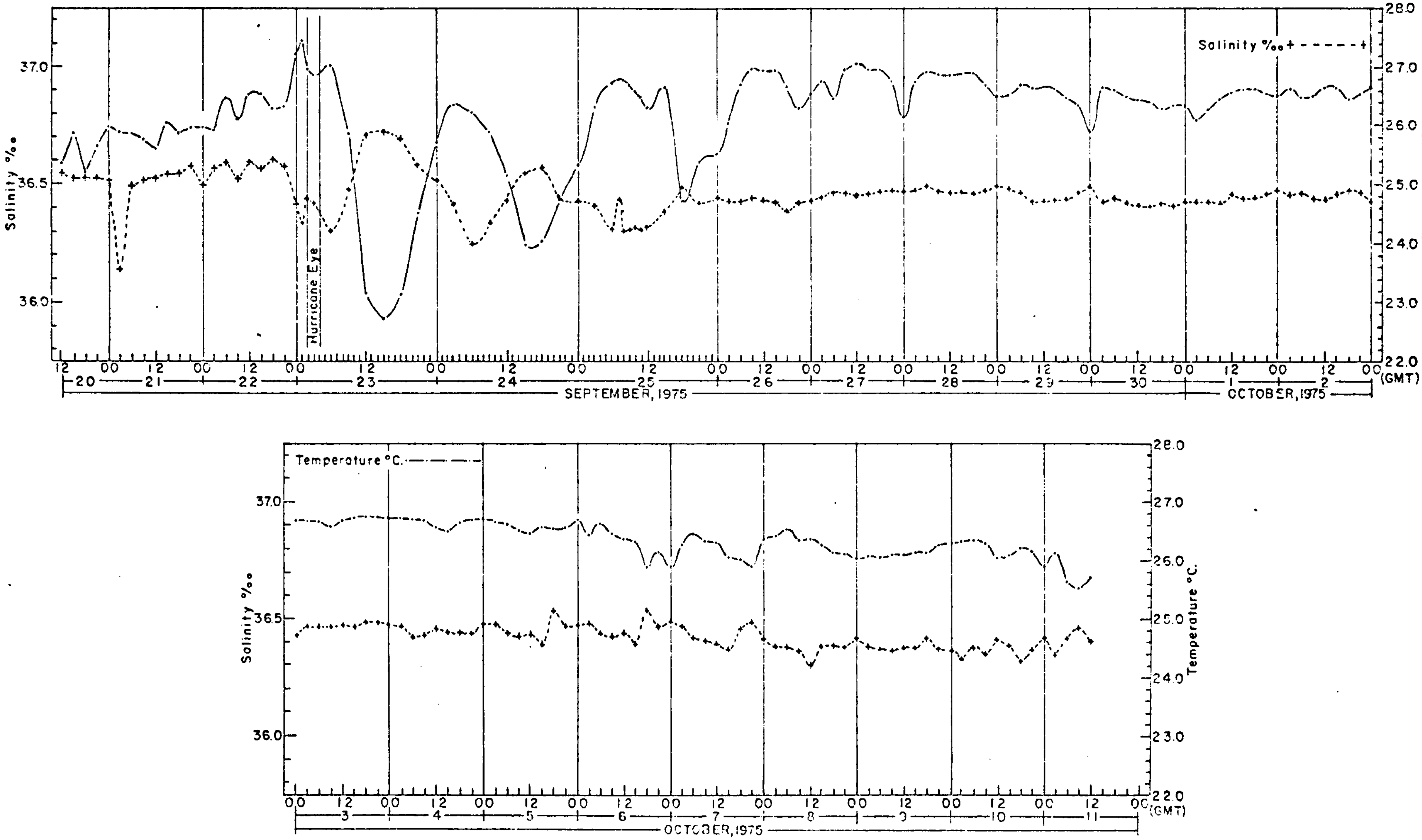


Figure 35. Environmental Measurements of Temperature and Salinity taken by EB-10 27°47'N, 89°02'W at 50 Meter Depth During "ELOISE"

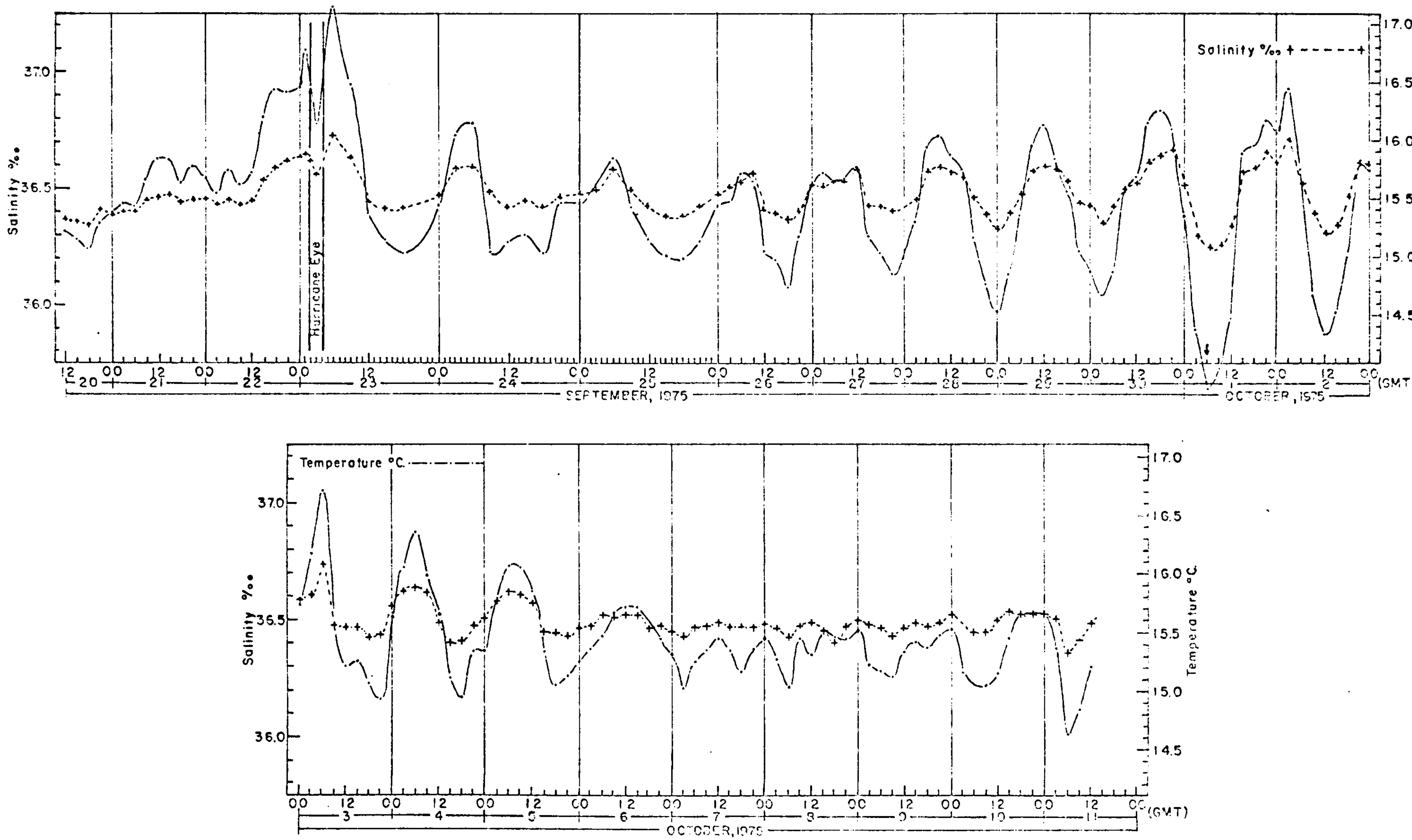


Figure 36. Environmental Measurements of Temperature and Salinity taken by EB-10 27°47'N, 88°02'W at 200 Meter Depth During "ELOISE"

The temperature data records at the two buoys vary in their time series lengths and sampling intervals. On both buoys, except for limited data gaps in one parameter or another, an observation was recorded every three hours. At selected times, depending upon the location of the hurricane, observations were taken at hourly intervals. On Buoy EB-04 hourly observations were taken from 0000 GMT, September 22, to 2100 GMT on September 23, 1975. Except for very short periods (6 to 7 hours on the 22nd and 25th of September), all observations on Buoy EB-10 were made at three-hour intervals. The foregoing figures show the time series distribution of both temperature and salinity with temperature (°C) shown as a solid line with the actual values represented by a dot and salinity shown as a dashed line with the actual values represented by a plus sign.

Since Buoy EB-04 had sensors only at two meters, comparison between EB-04 and EB-10 data must be restricted to the surface level. Each of the data records started at least 60 hours before the passage of the hurricane eye.

There are a number of similarities in the temperature field characteristics at each of these buoys before and after the passage of the hurricane both in the changes in temperature and in the short and long-term oscillation patterns. Approximately 30 hours before the passage of the eye a continuous decrease was recorded in temperatures. This decrease in both cases was approximately 0.7°C (within ± 0.09°C). Before this time, the data records indicated what appeared to have been either tidal or diurnal oscillations associated with pre-hurricane conditions. The surface temperatures were approximately 28.7°C (± 0.2°C) at Buoy EB-10 and 29.2°C (± 0.4°C) at

Buoy EB-04. A transect (Figure 37) from Galveston to within 17 nautical miles (31.5 km) of Buoy EB-04 by the R/V DELTA NORTE and the values from the stations on the Continental Slope on Transect IV (Figure 17) and Transect III (Figure 19) from the BLM-20 cruise indicate that the water temperature offshore from the MAFLA area were increasing from north to south. Based on these data it would appear that the first 30 hours of data from the buoys represent the non-hurricane environment.

At Buoy EB-04 during the passage of the hurricane eye there was a slight temperature increase of 0.15°C which did not occur at Buoy EB-10. Whether this was a reflection of the intensity of the hurricane wind stressing on the temperature field or motion effects on the buoy sensors cannot be determined. It is interesting to relate this feature to the data collected during Hurricane ELOISE Flight 750922A flown on September 22 and 23, 1975, as the hurricane was passing between Buoys EB-04 and EB-10. The northeast-southeast quadrants (maximum wind speed areas) of the hurricane were examined along with a transect through the eye of the hurricane from east to west and west to east. The transects through the eye of the hurricane were made along approximately 27°15'N at which time the maximum velocity was 90 knots (4632.8 cm/sec). Using the criteria established above for defining the area of gale and hurricane winds, this flight, in general, was within hurricane winds.

During this flight a total of 22 air XBT probes were launched of which 18 gave good traces. The results of these XBT sections across the hurricane eye indicated that there was a surface temperature gradient from west to east; that is, from the weaker to the stronger wind quadrants ranging from

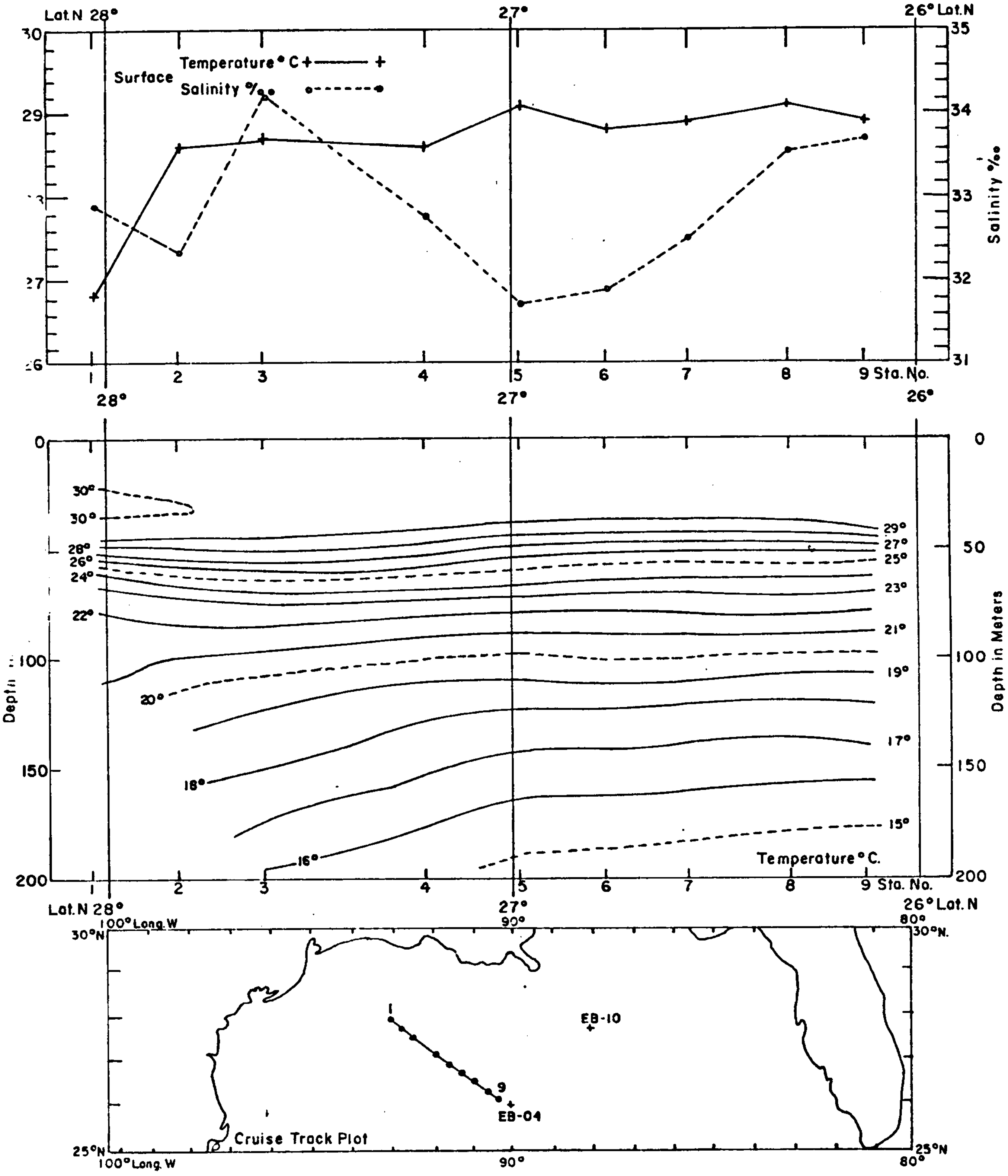


Figure 37. Surface Temperature °C and Salinity ‰ - Vertical Distribution Temperature °C Based on XBT from DELTA NORTE - SEPTEMBER 20, 1975 (NOAA/EDS/NODC).

29 to 27.5°C. The values at the hurricane eye were 28.4°C, which is between the values of 28.6°C at Buoy EB-04 and 28.0°C at Buoy EB-10. It is possible, therefore, that the momentary increase of temperature (0.15°C)- observed during the passage of the hurricane eye at Buoy EB-04 could reflect the transport of warmer water from the western side of the hurricane with a shifting of wind structure as the hurricane eye passed since EB-04 was to the west of the track of the hurricane.

After the passage of the hurricane eye, the temperatures continued to drop for another approximately seven and one-half hours at which time a small increase in temperature occurred. This increase was only of three-hour duration at Buoy EB-04 but of ten-hour duration at Buoy EB-10. Another decrease in temperature then ensued, and it was during this period that the maximum decreases in temperature were experienced respectively at Buoys EB-04 and EB-10 of 2.51 (22 hours) and 1.74°C (30 hours).

With minor fluctuations as noted above and starting approximately 30 hours before the arrival of the hurricane eye at the buoys, the surface temperatures decreased by 2.74°C (28.33 - 26.36) over 69 hours at EB-10 and 3.00°C (29.28 - 26.28) over 63 hours at EB-04. In short, a decrease of temperatures was experienced for approximately 30 hours before and after the passage of the hurricane.

In an attempt to determine the short-term variability of temperature the three-hourly values were examined and one and three-hourly change rates computed. Since at Buoy EB-04 there was a limited amount of actual hourly rates, these values were computed and compared with those based on three-hour observation data.

The maximum observed hourly rate was 0.4°C, which occurred at both buoys. The maximum three-hourly rate was 0.7°C (± 0.06). A comparison between the hourly rates determined for direct hourly or computed from observations taken every three hours indicated that maximum gradient must have occurred in one-hour intervals or less. The actual observed hourly changes are seldom a constant value over a three-hour period; rather, there is a very rapid drop followed by no drop or small drops of 0.1 to 0.2°C. The average hourly drop in temperature at Buoy EB-04 over this period would have been 0.05°C and at Buoy EB-10, 0.04°C.

At the end of these decreasing temperature changes a series of oscillation patterns developed, two of which can be seen in Figures 33 and 34. One of these is a 26-27 hour pattern, which appears not only in the temperature, but in the salinity, current, and pressure fields. It should be noted that these oscillations are a few hours greater than the normal diurnal or tidal period of 24 hours experienced before the hurricane. The second oscillation pattern appears to be one of seven days; however, the record at Buoy EB-04 is very short to make a positive determination.

Within the 26-27 hour oscillation pattern appears a number of short-term temperature gradients. The maximum three-hourly changes were 0.96°C at Buoy EB-04 and 0.52°C at Buoy EB-10. The maximum one hourly changes were 0.10°C at EB-04 and 0.17°C at EB-10.

These 26-27 hour temperature oscillation features are superimposed upon a seven-day oscillation pattern. Over each of these seven-day features the surface temperatures slowly increased until they appeared to reach an average of 26.5°C with an oscillation amplitude pattern of ±0.3°C. Although this oscillation pattern was still 26-27 hours, the amplitude of temperature variation is near those recorded under pre-hurricane conditions. A net decrease of temperature of 2.2°C (28.7-26.5) occurred over approximately 18 days. Based on XBT data from SEA LAND VENTURE on a run between Galveston and Dry Tortugas which passed between Buoys EB-04 and EB-10 on September 28th and the DELTA SUD, which passed to the west and south of Buoy EB-04 on October 18-19 on a run from Galveston to the Yucatan Straits, these features are confirmed. These data also show that the location of the Loop Current was south and east of Buoy EB-04 as shown on Figure 21 (Molinari, 1976). Further, the detached eddy of Loop Current water off the Mississippi Delta extended farther to the west than is depicted in Figure 21.

Figure 38, which shows XBT temperature distribution from the SEA LAND VENTURE, indicates the western eddy located off the Mississippi Delta extended over into the western Gulf of Mexico.

One should use care in extrapolating the deep basin surface conditions of the eastern Gulf of Mexico as recorded at Buoy EB-10 into shelf areas of MAFLA because they could be affected by the topographical features and forcing mechanisms. However, one can assume that there is a direct relationship between hurricane temperature changes and the variability of wind intensity.

Under these assumptions, data from the DELTA NORTE (Figure 37), the surface and mixed layer temperature distribution from the pre-hurricane transects on BLM #20 (Figures 17 and 19), and pre and post hurricane STD lowerings on Master Stations 1204 and 1205 on Transect II were examined and compared to the Buoy EB-10 surface time series record. In the MAFLA shelf

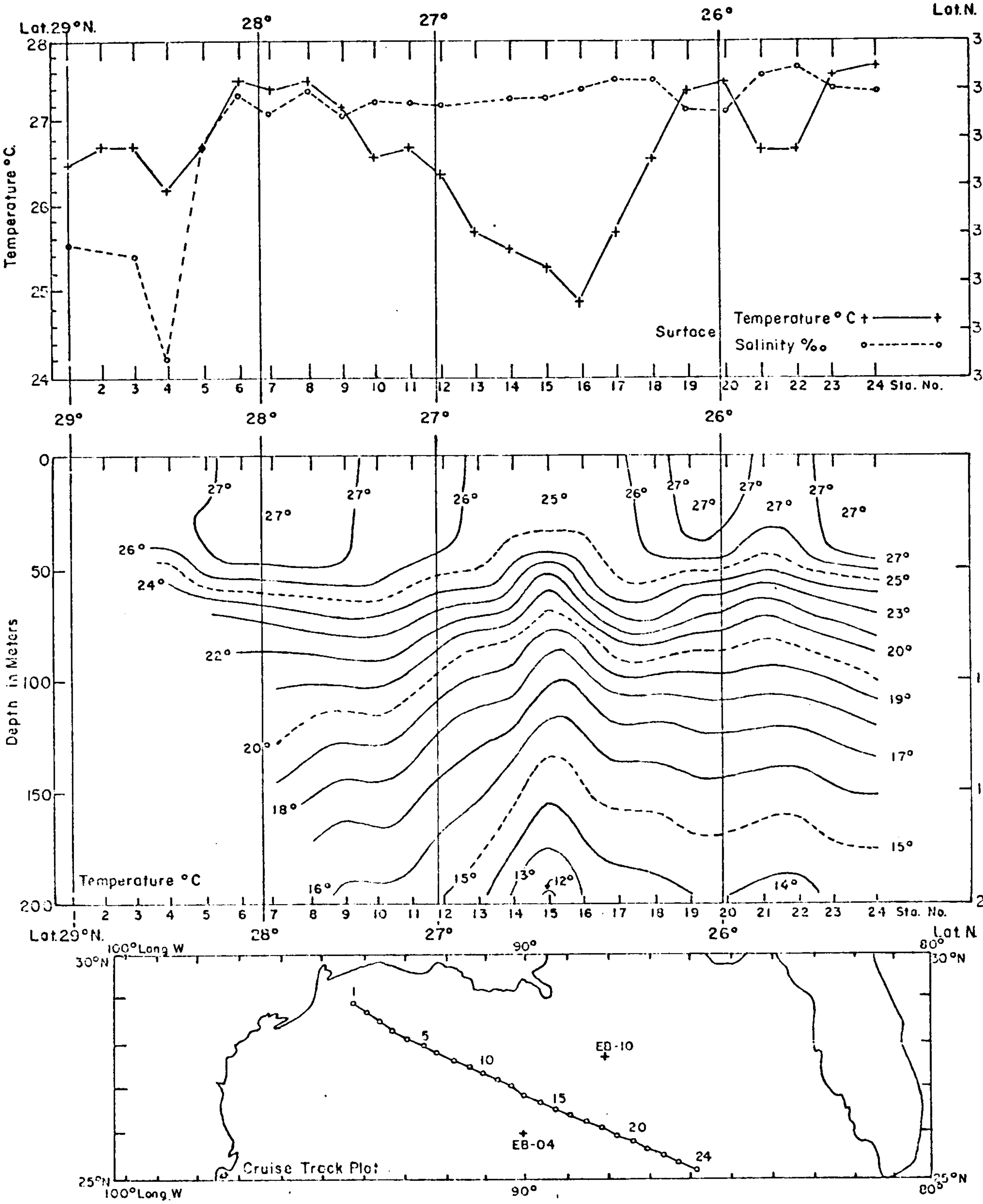


Figure 38. Surface Temperature °C and Salinity ‰ - Vertical Distribution Temperature °C. Based on XBT from SEA LAND VENTURE - SEPTEMBER 28-29, 1975 (NOAA/EDS/NODC)

areas, except for the inshore stations, the surface and mixed layer temperature variations were within the range of the EB-10 data (29.6-28.6 vs. 29.6-28.8°C). Uniform surface temperatures were present as is the normal condition in fall over the shelf and basin areas north of 26°N.

As has been stated before, there were differences in the wind intensity within the area. Hurricane force or greater winds were stressing the outer station on Transect IV and all along Transect III while gale force or greater winds were present on the outer station on Transect I, all along Transect II, and over most of Transect IV.

A temperature change of at least 2.5°C, as observed at Buoy EB-10, therefore, should have occurred along Transect III. Since the wind intensity had increased between EB-10 and Transect III, this change could have been even greater than 2.5°C. The STD on Transect II indicated 28.2°C before and 26.9°C after the hurricane or a change of 1.3°C which would have occurred all along the transect in wind just above gale force. Since the outer station on Transect I was just at gale force winds, there should have been a change of 1.3 to 1.0°C. The actual post hurricane value at Master Station 1103 was 27.4°C (Based on assumed pre-hurricane shelf values ranging between 29.6-29.8 the value could have been 28.3-27.5°C.). There is no post hurricane data from Transect IV, but based on the above a change of 2.5 to 1.0°C should have occurred across the transect from offshore to innershore.

These effects would have been felt down to the depth of the mixed layer. Usually these depths become greater after the passage of a hurricane. The mixed layer before and after ELOISE at Master Stations 1204 and 1205 deepened from 6 to 8 m and 12 to 18 m, respectively. In both cases this mixing was to the bottom.

Figure 39 is the change in temperature and salinity at Master Stations 1204 and 1205 before and after Hurricane ELOISE. It has been drawn by assuming the temperature changes with time were similar to those recorded at EB-10 and EB-04 where the entire change occurred over approximately 60 hours (30 hours before and after ELOISE); that 28% of this change was before ELOISE and 72% after; that the changes were uniform throughout the mixed layer; and the change in wind direction caused by ELOISE at these stations occurred at 0100 GMT on September 23rd. The actual surface temperature change was 1.35°C at Master Station 1204 (28.23-26.88) and Master Station 1205 (28.24-26.89).

Figure 40 is the wind speed and direction from the R/V BELLOWS and the R/V TURSIOPS from September 2 to October 6, 1975. The R/V BELLOWS was forced to stop diving operations on the 20th because of weather. Its results have been supplemented by data from the R/V TURSIOPS, which was able to operate until the 22nd when it was forced into port by the hurricane. These data indicated that the transect was not stressed by winds greater than 25 knots (1286.8 cm/sec) before the 23rd or after the 26th. Further, the post hurricane sampling by STD and XBT on Transect II and I occurred with wind speed and direction similar to those experienced before the effects of ELOISE. The agreement in wind direction between the different transects was good, but the wind speeds showed lower speeds on Transects IV and III compared to Transect II. Examination of Figure 40 indicates considerable difference in wind speed when both vessels were operating on Transect II. Whether these are real or caused by observation techniques cannot be determined, however, the data from the R/V BELLOWS were taken when the vessel was anchored and the R/V TURSIOPS when drifting or in towing operations. Further, the R/V BELLOWS data are the results from averaging a large number of observations over the day which would tend to remove gusted values.

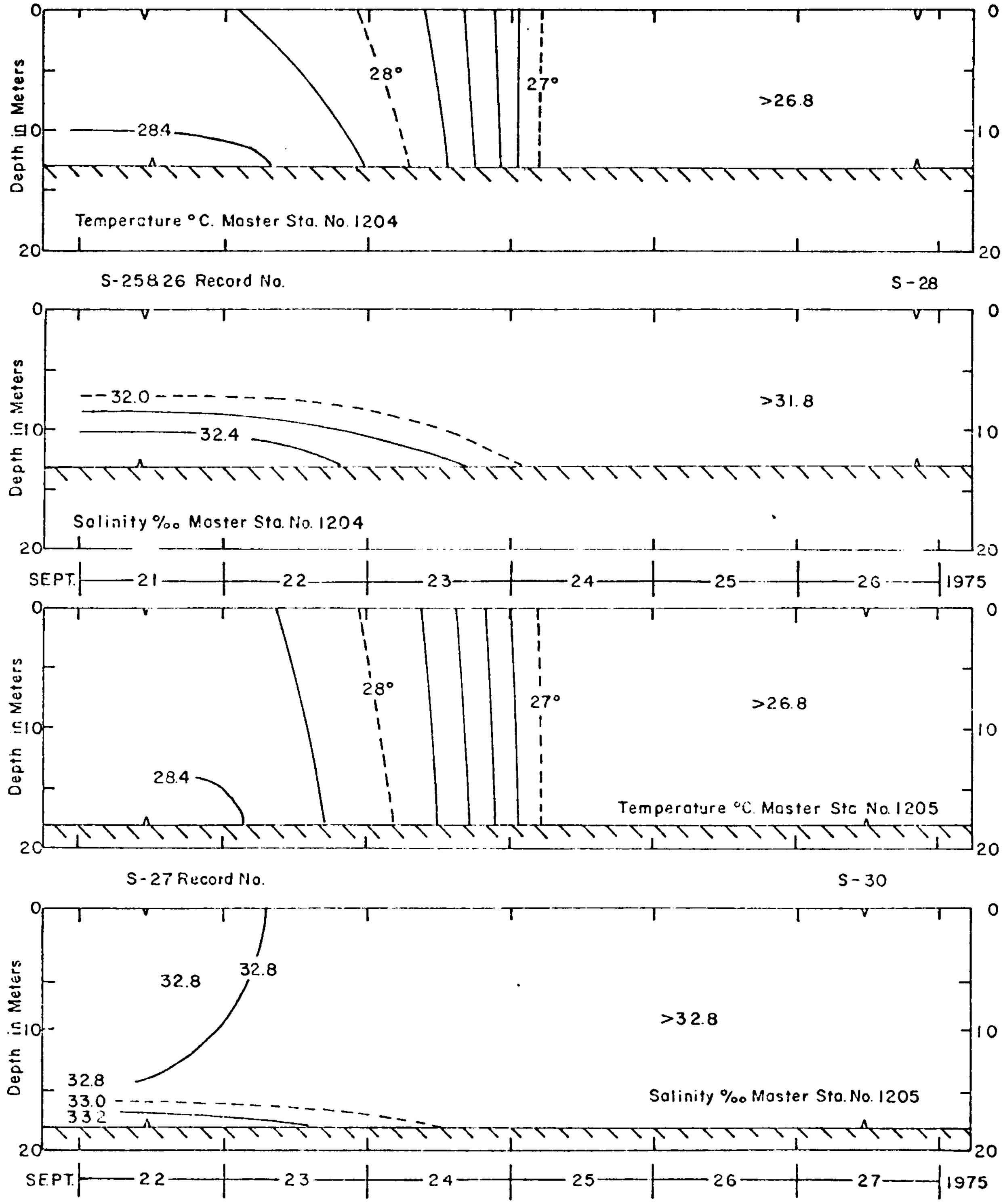


Figure 39. Vertical Distribution Temperature °C and Salinity ‰ based on STD Data taken before and after Hurricane ELOISE at Master Station 1204 and 1205 between SEPTEMBER 21 - 26 and 22-27, 1975.

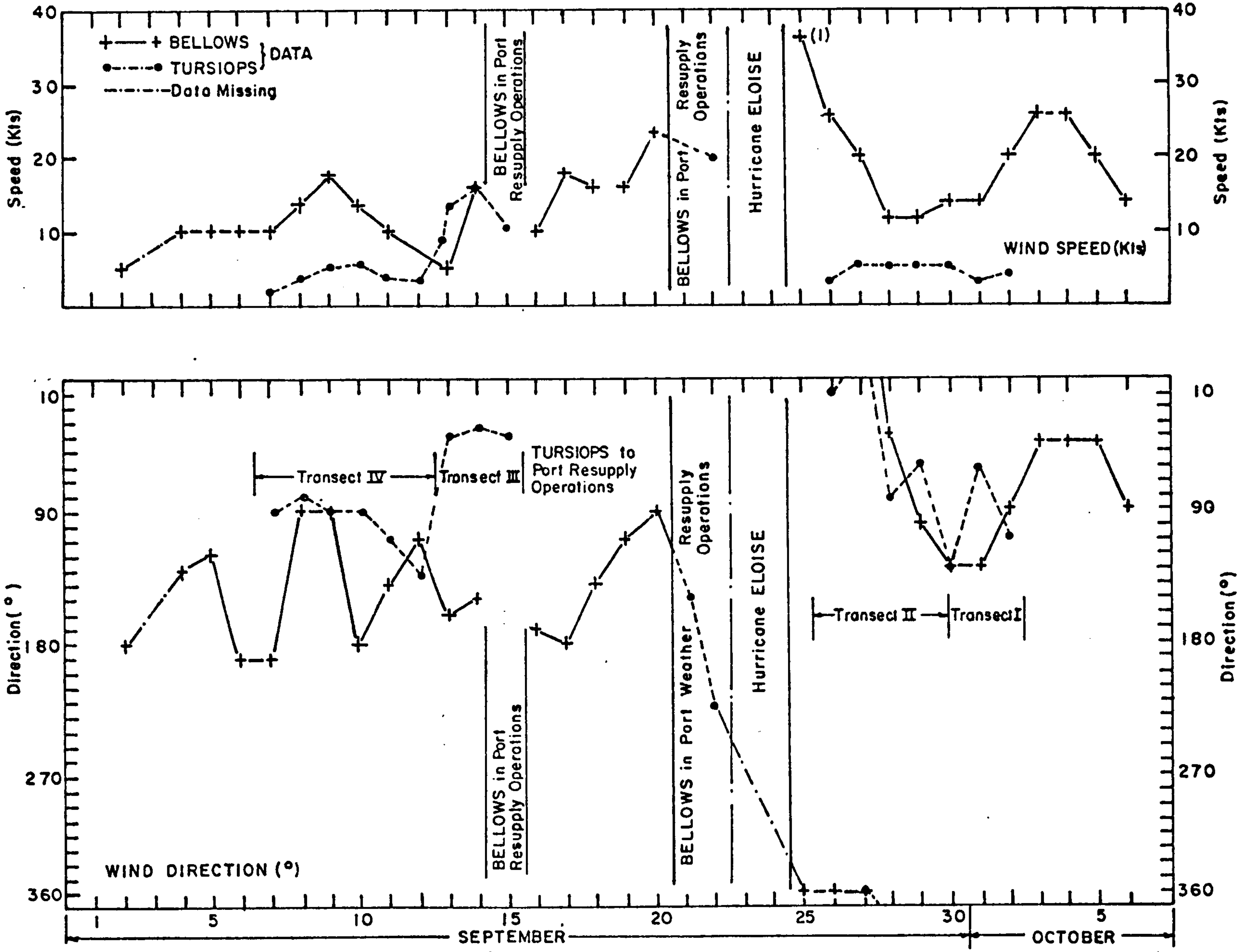


Figure 40. Wind Speed and Direction from R/V BELLOWS and TURSIOPS - SEPTEMBER and OCTOBER, 1975. BELLOWS on anchored Diving Stations on or near Transect II. TURSIOPS Data from Water Column Stations.

A feature associated with historical hurricane studies has been a deepening of the thermocline depth caused by the increase in winds. Attempting to determine the effect of ELOISE on the thermocline depth is difficult because only two stations were repeated on Transect II. Examination of pre-hurricane data, in general, indicated that thermocline depths increased from 6 to 30 m from the inshore stations to the deep basin area except where they were influenced by run-off. An indication of the short-term oscillation patterns at a station location is shown in Figure 41 for STD time series taken at Master Stations 1412 on Transect IV before and 1207 after Hurricane ELOISE (See 41C and 41J.).

Before the hurricane on Master Station 1412 (bottom depth 17 m), the thermocline depth varied between 65 and 85 m or two meters. After the hurricane on Master Station 1207 (bottom depth 35 m), it varied between 3 and 17 m or 14 m. Comparison of before and after hurricane thermocline depths where the bottom depths within the MAFLA area were 17, 35, and 185 m indicated the thermocline deepened by 3-4 m out to a depth of 35 m and possibly to as much as 15 m at the edge of the Continental Shelf. The mixed layer was from the surface to the bottom out to a depth of about 15 to 18 m and 30 to 45 m at the edge of the Continental Shelf.

Another way of looking at it is the tranmissometer data. As a thermocline develops, particles are trapped establishing a nepheloid layer (Manheim, 1976). There is a sharp zone of increased turbidity at the halocline (Figure 22, 24, 41B, and 41I).

Figure 42 is the vertical distribution of transmission (%) at Master Stations 1412(b) and 1207(a) before and after ELOISE. Figure 43.

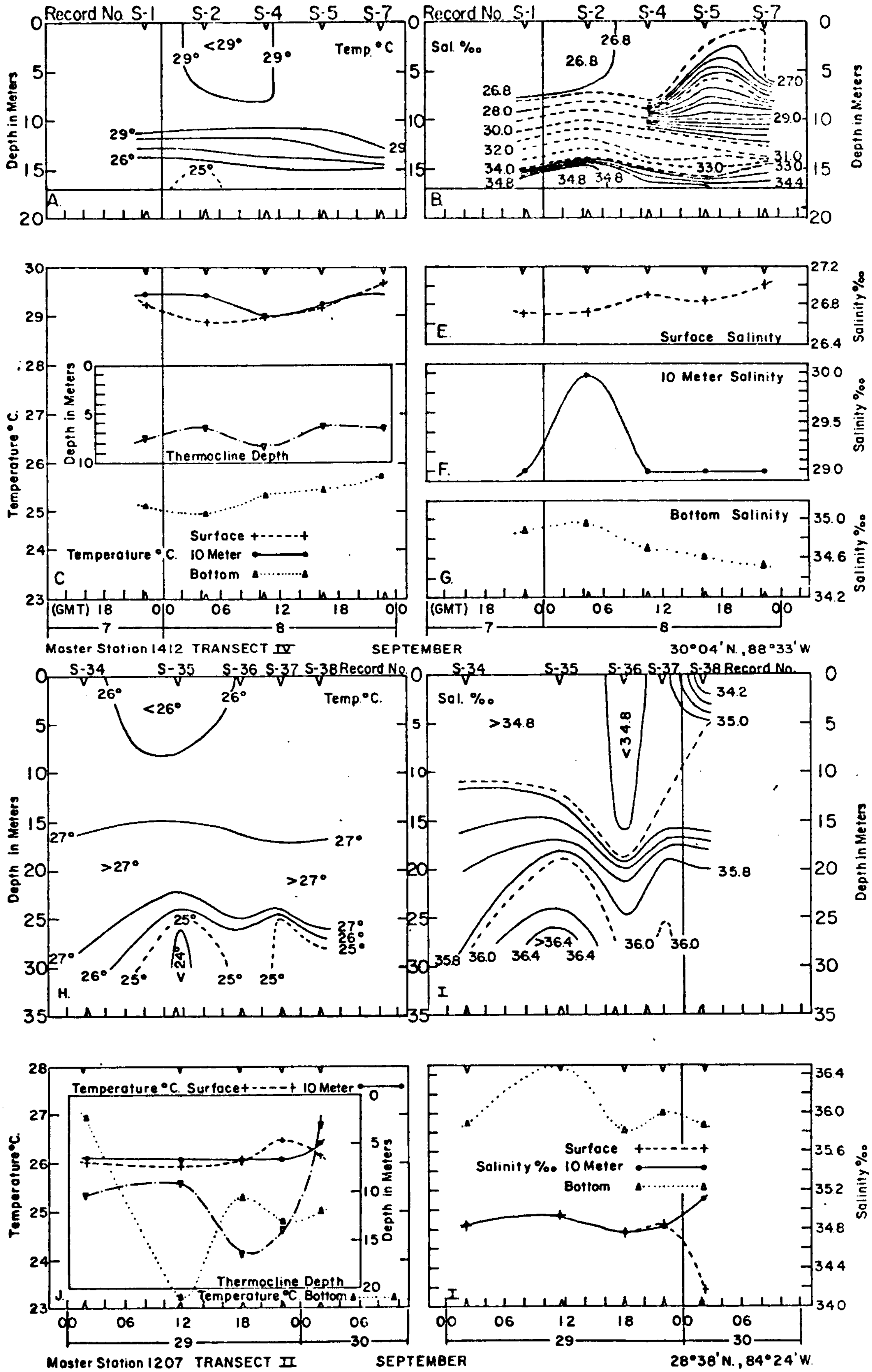


Figure 41. 24 Hour STD Time Series Stations R/V TURSIOPS BLM-20 - Master Station 1412 before and Master Station 1207 after Hurricane ELOISE.

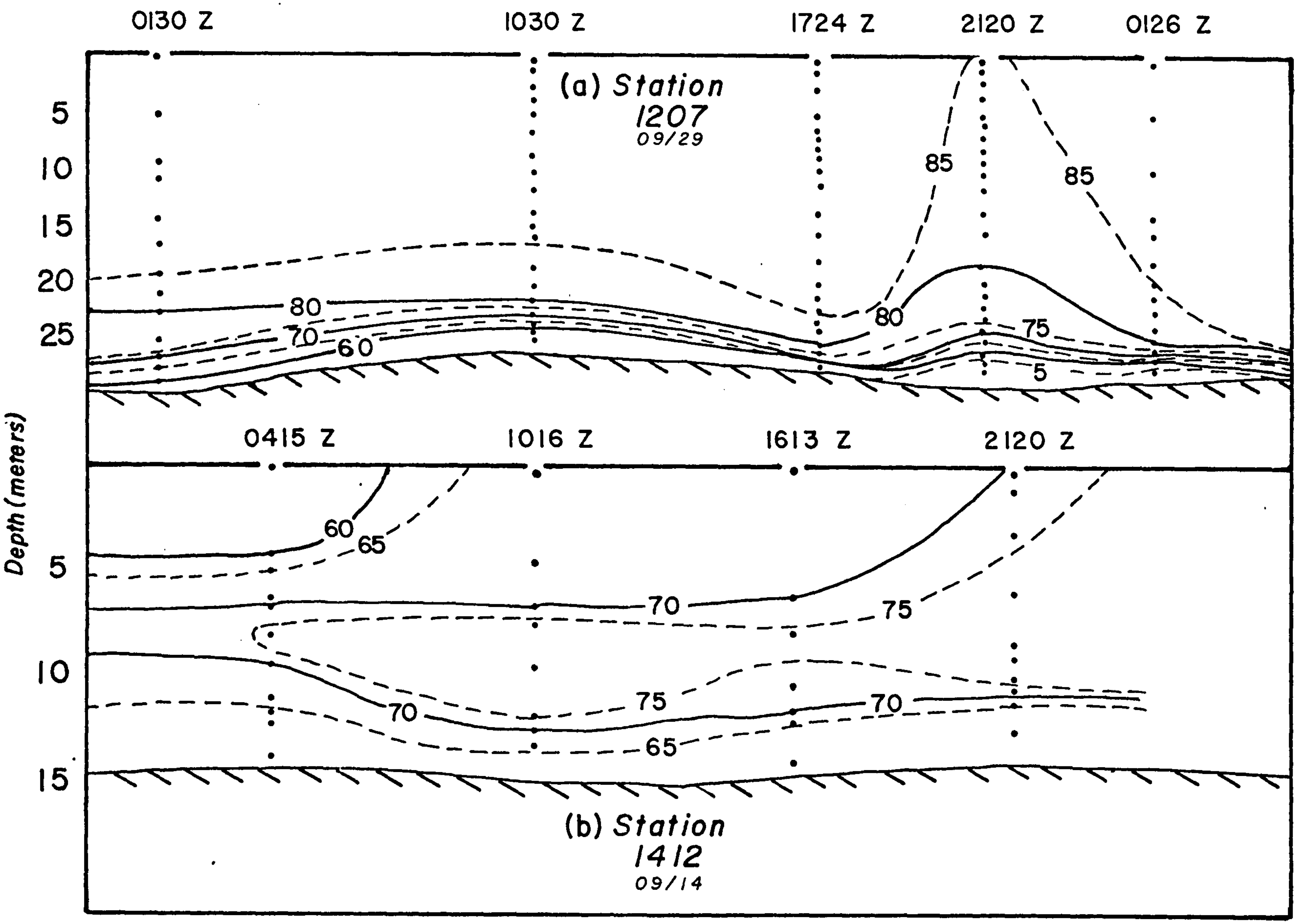


Figure 42. Transmissometer stations (24 hour). (a) station 1207, (b) station 1412.

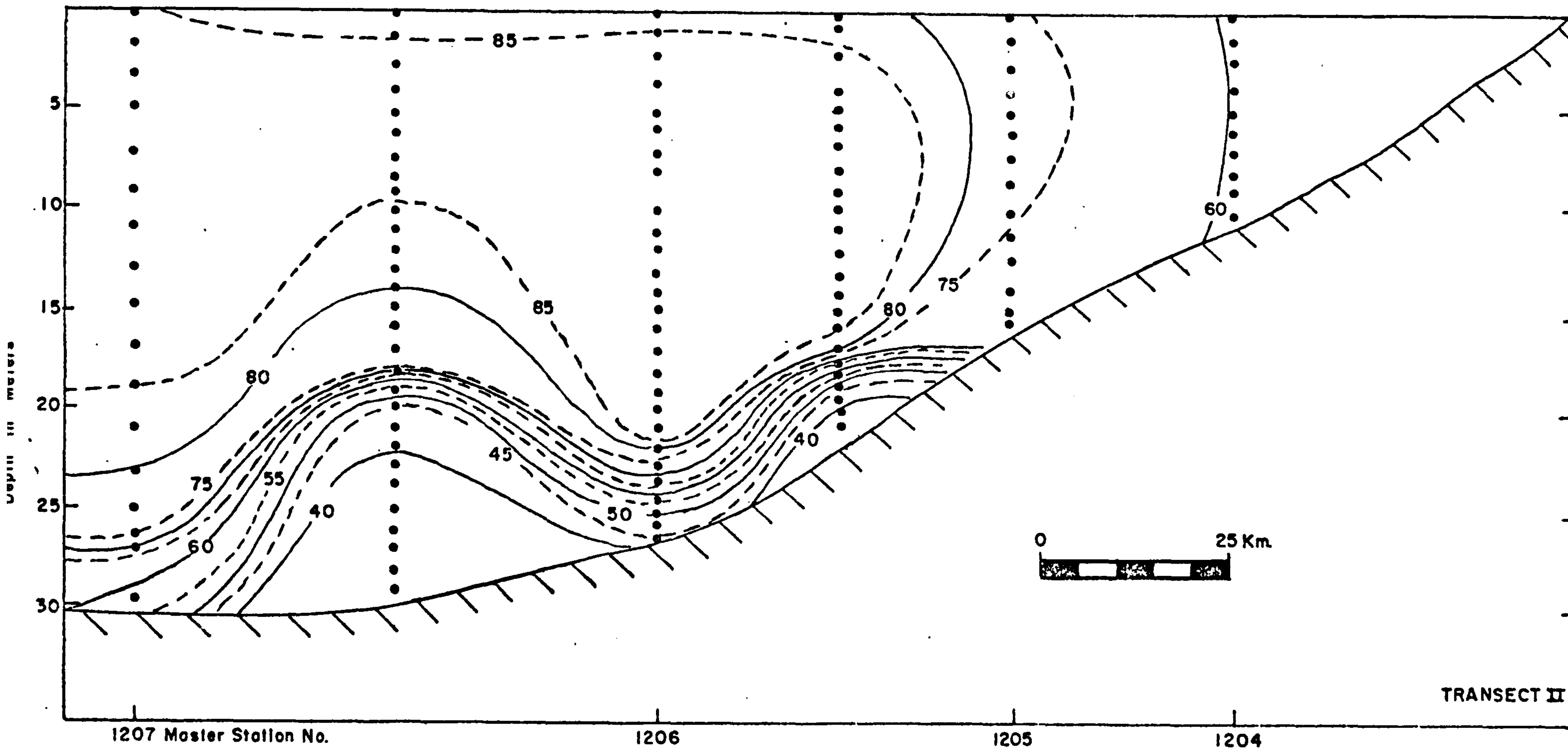


Figure 43. Vertical Distribution Transmission (%) SEPTEMBER 26-27, 1975

Transect II represents data after ELOISE. These figures support the STD data and show the presence of an oscillation pattern along with a strong temperature gradient structure with a thickness of 5-6 m.

In the deep basin area, pre-hurricane data at Buoy EB-10 indicate that the thermocline depth was above 50 m (sensors at 2 and 50 m). Data from DELTA NORTE (Figure 37) suggests a thermocline depth of 35-40 m near Buoy EB-04. Hurricane ELOISE Flight 750922A data to the north through the eye (Figure 44) and to the south measured the thermocline depths of 25-30 m when the winds were between gale to hurricane force. Data from the SEA LAND VENTURE taken between Buoys EB-10 and EB-04 six days after the hurricane had a depth of 43-44 m.

With this limited amount of data it is difficult to determine the effects on the thermocline depth in the deep basin by the hurricane. However, the 50 m data from EB-10 suggests the depth was very near 45-50 m. The rationale for this is the oscillation patterns observed after the hurricane along with their temperature values. Before discussing this, it is important to examine the 50 m data record not only because of its location relative to the thermocline depth but since it is assumed that the temperature changes and temperature hourly and three-hourly rates should have occurred along Transect III and the outer station on Transect IV.

For approximately 61 hours before the passage of the eye, these temperature records indicate a semi-diurnal oscillation pattern with an increase in temperature up to the arrival of the eye itself. The temperature increased from 25.37° to 27.47°C, or 2.10°C. The maximum hourly increase, based on direct measurements was 0.53°C, and the maximum three-hourly was 0.59°C. Based on the circulation around ELOISE this increase is associated with the transport of warm water from the east. The water can be seen in Figure 44 on the two AXBT sections across the eye taken between Buoys EB-10 and EB-04 on September 22, 1975, at 27°15'N.

With the arrival of the eye, a rapid decrease occurred in 14 hours with the temperatures dropping from 27.43°C to 22.69°C, or 4.74°C with an average hourly decrease of 0.34°C. The maximum observed hourly decrease was 0.89°C, and the three-hourly decrease was 2.68°C. At the completion of this spectacular drop, a 26 to 27 hour oscillation was observed superimposed on a seven-day long-term oscillation pattern. The amplitude of these 26 to 27 hour oscillations started with a value of 3.69°C and steadily decreased over the next 80 hours until it settled into a pattern ranging from 0.4° to 0.75°C on the 27th. Within 14 days the temperature had settled down until the oscillation amplitudes were very similar to those recorded at the surface before the hurricane. The period was still 26-27 hours.

Starting on the 26th of September these combined oscillation patterns ranged between 25 to 27°C. These are the values associated with the temperature gradient located below the thermocline (Figures 41H, 23, and 25) on Transects II and I after the hurricane. The SEA LAND VENTURE recorded 35 nautical miles (64.8 km) flat dome structure with temperature $\geq$ 25° at 45 m (Figure 38). It is assumed, therefore, that the thermocline depth was at 45-50 meters at Buoy EB-10 with an oscillation amplitude of 5-6 m. Because of the track of ELOISE, a similar situation must have occurred on Transect III (It might have been greater because of strong winds.).

The patterns at 200 m at Buoy EB-10 (Figure 30) were similar to those at 50 m except for two differences. When the northern edge of the eye passed,

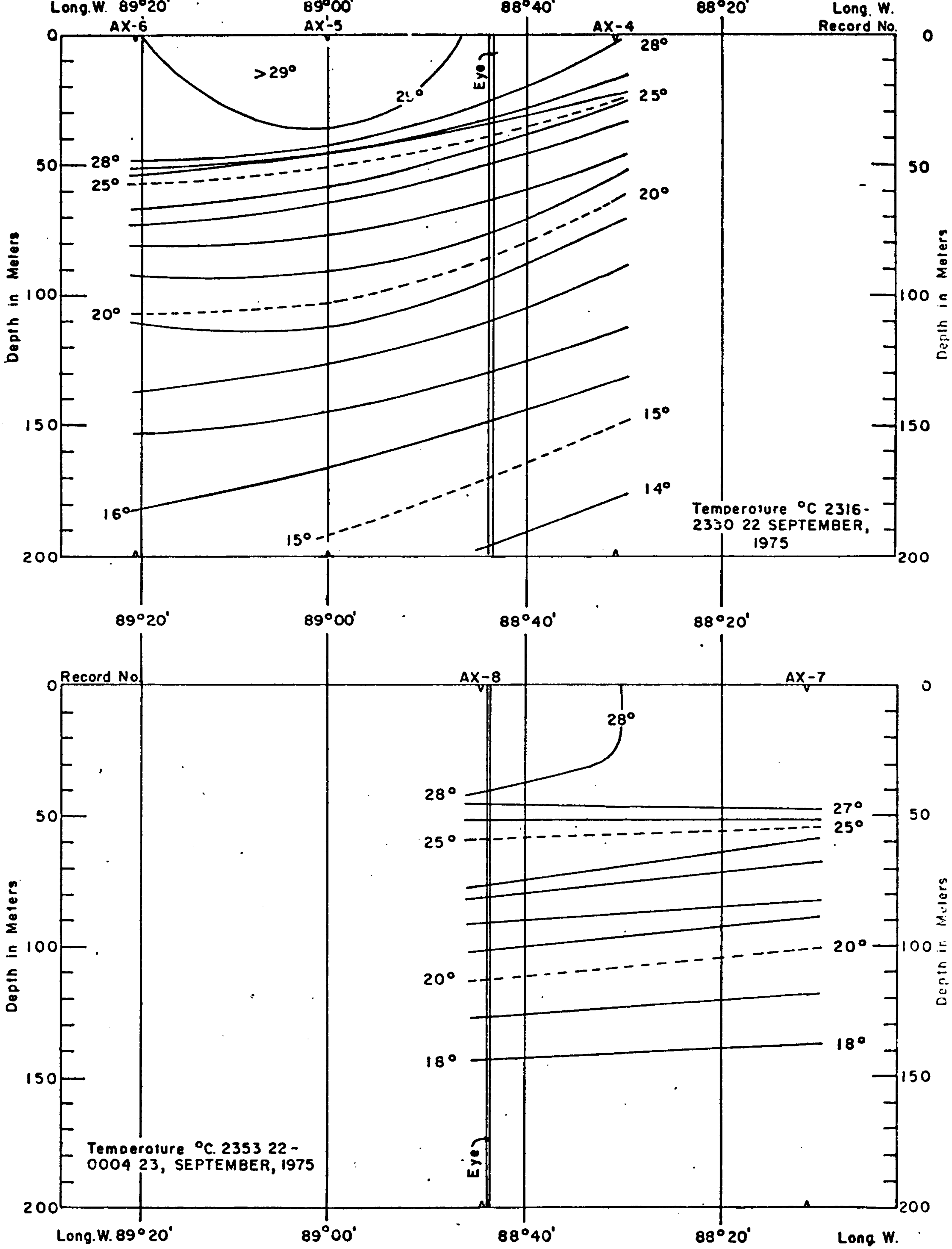


Figure 44. Vertical Distribution Temperature °C. from AXBT taken on Hurricane "ELOISE" Flight 750922A along 27°15'N through hurricane eye

the temperature decreased from 16.79° to 16.14°, or 0.64°C, and when the southern edge passed, the temperature increased from 16.14° to 17.16°, or 1.02°C. The very large oscillation amplitude started six days after the passage of the eye running until the twelfth day (maximum value 2.68°C (16.46-13.78)). The increase in temperature before the eye was 0.58. After the eye, the decrease was 17.16 to 15.03°C, or 2.13°C. This decrease returned the temperature to pre-hurricane values. Both the 26-27 hour and seven-day oscillation patterns were then present; however, unlike the 50-meter values, the temperature became cooler reaching its lowest value nine days after the hurricane (13.78°C) before it returned to pre-hurricane condition. The maximum hourly change was 1.5°C, and the maximum three-hourly change was 2.2°C.

The buoy data shows that over a period of 21 days the temperature changes associated with the hurricane were between 3.0 and 4.74°C with the maximum change occurring at 50 m. The maximum hourly change was from 0.4 to 1.5°C with the maximum at 200 m, and the maximum three-hourly change was 1.0 to 2.7° with the maximum at 50 m. The temperature in the water column ranged from 29.6 to 13.8°C. Because of the hurricane and Loop Current present, these temperatures might have appeared on the shelf.

The variation in temperature and salinity observed in historical long-term monthly studies along Transect III in September and October is shown in Table XI; the ranges of temperatures recorded at Buoy EB-10 were within those recorded in the historical past. However, the temperature gradients within short time periods (24 hours) do not approach those seen at the buoy. If one assumes that the 24-hour historical gradient could be representative of hourly changes, they were only 80% of those recorded at EB-10 and for three-hourly gradients, they were only 50%.

Table XI. Historical variations in temperature/salinity along Transect III.

JUNE		1964				1965				BLM 1975				
Station No.		Temp. Range	Salinity Range	Temp. 24H	Sal. 24H	Temp. Range	Salinity Range	Temp. 24H	Sal. 24H	Temp.	Sal.	Temp. 24H	Sal. 24H	Sta. No.
II	S	30.0-27.5=2.5	34.95-31.08=3.87	1.3	1.39	28.6-26.0=2.6	34.11-28.31=5.80	1.3	1.46	27.74	31.64			1308
	B	28.5-23.2=5.3	34.99-32.97=2.02	1.8	1.30	27.0-22.6=4.4	35.34-33.99=1.39	2.0	1.72	21.34	36.12			
I	S	30.3-28.2=2.1	33.49-29.47=4.02	1.1	1.75	27.6-26.4=1.2	35.22-32.66=2.56	1.2	0.96					
	B	26.4-22.6=3.8	35.35-34.27=1.08	3.2	0.89	26.8-21.1=5.7	35.70-34.90=0.80	1.3	0.96					
D-2	S	29.3-20.3=9.0	35.71-33.64=2.07			27.2-26.3=0.9				28.59	31.93			1309
	B					21.4-19.1=2.3				20.00	36.29			
D-5	S									28.65	31.52			1310
	B									16.50	36.20			
IV	S					27.0-26.7=0.3	36.34-30.67=5.67			28.15	32.56			1311
	B					13.5-12.2=1.3	35.68-35.53=0.15			13.80	35.81			

SEPT.		1964				1965				BLM 1975				
Station No.		Temp. Range	Salinity Range	Temp. 24H	Sal. 24H	Temp. Range	Salinity Rante	Temp. 24H	Sal. 24H	Temp.	Sal.	Temp. 24H	Sal. 24H	Sta. No.
II	S	29.7-21.8=7.8	34.76-31.15=3.64	0.2	0.20	28.1-28.0=0.1	33.39-32.82=0.57			28.2	31.686			1308
	B	26.9-21.6=5.3	36.24-33.62=2.62	0.1	0.29	27.4-27.3=0.1	34.87-34.51=0.36			23.3	35.92			
I	S	31.4-22.4=9.0	35.25-30.10=5.15	1.1	1.30	28.2-26.4=1.8	35.22-32.60=3.62	0.8	1.31					
	B	25.2-20.6=4.6	36.62-36.26=0.36	1.0	0.36	27.7-25.5=2.2	35.70-34.26=1.44	0.7	0.36					
D-2	S	29.9-23.9=6.0	35.82-32.00=3.82			28.0-27.5=0.5	35.53-34.70=0.83			28.91-28.86	33.76-33.76	0.05	0.00	1309
	B	23.7-19.6=4.1	36.55-35.50=1.05			26.6-22.1=4.5	36.23-35.69=0.54			23.40-23.13	36.19-36.18	0.27	0.01	
D-5	S									29.10	35.31			1310
	B									19.35	36.53			
IV	S					28.6-27.8=0.8	36.36-34.85=1.51	0.6	0.11	28.93	34.63			1311
	B					13.7-12.1=1.6	36.09-35.41=0.68	1.2	0.11					

S = Surface
B = Bottom

It would appear that the effect in the temperature field by Hurricane ELOISE was unique only in the short time changes. The question posed to the BLM and the interdisciplinary scientists in MAFLA is "Do unusual large short time temperature gradients affect the environmental study?" Within past studies in Florida it has been shown that organisms have upper and lower temperature tolerance levels. At these levels a very small change in temperature can result in "fates and effects catastrophy." Is this true for larger rapid temperature changes?

In September of 1965 the Loop Current was present in the eastern Gulf of Mexico (Leipper et al, 1972). The main flow of the current was in the location very nearly as shown in Figure 21 (October, 1975). A detached eddy was located north of the main flow between 25 - 27°N and 86° - 88°W. Hurricane BETSY (September 8, 1965) moved across this eddy. Four days after her passage this eddy had split into two smaller eddies. One location was 100 km south and the other, 140 km north-northeast of the original location. The calculated average volume of transport was reduced from 40 million M^3/sec to 19 million M^3/sec and the average geostrophic velocity from 113 cm/sec to 73 cm/sec.

As has been stated above, Loop Current eddy water appeared on Transect III (Figure 18) but not on Transect IV (Figure 16) in 1975. If this had been a single Loop Current eddy and it had been split by Hurricane ELOISE, as occurred in 1965, two eddies would be present as illustrated in Figure 21. The distance between their centers is similar to those observed in 1965. This could explain the lack of evidence of an eddy in the temperature field in Figure 37 and in the salinity field on Transect IV, but it is present in the temperature field in Figure 38.

It can also be assumed that transport off the shelf was slowed down and moved to the east and south between Transects III and II in the eastern eddy. The western eddy would have increased volume transport. The combined hurricane-Loop Current eddy effects on the shelf circulation would have caused upwelling on Transect IV, DeSoto Canyon, and on the outer part of Transect I and the transportation of material to the east and south between Transects III and II and off the shelf near Transect I. Within the hurricane wind extent area upwelling processes, which occur in hurricanes, would have taken place; however, their effects on the temperature field would not be great because of the immature and very rapid movement of Hurricane ELOISE. This is evident in the small increase in the thermocline depths. Although nutrients were not measured in the BLM study, upwelling would result in an increase in their values. Enrichment should cause unusual biological activities, which have been noted in ATP and live foramnifera (LaRock and Bock, personal communication).

The salinity data from the buoys, unlike the temperatures, have different features at the surface. The pre-hurricane environment at Buoy EB-04 shows a random type of oscillation pattern unlike the semi-diurnal experienced at Buoy EB-10. At EB-04 these values ranged from 33.59 to 32.98 °/oo, or 0.62 °/oo, compared to 36.47 to 36.07*, or 0.40 °/oo. The salinity value of approximately 33 °/oo at EB-04 is approximately 0.7 °/oo lower than that recorded for the DELTA NORTE (Figure 37). The value recorded at EB-10 is within ± 0.1 °/oo of the eastern Gulf of Mexico water (36.4 °/oo). At neither of the buoys, except for random values, there was no marked increase or decrease in the salinity values until the arrival of the hurricane.

* This is based one one value. If dropped, it would be 0.22 °/oo.

At Buoy EB-04 a rapid increase occurred starting three hours before the arrival of the hurricane and ending 24 hours after its passage. During this period of time the salinity values increased from 32.83 to 35.92, or 3.09 °/oo. The values after the passage of the hurricane at Buoy EB-04 were approximately 0.6 °/oo lower than that recorded by SEA LAND VENTURE (See Figure 38).

After the passage of the hurricane by both buoys 26 to 27 hour oscillation patterns were observed which seemed to be superimposed on a 7-day pattern similar to those observed in the temperature field. In the case of EB-04 the salinity values slowly decreased reaching an average value of 35.2 °/oo. The 26-27 hour oscillation amplitude was 0.70 °/oo. At Buoy EB-10, except for one or two unusual values, the salinty ranged between 36.4 and 36.7, or 0.3 °/oo. These values, if they are real, would indicate Loop Current water moving back and forth across the buoy location. This would require the location of the main flow of the Loop Current beginning 250 nautical miles (463.3 km) northwest of its location in Figure 21.

Because of the importance of the presence of Loop Current water, it seems appropriate at this time to review not only the estimated accuracy of the sensors but their operational history. According to the "Data Report on Buoy Observations" during Hurricane ELOISE (Data Report, 1975), the accuracy estimates of the environmental measurements for salinity were 0.2 °/oo. Obviously the relative amplitudes of the fluctuation of salinity values (0.70 °/oo) as observed on the data record during the two oscillation patterns can be considered as real. However, the identification of the water masses, particularly in regard to eastern Gulf of Mexico (36.4) and Loop Current

(36.7) water, would require calibration by in situ methods near the buoy which did not occur according to the report. To quote the report "The only "in situ" reference checks have been from Nansen salinity-temperature-depth (STD) casts taken in the proximity of EB-04 and EB-10." These appear to be the data from DELTA NORTE and SEA LAND VENTURE. Because of the importance of Loop Current water, the investigator took the opportunity to talk with Dr. E. G. Kerut of the NOAA Data Buoy Office at the STD conference on January 21, 1977, and discussed the sensors at EB-10 and EB-04. He was advised that this particular sensor system was used only once and that was during the engineering tests on EB-04 and EB-10 which occurred during ELOISE. The general impression was that the salinity collection system had inherent instrument problems, which precluded its use for either technical considerations or the lack of accuracy.

Under these conditions, no conclusions will be drawn as to whether Loop Current water was present at Buoy EB-10. Based on the location of the main flow of the Loop Current (Figure 21) and the above discussion as to what might have happened to the detached Loop Current eddy system, it is not believed that Loop Current water was present at Buoy EB-10 after the hurricane.

Increases in salinity at EB-10 after the hurricane probably resulted from the transport of higher salinity water from the eastern Gulf of Mexico due to the circulation pattern of the hurricane. The slight increase in salinity noted at EB-10 after the passage of the eye is probably a reflection of the lack of rainfall associated with the hurricane as it fed into the stationary front between EB-04 and EB-10 and the bringing up of higher salinity values in the surface layers by the wind stressing. If the data from Buoy EB-10 were looked upon as an indication of the general salinity situation in the northern part of the eastern basin or near the shelf, there should have been little or no change in the salinity values on Transects III, II, and I. Because of the action of the Loop Current eddies and hurricane circulations, the changes in the salinity of Transect IV, however, could have resulted in decreased salinity due to the transport of low salinity water from the inshore areas of the shelf and because of the larger rainfall amounts in the northwest and southwest quadrants of the hurricane compared to the northeast and southeast quadrants. What the surface salinity values would have been has not been estimated because of the lack of good rainfall distribution pattern data around the hurricane.

If the pre/post hurricane stations on Transect II are examined at Master Stations 1204 and 1205 (Figure 39), it can be seen that a tongue of high salinity water existing along the bottom was eroded away by the mixing action of the hurricane. If the salinity values from these stations are digitized at every meter from the STD traces and averaged, the values before and after the hurricane differ at Station 1204 by 0.08 °/oo and at Station 1205 by 0.15 °/oo. The normal tidal oscillation values from those stations and as experienced on Master Station 1412 on Transect IV (Figure 41B) indicate that these fluctuations are within the range of natural phenomena. For this reason it is felt that the hurricane at least on Transects III, II, and I did not change the average salinity values throughout the mixed layer because of the lack of rainfall influence caused by the abnormal meteorological conditions during the hurricane's passage across the shelf.

Based on the analysis of the 50-meter temperature data at Buoy EB-10, the salinity sensor should have observed a salinity time distribution pattern very similar to the temperature field. In the temperature field, the level was below the thermocline depth in an area of large negative temperature gradients. The salinity time distribution, therefore, should have had similar gradient distribution patterns as observed in temperature except for a reversal in the gradients as the salinity built toward the subsurface salinity maximum (SUSIO, 1975, p. 17). If this occurred, it would have been another indication that the 50-meter sensor was located just below the thermocline.

The observed values (Figure 35) had an overall similarity in their oscillation patterns to the temperature values after the passage of the hurricane eye. Before this the salinity had a gradual increase of 0.11 °/oo, which was associated with the transport of high salinity water from the south. Starting three hours before the arrival of the eye and until the passage of its northern edge, salinity values decreased by o.30 °/oo. An increase was then recorded until the passage of the southern edge of the eye of 0.41 °/oo. This was followed by the normal structure of 26-27 hour oscillations superimposed on a 7-day pattern.

The maximum oscillation amplitude of 0.47 °/oo and the maximum one hour (0.08 °/oo) and three-hour (0.24 °/oo) gradients were recorded in the salinity field three days after ELOISE. By the start of the fourth day after the hurricane, the oscillation amplitudes decreased to between 0.01 and 0.44 °/oo. The average was 0.20 °/oo.

The 200 m salinity sensor mirrored the temperature field. Since this sensor was below the subsurface salinity maximum, the oscillation patterns between temperature and salinity were in phase. The increase in salinity before the passage of the northern edge of the eye was 0.31 $^{o}/oo$. The drop in the eye was 0.10 $^{o}/oo$. The increase in the southern edge of the eye was 0.16 $^{o}/oo$. The maximum oscillation amplitude was 0.47 $^{o}/oo$, and the maximum one hour (0.08 $^{o}/oo$) and three-hour (0.24 $^{o}/oo$) gradients were recorded in the salinity field nine days after the passage of ELOISE. By the 14th day the oscillation amplitudes were an average of 0.15 $^{o}/oo$.

If these changes are representative of the hurricane effects on the shelf, according to the data from Table XI, they are much smaller than changes that result from the normal force mechanisms (i.e., run-off, Loop Current, etc). Even the maximum one hour and three-hourly gradients are within the normal tidal variations seen at the master stations.

A discussion of the horizontal distribution of salinity as an indication of transport, however, would seem appropriate since there is little evidence that the salinity values were markedly influenced on Transects II and I by ELOISE. The uniform temperature regime in September and the major constant decrease in temperature caused by ELOISE prevents this parameter use in discussion of transport. The user should take care in applying the conclusions to the data collected on Transects IV and III after ELOISE because of the uncertainty of the effects of the possible relocation of the Loop Current eddy water and the surface wind stressing in the area of Transect IV. The horizontal charts for salinity are shown in in Appendix III (Figures 1 through 3).

The surface and ten-meter charts show a flow of water onto the shelf in the vicinity of Transect III influenced by the presence of Loop Current eddy waters and its exit off the shelf near Transect II. The circulation pattern would support the existence of a single Loop Current eddy before the arrival of ELOISE. There is no indication of the transport of Mississippi River System water (WEST) to the east and south as observed in the summer months.

After the hurricane, the discharge off the shelf near Transect II and Transect I must have been much slower (Leipper, et al, 1972) because of the adverse effects of the cyclonic wind-induced surface/mixed layer currents on the anticyclonic Loop Current eddy circulation. The maximum salinity values for the Loop Current water on Transect III (before) and Transect I (after) ELOISE were 36.67 and 36.65 °/oo. These are within the accuracy of the method and lend themselves to the single pre and dual post hurricane Loop Current eddy system.

The trace metal data were independently contoured and then superimposed on the surface and 10-meter salinity charts. These are in good agreement for refractory lead and chromium.

The bottom salinity distribution, on the other hand, in general follows the bottom isopleths.

After the passage of ELOISE, the time series studies at Master Station 1207 (Figure 41I and 42) and data on Transect II (Figures 22 and 43) indicate the presence of major oscillation patterns along the bottom and in the nepheloid layer. Whether these are tidal or 26-27 hour patterns cannot be determined by the data record. It is assumed they are 26-27 hour patterns and associated with ELOISE (Figures 33, 34, 35, and 36).

In the salinity field during the time series study (Figure 41I) 36.4 ‰ (eastern Gulf of Mexico water) and a pocket of bottom >36.2 ‰ (outer shelf) water (Figure 22) were present as a 6-8 meter layer at the bottom. The time series Master Station 1207 was on Transect II. The method of constructing the transect section (See p. vii) does not result in the 36.4 ‰ water appearing in Figure 22. The 36.4 ‰ water was actually present in the bottom pocket lens. In the time series data (Figure 41I) the 36.4 ‰ water appeared in an oscillation mode and on Transect II as a shelf "ring type" feature (SUSIO, 1972). This could have resulted from the transport of water by internal waves generated by ELOISE or by a bottom current along the isopleths.

The STD lowering (taken within two to three meters of the bottom) on Master Station 1207 (area of the 36.4 ‰ water) had large abnormalities in the lower 3-5 meters of the salinity trace. This feature can be caused either by the instrument hitting the bottom or unusual amounts of particulate as well as biological matter in the water column (experienced by the investigator in studies of the Amazon River discharge area). As the STD had not struck the bottom, the STD calibration salinity samples were filtered, in a closed system, through micropore filter pads before determining the salinity values. These pads were then analyzed. The pads from samples taken at Record Nos. S-34, S-35, and S-36 (Figure 41I) where 36.4 ‰ was present contained clay mineralogy matter. After these lowerings, the pad did not contain any clay mineralogical matter, but cursory examination of the salinity samples indicated that the suspended material was Diatoms. The composition of the clay mineralogy matter indicated that it had been transported from Transect III since this type of material was not present on Transect II or south of it. Based on the surface/mixed layer circulation system (Appendix III, Figures 1 and 2), the depth and oscillation amplitude of this strong temperature gradient field, the influence of the Loop Current eddies and the effects of ELOISE it would appear that a bottom circulation system with a thickness of 5-6 meters was flowing from Transect III east and south through Transect II and discharging off the shelf near Transect I in the form of a ring of water. This water was not only transporting bottom material but was causing enrichment and increased biological activity.

Based on the temperature and salinity changes that might have occurred on the shelf, it is not felt that a presentation of temperature-salinity (T-S) characteristics would be productive during the fall season because of the abnormal change in temperature before and after the passage of the hurricane.

WINTER SAMPLING
January 9-February 10, 1976
(32 days)

A total of 45 STD and 12 XBT lowerings were made during the winter sampling period. At each of the 15 master water column stations at least one STD lowering was made. In connection with the transmissometer time series program, six STD's on Master Station 1412 (the inshore station on Transect IV) and five STD's on Master Station 1207 (the outer edge of Transect II) were taken over a 24-hour period. In support of neuston studies, two STD's were taken on Master Station 1310, three on Master Station 1205, two on Master Station 1102, and two on Master Station 1101. The data from these programs can and will be used to determine short time variations in the environmental parameters of temperature, salinity, and sigma t.

Following the same grouping of transects as has been previously discussed, an examination of the vertical sections for temperature, salinity, and sigma t was made of Transects IV and III. The vertical salinity distribution for Transect IV is shown in Figure 45 and for Transect III in Figure 46. The temperature distribution is shown for Transect IV in Figure 47 and for Transect III in Figure 48.

On Transect IV the salinity Distribution (Figure 45) was dominated by an inshore low salinity isohaline layer rather than a pocket as in the summer and fall seasons and two shelf low salinity surface pockets. The isohaline salinity layer extended out thirty nautical miles (55.6 km) offshore. It had a minimum value of 31.83 $^{o}/oo$. A low surface salinity pocket

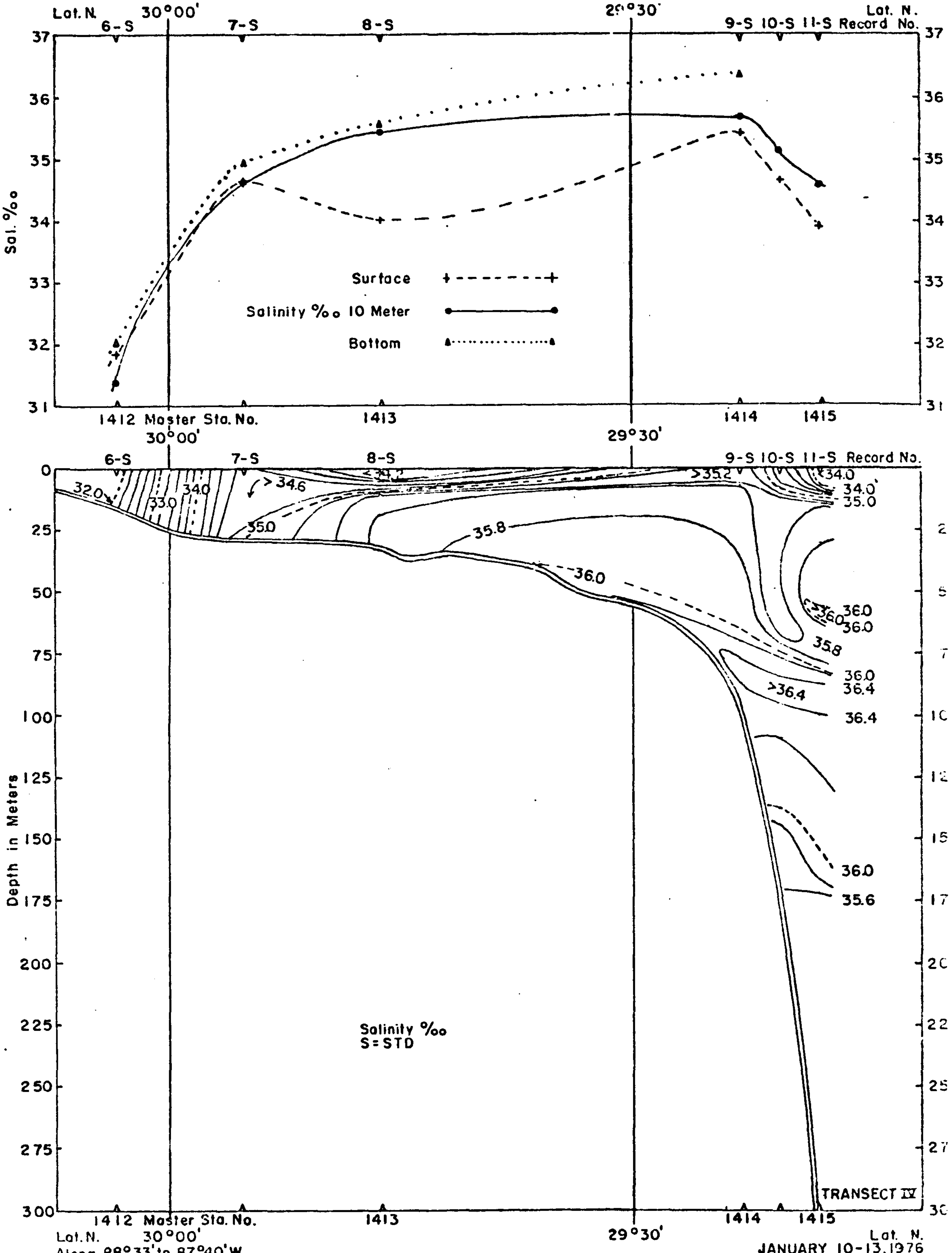


Figure 45 Vertical Distribution Salinity ‰ BLM-28

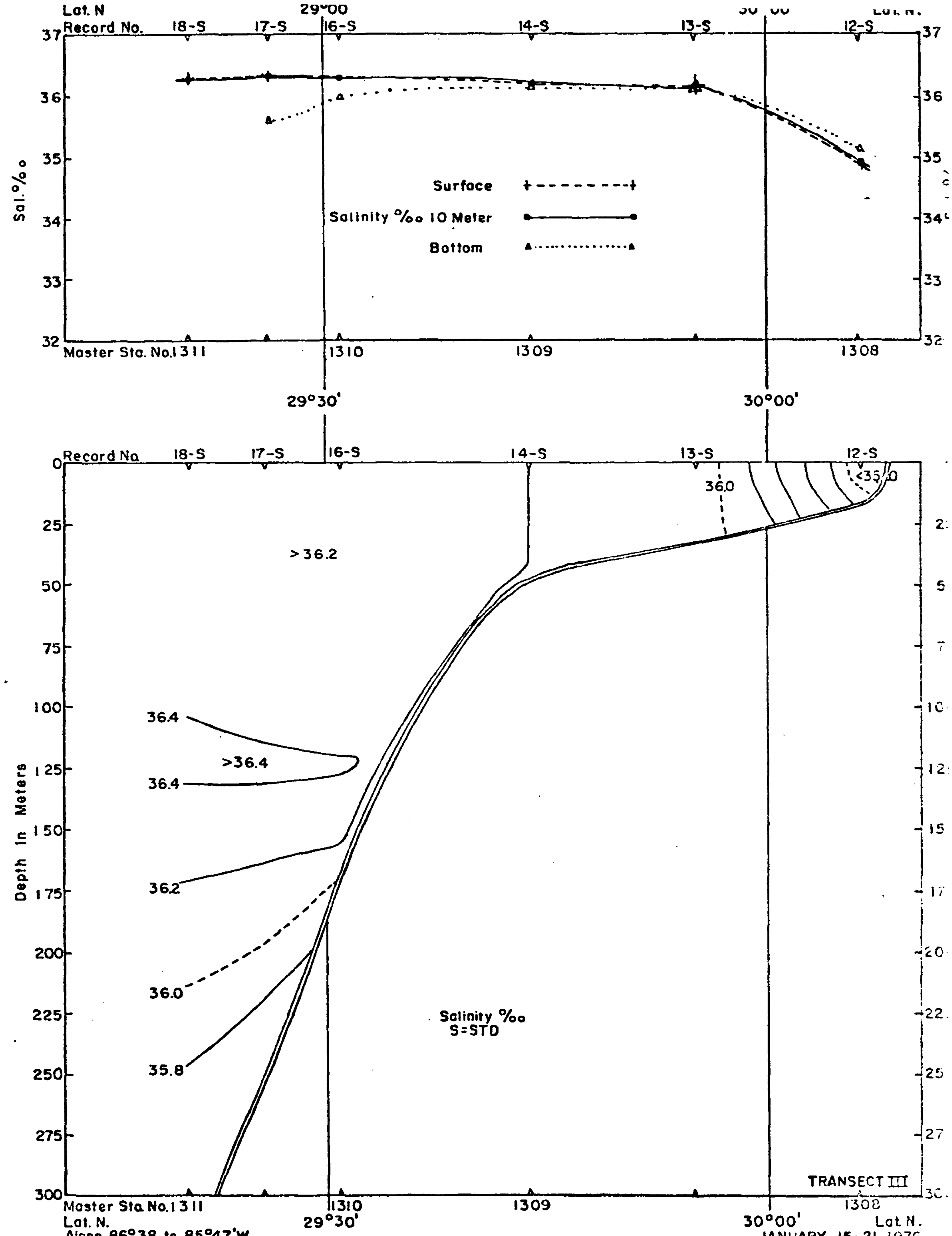


Figure 46 Vertical Distribution Salinity ‰ BLM-28

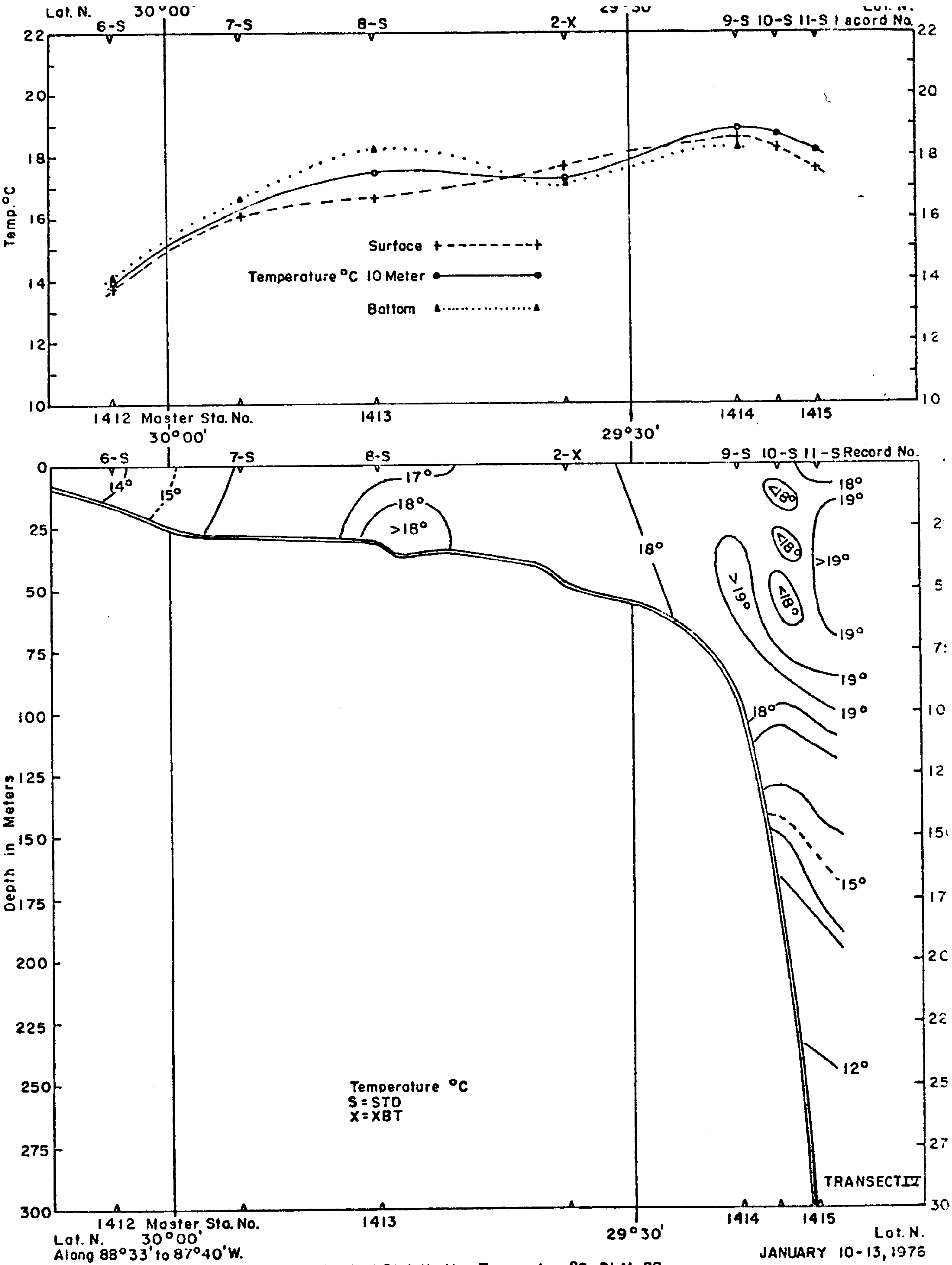
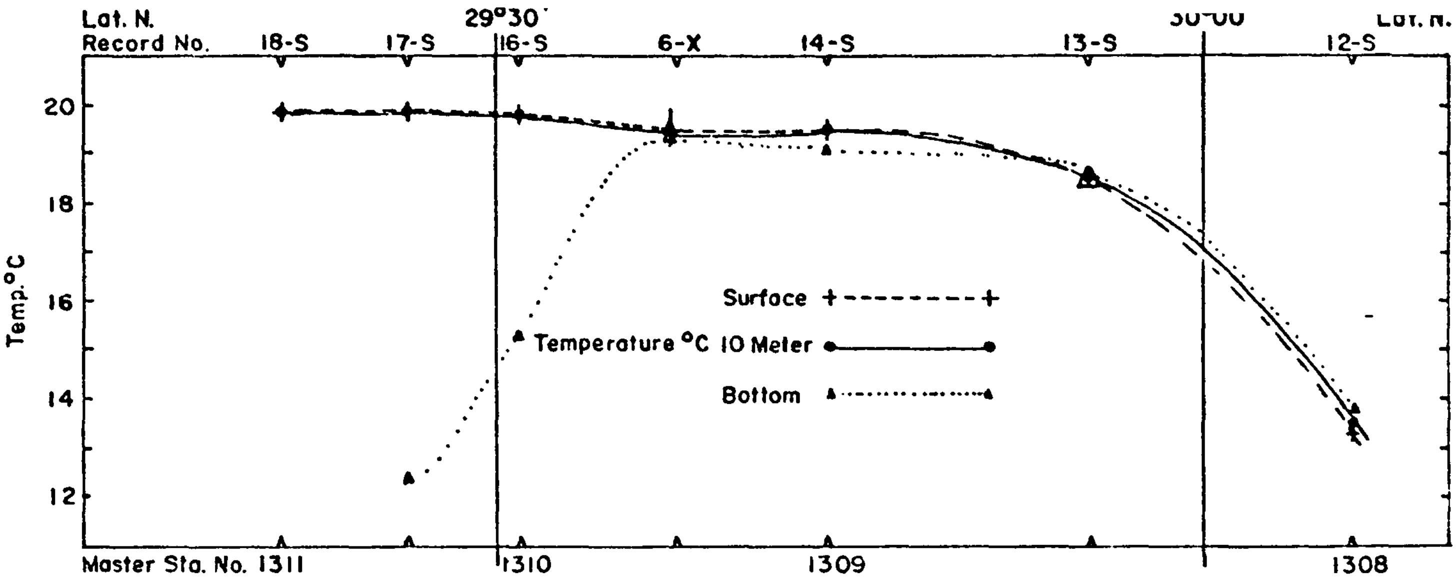


Figure 47. Vertical Distribution Temperature °C BLM-28



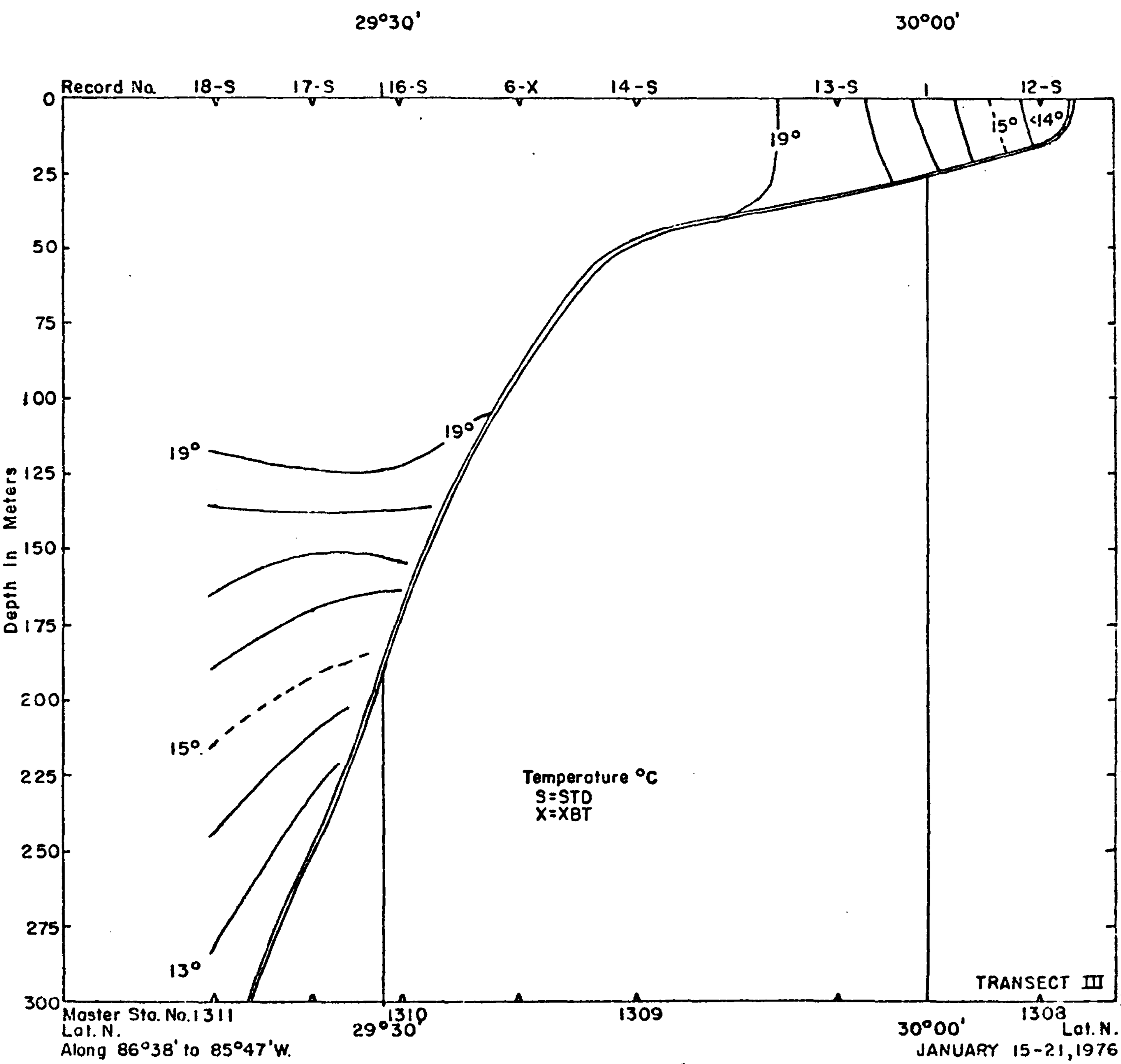


Figure 48. Vertical Distribution Temperature °C BLM-28

was located around Master Station 1413 within a minimum value of 34.01 $^o/oo$. The other pocket was located on the slope of the Continental Shelf at Master Station 1415 with a minimum value of 33.90 $^o/oo$. There was eastern Gulf water along the edge of the Continental Slope and apparently moving up onto the break of the slope itself at an approximate depth of 100 m. Unusual turbulence was exhibited at the slope of the Continental Shelf (Master Station 1415) as shown by microstructure eddy systems in the STD traces.

On Transect III (Figure 46) no low surface salinity pockets were present, and the salinity (34.88 to 36.2 $^o/oo$) was isohaline outward to Master Station 1309. In the summer and fall two surface salinity pockets were present.

At a depth of 100 to 125 m at the slope of the Continental Shelf a small tongue of eastern Gulf of Mexico water (36.4 $^o/oo$) appeared. This tongue was overlaid down to a depth of 100 m with outer shelf salinity waters (36.2 $^o/oo$).

The water was isohaline out to a depth of about 25 m on Transect IV and out to the break in the Continental Shelf on Transect III.

There was no Loop Current water present on either transect. The location of the Loop Current based on the 20^{o}C topography in February, 1976, (Figure 49) was south of 26^{o}N.

In general, the temperature distribution (Figures 47 and 48) shows a nearly isotherm structure across both sections. The thermocline reached a depth of 75 m (Transect IV) and 100 m (Transect III) at the outer edge of the shelf. On Transect IV at the Continental Slope area appears a shallow thermocline, which is probably associated with the cooling created by the

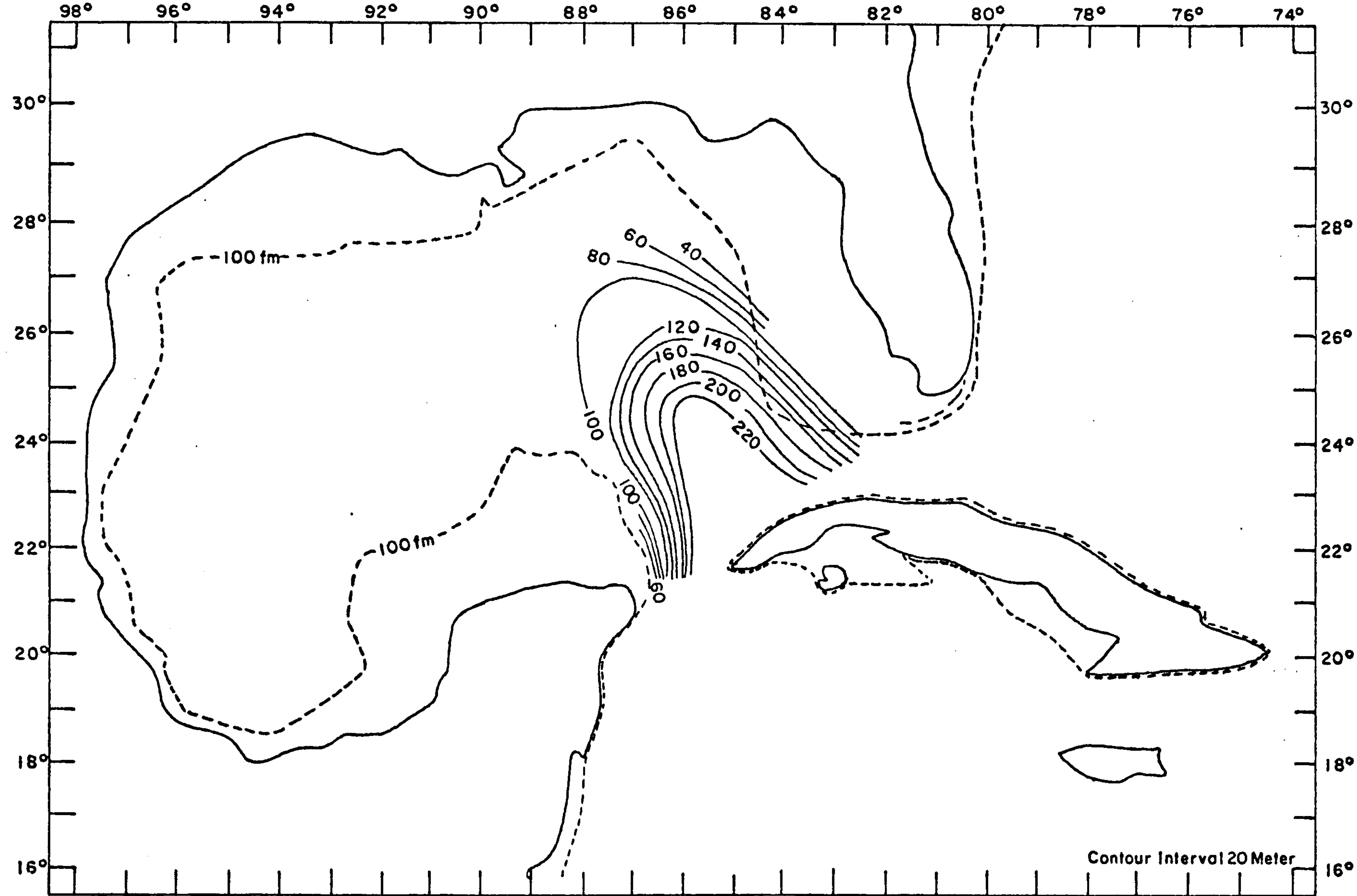


Figure 49. Depth of 20° C. Isotherm Levels in Eastern Gulf of Mexico During February, 1976 From XBT and STD Lowerings (From Molinari, 1976)

passage of a cold front on January 12-13, 1976 (Daily Synoptic Weather Charts). It's depth is approximately five meters.

The distribution of temperature as has been previously noted in the salinity distribution pattern had turbulence at the slope of the Continental Shelf on Transect IV (Figure 47). There was a low temperature nearly isothermal layer run-off distribution pattern inshore. A high temperature bottom feature was located at Master Station 1413 although there was no major change in the salinity values at that station.

Unlike the summer and fall seasons, there were no strong horizontal gradients present on Transect III. However, on Transect IV there was a weak salinity-sigma t gradient structure present below the low salinity surface pocket around Master Station 1413. This gradient was at a depth of approximately 12 m. Similar gradients were recorded during the summer and fall seasons.

The salinity values on Transects IV and III (Table II) at the surface were between 35.40 and 31.83 ^{o}/oo and 36.30 and 34.88 ^{o}/oo, respectively, with ranges of 3.57 and 1.42 ^{o}/oo with the largest range on Transect IV; at ten meters, 35.69 and 31.91 ^{o}/oo and 36.30 and 34.95 ^{o}/oo, respectively, with ranges of 3.78 and 1.35 ^{o}/oo with the largest range on Transect IV; and at the bottom, 36.38 and 32.08 ^{o}/oo and 36.29 and 36.12 ^{o}/oo, respectively, with ranges of 3.30 and 0.17 ^{o}/oo with the largest range on Transect IV.

The temperatures on Transects IV and III at the surface were between 18.62 and 13.73^{o}C and 19.84 and 13.24^{o}C, respectively, with ranges of 4.89 and 6.60^{o}C with the largest range occurring on Transect III; at ten meters, 18.90 and 13.93°C and 19.84 and 13.46°C, respectively, with ranges of 4.97 and 6.38°C with the largest range on Transect III; and at the bottom, 18.30 and 14.04°C and 19.09 and 12.44°C, respectively, with ranges of 4.26 and 6.65°C with the largest range on Transect III.

The vertical distribution for salinity and temperature are shown on Figure 50 and 51 for Transect II.

The salinity field was dominated by an isohaline low salinity inshore layer extending 24 nautical miles (44.5 km) offshore to an isohaline high salinity ridge of 35.60 °/oo. To the west of the ridge was a very narrow low salinity surface pocket between Master Stations 1205 and 1206 with a minimum value of 35.38 °/oo. A similar pocket was near the Florida Middle Grounds (between Master Stations 1206 and 1207) with a minimum value of 35.87 °/oo. These pockets extended downward to an approximate depth of 12 to 15 m, and their boundary gradients were weak.

In general, except for a ridge of high salinity located over Master Station 1205, the salinity values increased the farther one went offshore. The outer part of the transect (Master Station 1207) was covered with 36.2 °/oo outer shelf water. At no place on the transect was there any indication of eastern Gulf of Mexico water or Loop Current water.

The dominant feature on the distribution of temperature was that it was isothermal all the way across Transect II with increasing temperatures outward across the shelf. The temperature ranged from 11.97 to 17.68°C.

Associated with the low salinity surface pockets between Master Stations 1205 and 1206 and the Florida Middle Grounds appeared 0.2 to 0.3°C temperature inversions, which were associated with the interface between

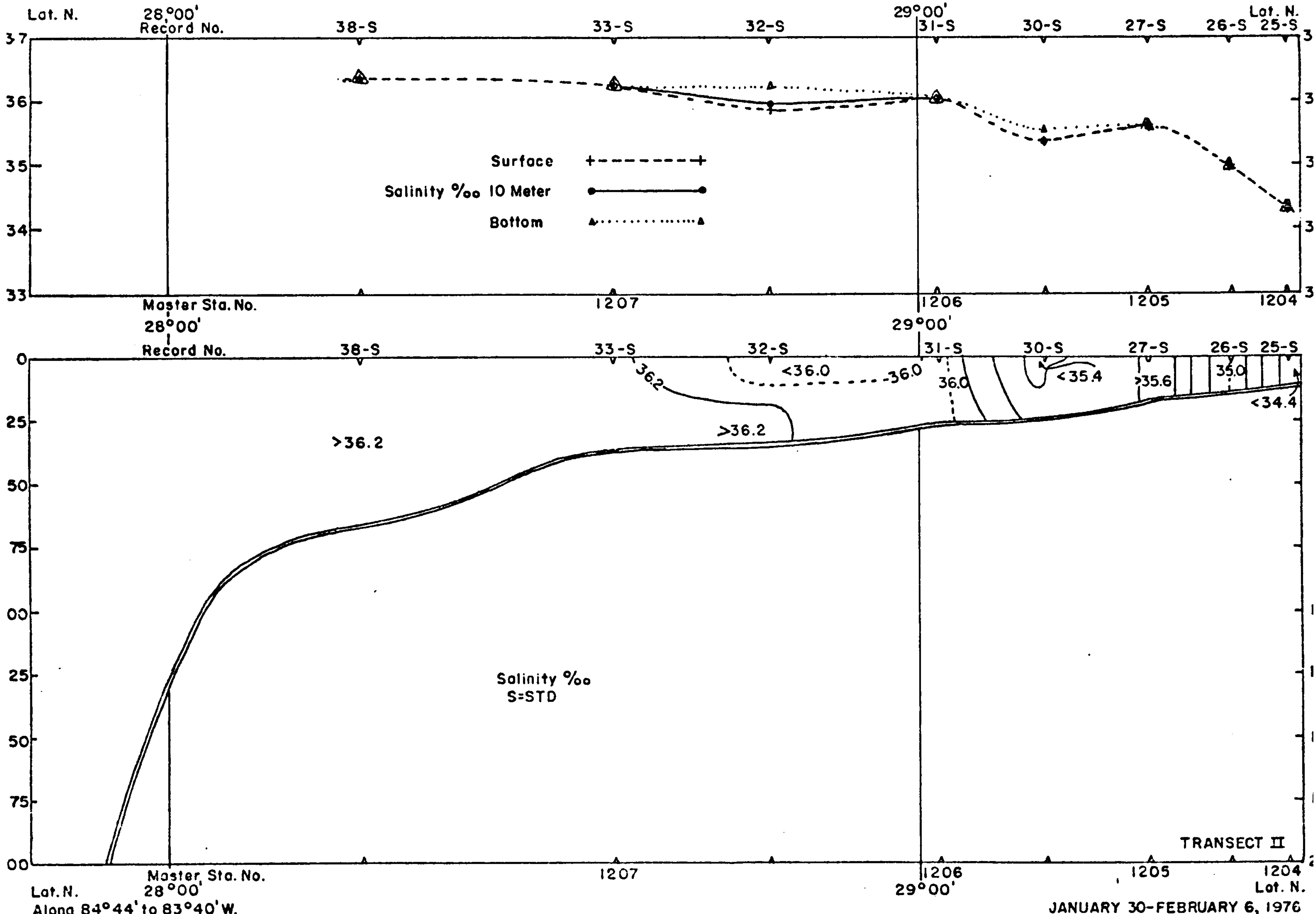


Figure 50. Vertical Distribution Salinity ‰ BLM-28

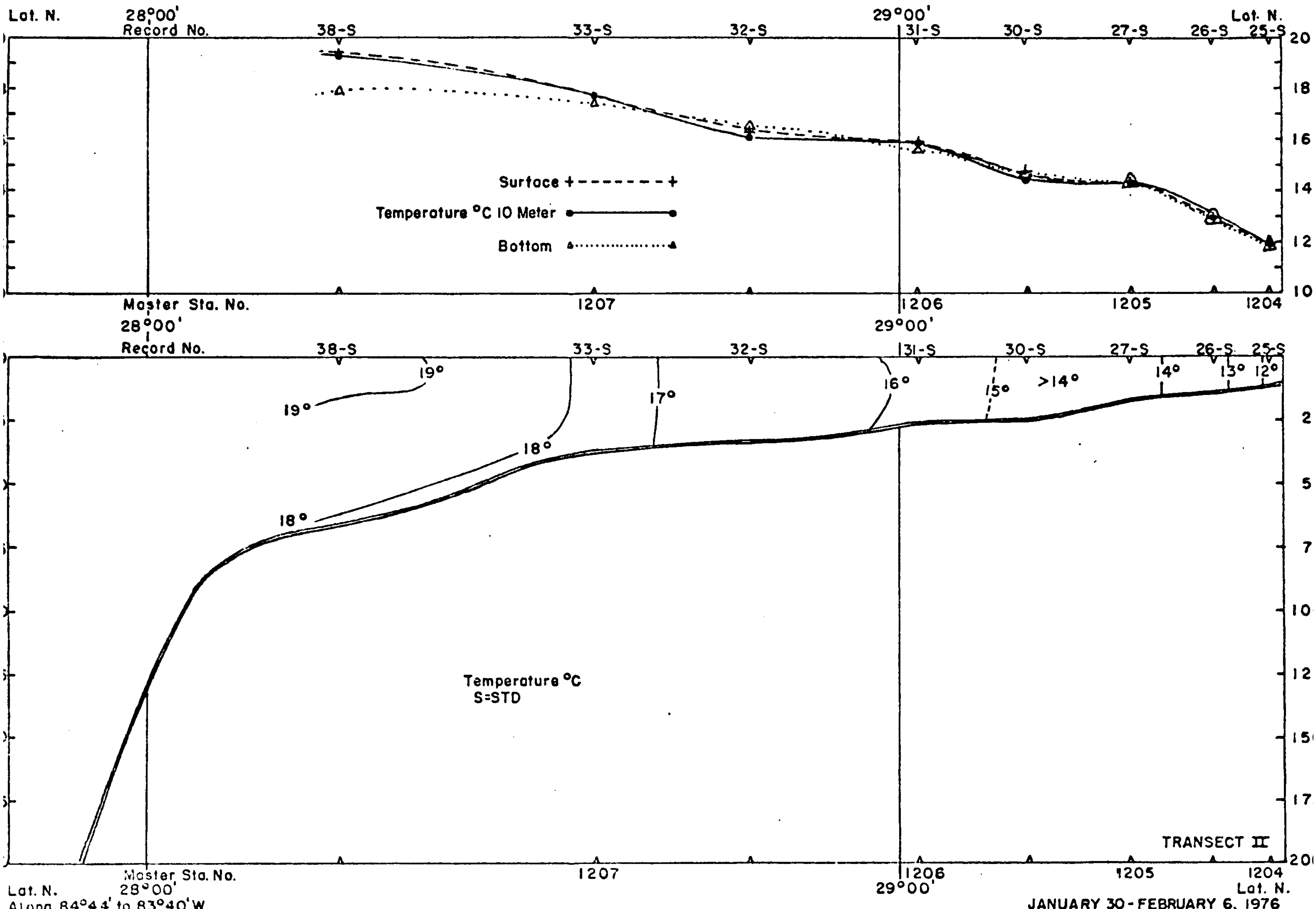


Figure 51. Vertical Distribution Temperature °C BLM-28

the low salinity surface pockets and the underlying shelf water. This resulted in two areas of shallow surface thermoclines, which reached to a maximum depth of approximately 10 m.

The salinity at the surface was between 36.24 and 34.30 ‰ with a range of 1.94 ‰; at ten meters, 36.27 and 34.31 ‰ with a range of 1.96 ‰; and at the bottom, 36.25 and 34.30 ‰ with a range of 1.95 ‰.

The temperature on Transect II at the surface was between 16.68 and 11.97 °C with a range of 5.71°C; at ten meters, 17.68 and 11.97‰ with a range of 5.71°C; and at the bottom, 17.53 and 11.97°C with a range of 5.56°C.

On Transect I the vertical distribution is shown for salinity in Figure 52 and temperature in Figure 53. Both of these fields were dominated by isohaline and isothermal structures out to approximately 84°00'N or to a depth of 50 m. In both cases the parameter values increased out to the edge of the Continental Shelf.

In the salinity distribution there was no indication of either eastern Gulf of Mexico water or Loop Current water. This agrees with Figure 49 where the location of Loop Current water can be seen entering onto the outer edge of the Continental Shelf at approximately 25°N or about 160 nautical miles (296.5 km) to the south of Transect I. There were no strong gradients in the salinity field. On the slope of the Continental Shelf and on the outer half of the shelf appeared outer shelf water (36.2 ‰), which extended downward to within five to ten meters of the bottom.

In the temperature distribution on the outer portions of the Continental Shelf appeared two low temperature pockets. These were a surface pocket to a depth of four meters and a bottom pocket from the bottom up to a depth of 16 m located between Master Stations 1103 and 1101. The range of temperatues

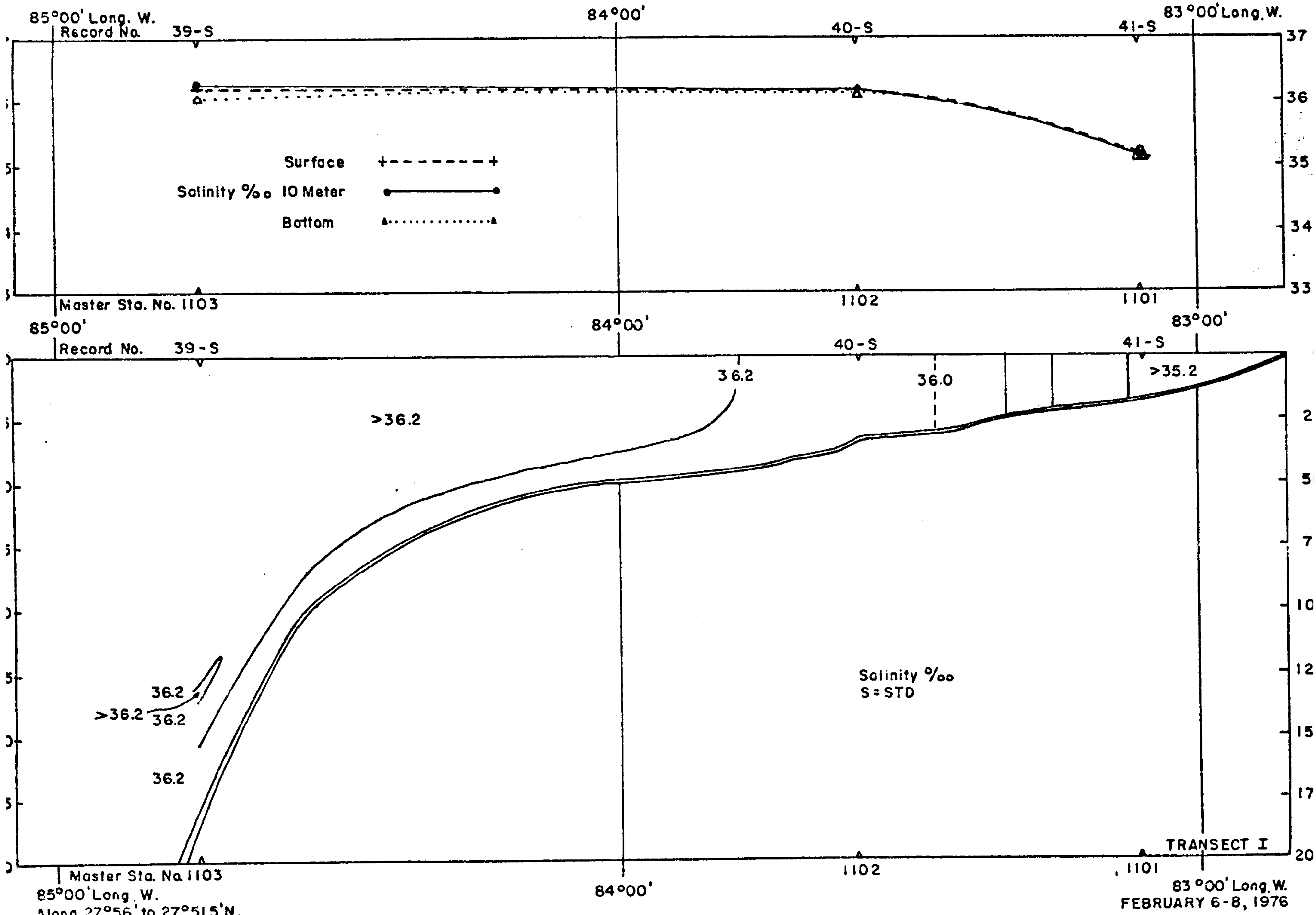


Figure 52. Vertical Distribution Salinity ‰ BLM-28

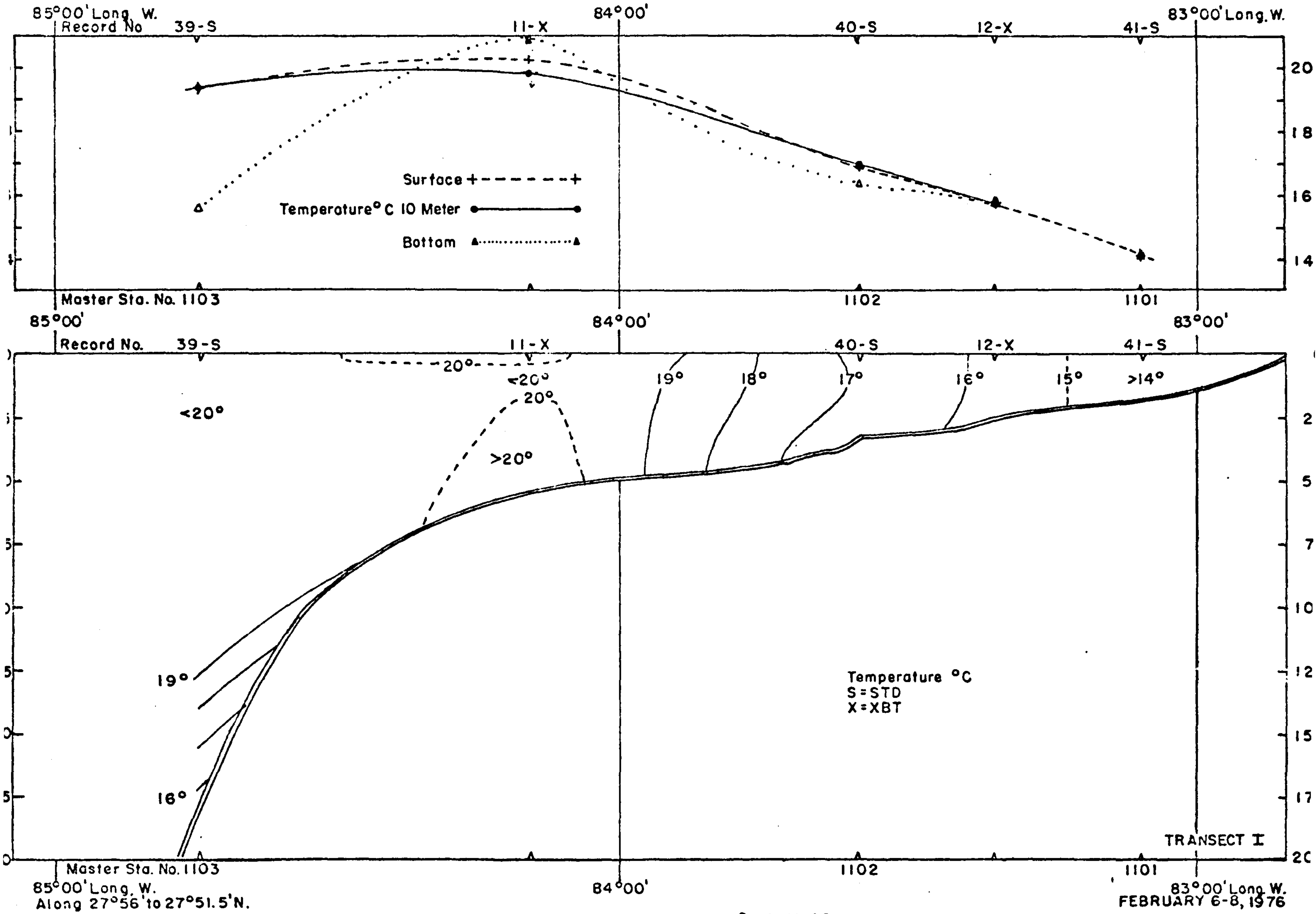


Figure 53. Vertical Distribution Temperature °C BLM-28

throughout the water column on this station was between 20.7 and 19.8°C or 0.9°C. These data at this particular station came from an XBT, and although the claimed reproducibility indicated that the values were real, the inner comparison of XBT's and STD lowerings on the shelf during BLM studies on the shelf makes one question whether it is an artifact of the different collection system or a real value.

The salinity on Transect I (Table II) at the surface was between 36.21 and 35.17 °/oo with a range of 1.04 °/oo; at ten meters, 36.28 and 35.16 °/oo with a range of 1.12 °/oo; and at the bottom, 36.16 and 35.15 °/oo with a range of 1.01 °/oo.

The temperature on Transect I at the surface was between 20.20 and 14.12°C with a range of 6.08°C; at ten meters, 19.80 and 14.14°C with a range of 5.66°C; and at the bottom, 20.90 and 14.16°C with a range of 6.74°C.

The uniformity of these ranges amoung the different depth levels was simply another indication of the isothermal-isohaline features of this transect.

Because of difficulties with the transmissometer, this transect was reoccupied after a two-day break from the inshore station (Master Station 1101) out to the edge of the Continental Shelf but did not include Master Station 1103 on the slope of the Continental Shelf. These data are shown in Figure 54 for salinity and Figure 55 for temperature and are presented here as an indication of the horizontal changes that can occur in the distribution over a short time period due to combined effects of weather conditions, diurnal changes, internal waves or tide oscillations on the shelf.

The salinity at the surface at Master Station 1101 over a 38-hour period changed 0.73 °/oo. There was a change in the isohaline nature of the

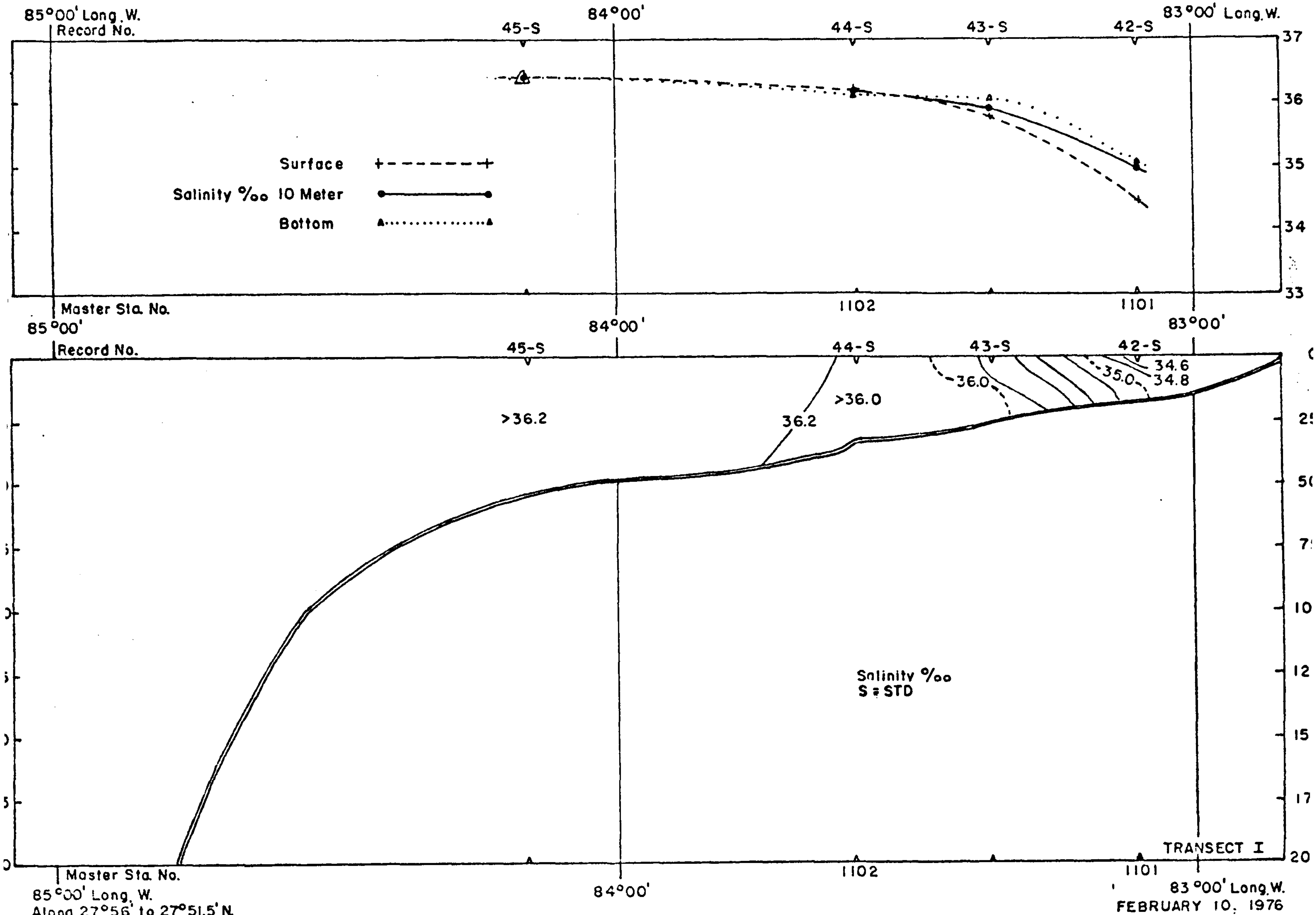


Figure 54. Vertical Distribution Salinity ‰ BLM-28

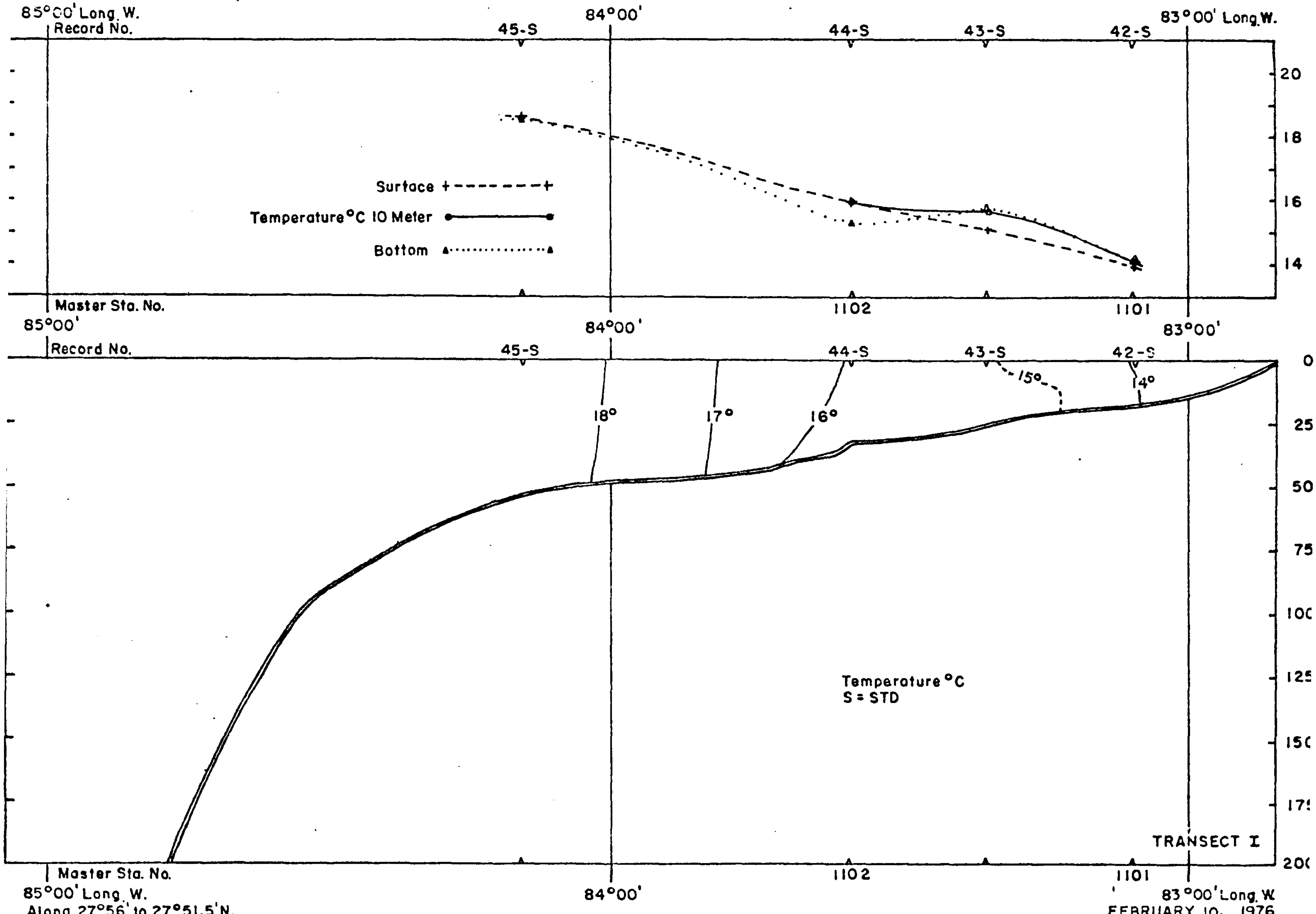


Figure 55. Vertical Distribution Temperature °C BLM-28

station to a gradient structure. The salinity values on the bottom did not change within the reproducibility of the method of data collection throughout the entire water column. From that station out to the edge of the Continental Slope over 92 hours the salinity values increased by 0.10 $^{o}/oo$ at the surface and 0.30 $^{o}/oo$ at the bottom with not only a downward displacement of outer Continental Shelf water but a net movement towards shore of approximately ten nautical miles (18.5 km).

The temperature at Master Station 1101 had a half degree increase throughout the entire water column. At a shelf depth of 25 m and outward to the edge of the Continental Shelf the temperatures changedby approximately 1^{o}C. During this sampling time period a cold front moved through the area on February 6 and 7 followed by a large high system on February 8, 9, and 10 which caused strong northeasterly and easterly winds on the 9th and 10th. Whether this shift in temperature was the result of the meteorological condition or whether this was the result of an internal oscillation of the outer shelf water cannot be determined from these data.

The horizontal movements of both temperature and salinity distribution patterns westward from the 25-meter depth on the Continental Shelf indicated that these changes were not related to tidal oscillation patterns. The need for long-term time series studies at a fixed location at critical positions within the MAFLA area was apparent from the examination of the different distribution patterns of temperature, salinity, and sigma t which resulted from the reoccupation of certain of these transects during the fall and winter seasons. This was further supported by the examination of the 24-hour time series stations taken in support of the transmissometer studies at Master

Station 1412 and the Florida Middle Grounds position at Master Station 1207 during the fall and winter seasons. A similar situation exists in the data shown in Table VII by the repeated sampling at certain stations over the time intervals from thirty minutes to twelve days during the fall and winter season. Table XI records the results of similar measurements in the summer and fall seasons at stations along Transect III from the historical data (SUSIO, 1975). In this table the station numbers to the left indicate data from the work of Gaul, et al (1964, 1965, and 1966). The station numbers to the right represent master station numbers from the BLM monitoring survey. When three or more samples were collected in a representative sampling manner within a 24-hour period, the range of these values is shown under the headings "Temp. 24H" and "Sal. 24H."

Because of these observed horizontal movements and the time variability of the parameters with depth at a fixed location, the use of temperature and salinity to infer current circulation patterns or supply environmental support information to the biological, geographical, and chemical interdisciplinary studies is very difficult without long-term time series records. Each investigator and management policy decision-makers should keep these variables firmly in mind to insure that the proper interpretation has been made of the existing background data. It is strongly recommended that in future work not only the variable of the physical parameters be determined but that similar variables be measured for the other water column parameters particularly in the field of trace metals and hydrocarbons. By the use of the latter it might be possible to increase our knowledge of the source materials on the shelf.

Re-examination of these distribution patterns as discussed above in relation to the forcing mechanisms, which influence the shelf circulation patterns, revealed that the Loop Current was not affecting the water column conditions in the MAFLA area in the winter season. Neither direct intrusions of main stream Loop Current water (36.7 ^{o}/oo) or eddy or boundary conditions of Loop Current water (36.55 ^{o}/oo) were present. Further, there was no eastern Gulf of Mexico water (36.4 ^{o}/oo) on the shelf. On Transects IV and III a very small wedge was either at the break of the slope or on the slope itself. The patterns indicated that the circulation patterns were carrying outer shelf waters off of the shelf.

The effects of run-off can be seen on the inshore portions on each transect, and they do not appear to be extending out any farther than those observed during the summer and fall periods. There was a difference, however, in their influence as represented by the isothermal and isohaline conditions on these inshore stations rather than the existence of surface pockets. Only on Transect I and then only on the second sampling of the transect could any surface pockets be detected.

Figure 56 is the monthly precipitation at Mobile, Pensacola, Apalachicola, and Tampa or very near the coast in the MAFLA area. Table XII represents the maximum, minimum, and normal monthly precipitation amounts at these meteorological stations and also indicates the monthly values for December, 1975, and January and February of 1976. These figures show that the rainfall during 1976 was below the normal except for the January data at Pensacola and Apalachicola, Florida. Examination of the daily precipirates indicates that at these two stations that 3.65 (9.3 cm) of the

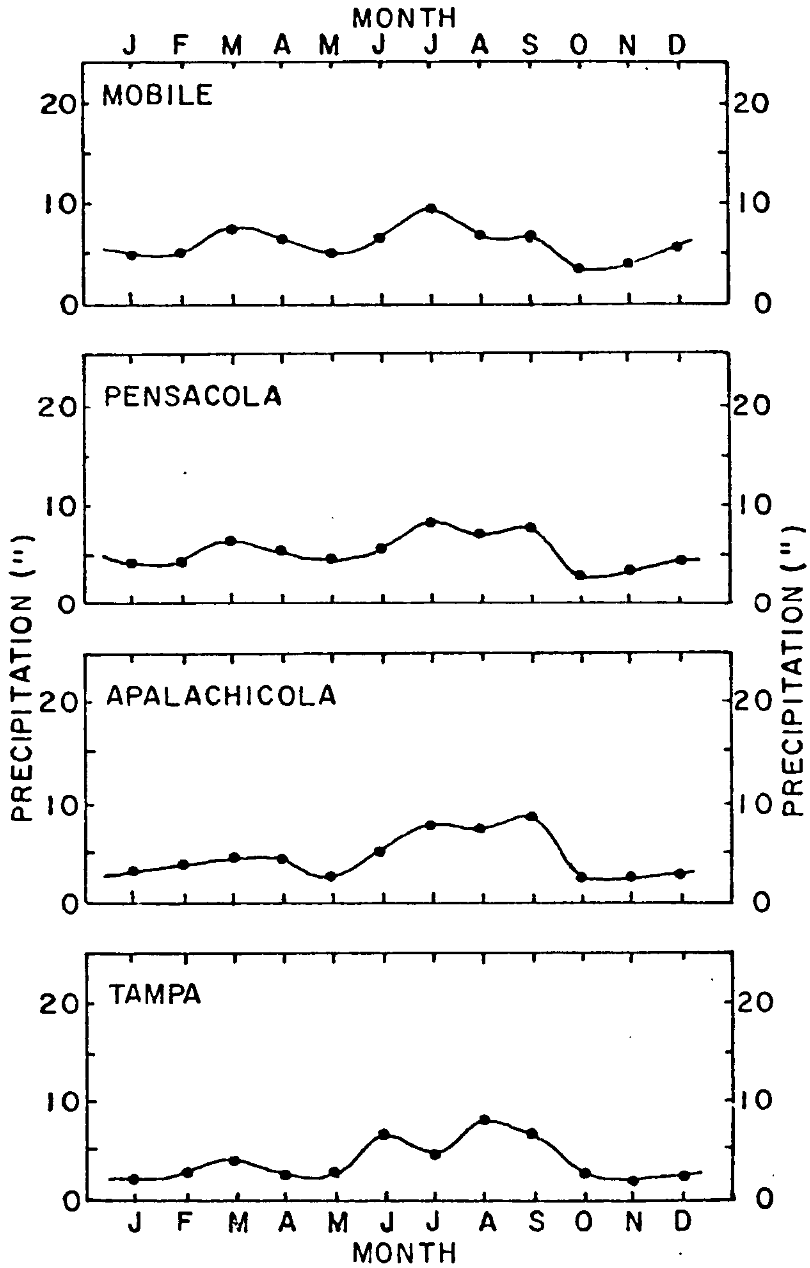


FIGURE 56. Monthly Precipitation Values (in Inches) at Mobile, Pensacola, Apalachicola, and Tampa.

Table XII. Monthly Precipitation Values in Inches

Station	Maximum Monthly			Minimum Monthly			Normal Total			1975			1976		
	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.
Mobile	11.38	9.35	9.01	1.45	0.48	1.31	5.92	4.71	4.76	4.98	3.43	3.75	----	1.80	2.36
Pensacola	6.53	11.83	11.66	3.46	1.22	2.78	4.66	4.66	4.69	3.17	4.51	4.28	----	6.11	3.07
Apalachicola	7.87	8.25	9.19	0.30	0.04	0.38	3.32	3.07	3.78	5.98	6.77	3.36	----	4.63	0.47
Tampa	----	----	----	----	----	----	2.19	2.11	2.86	0.87	0.91	1.56	----	0.40	0.49

4.5 inches (11.4 cm) at Pensacola and 3.23 (8.2 cm) of the 6.77 inches (17.2 cm) at Apalachicola were recorded after the occupation of Transects IV and III.

Examination of Appendix I indicates that the discharge rates in cubic feet per second (cfs) during January and February, 1976, from the major river systems along Transect IV (Figures 1-4) and Transect III (Figures 7-9) were very low. In fact, in general, they were lower than similar data recorded for 1974 and were at or near the values recorded for the summer BLM sampling period in 1975. A similar condition was present on Transect II (Figures 11 and 12, Appendix I). Historically, the discharges in the region of Transect I were at their lowest values (Figures 14-22), and this was also true in 1976.

Taking these factors into account, and based on the December and January records, it would appear that the coastal drainage during the winter in the MAFLA area which would affect the salinity distribution patterns was lower than normal.

If these data are used as an indicator of the conditions in the major river system run-off area (Table I), the 1976 winter season was a period of low run-off. The isothermal-isohaline conditions experienced on the inshore stations were not related to large run-off effects.

The only pocket of low salinity surface water noted on any of the transects which cannot be explained by inshore run-off was a low pocket on Transect IV on Master Station 1415. Based on the summer and fall horizontal distribution patterns and vertical sections, this water appears to be Mississippi River System discharge.

Figure 57 is a horizontal distribution of salinity at the surface during the winter. Keeping in mind the limitations of the transect data as previously discussed, it would appear that the Mississippi River System drainage discharges were not moving to the east as was the case during the summer and winter seasons when Loop Current water and eddies were present. A similar condition was present on the ten-meter horizontal salinity distribution pattern. There was indication that some form of upwelling was occurring along the DeSoto Canyon area. The Horseshoe Bend eddy water mass had now established itself as a ridge of high salinity. Perhaps more important was the extent to which Outer Continental Shelf water had moved out onto the Continental Slope.

Figure 58 is the bottom salinity which shows the bottom flows, in general, along the isopleths. It also shows that Outer Continental Shelf water had protruded well over half way onto the shelf on Transects II and I.

The effects of the short-term fluctuations referred to above can be seen on Figure 52 where the salinity value of 36.06 $^{o}/oo$ at Master Station 1103 was taken some three days before the remaining data on the transect (Figures 54 and 55). The inherent danger, therefore, for using non-synoptic data or not knowing the short-term fluctuation of the physical parameters at a fixed location can be illustrated by that data point since if it was contoured, it would appear that a tongue of 36.20 $^{o}/oo$ water had moved out onto the shelf.

Having eliminated the influence of large run-offs and the effects of the Loop Current as causes of the isothermal-isohaline conditions over three quarters of the MAFLA area (Transect III through Transect I) out to a depth

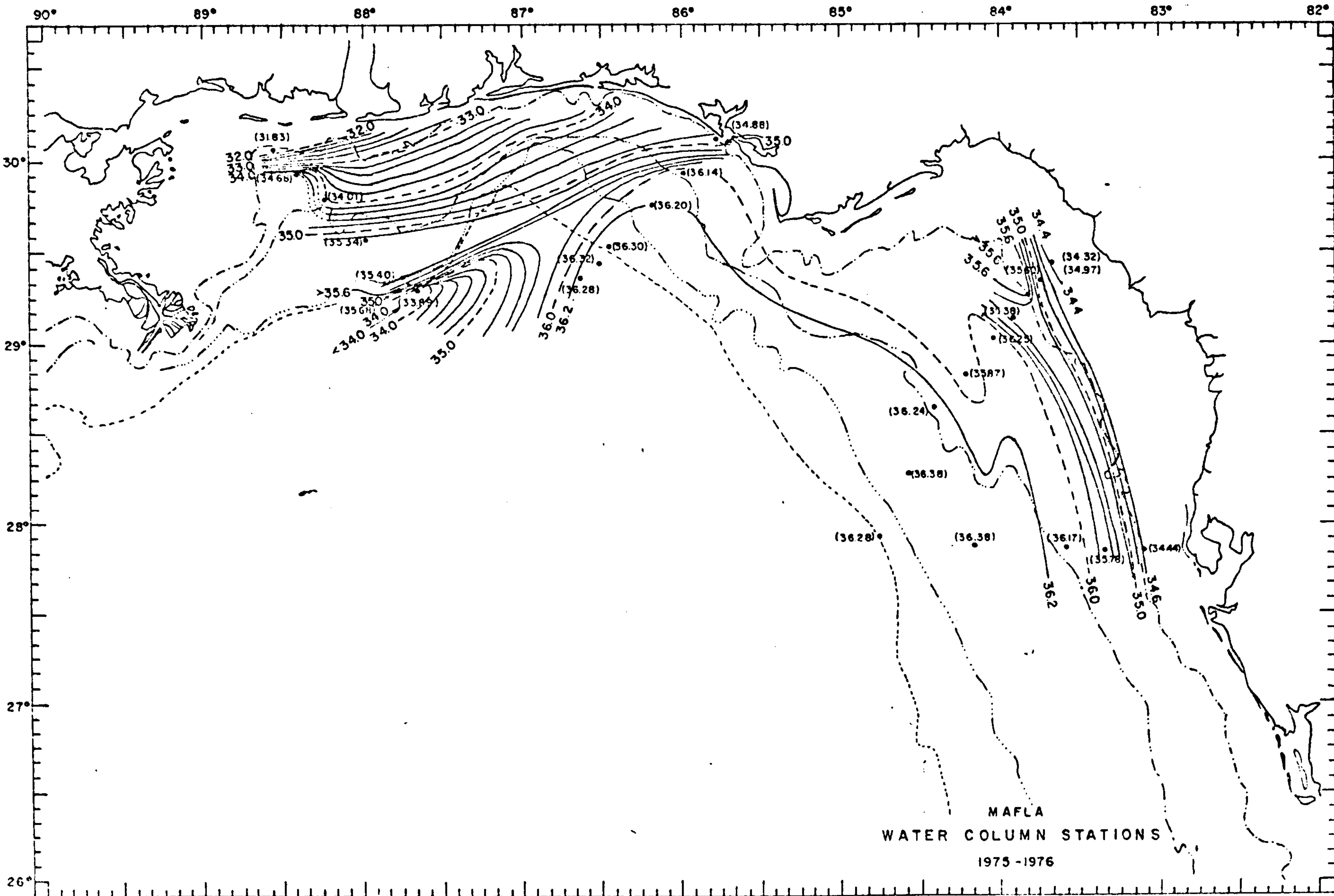


Figure 57. Surface Distribution Salinity ‰ BLM-28 JANUARY 9 - FEBRUARY 10, 1976

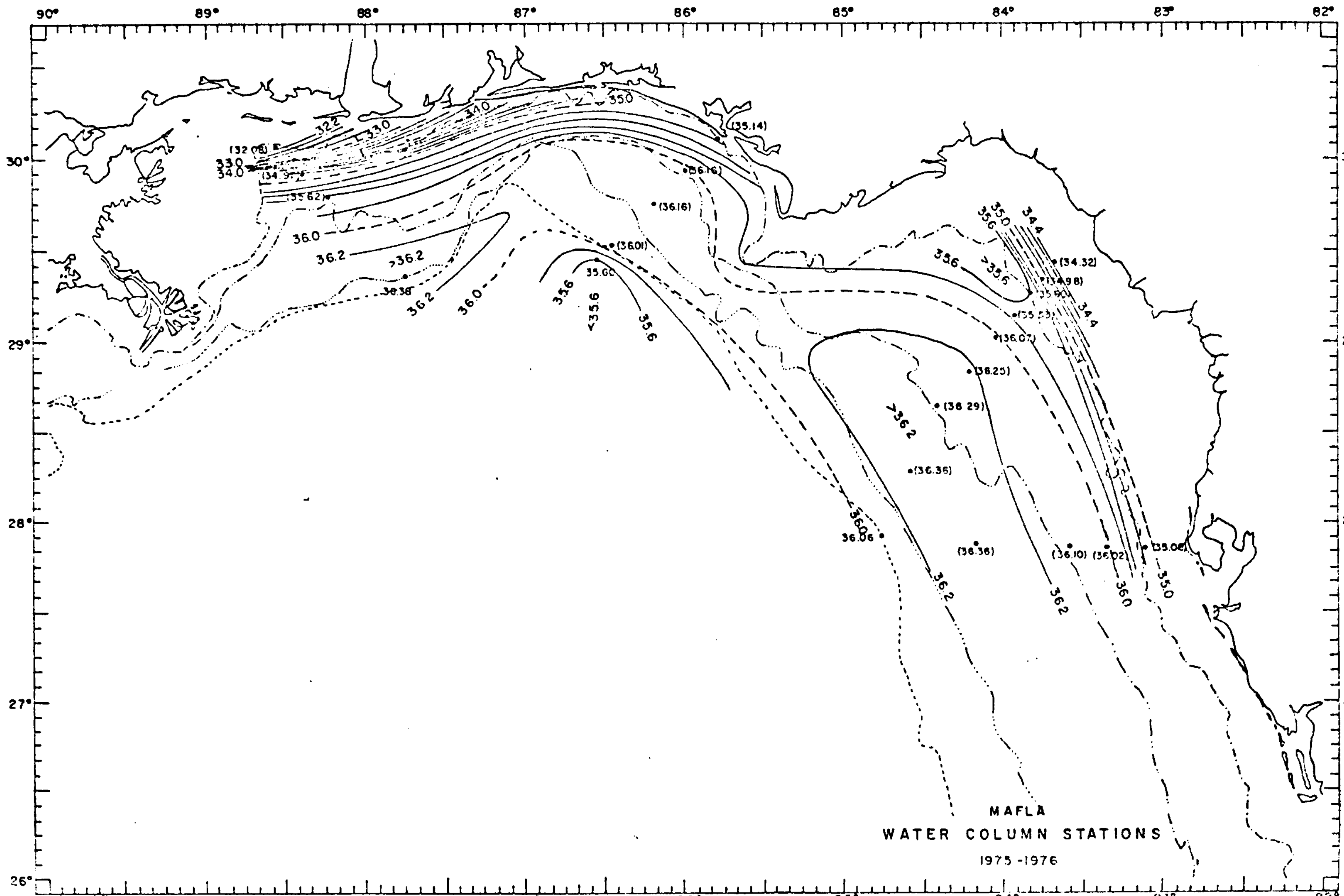


Figure 58. Bottom Distribution Salinity ‰ BLM-28 JANUARY 9 - FEBRUARY 10, 1976

of approximately 50 m, the wind stressing had apparently completely mixed the water column.

This was further supported by an examination of the data synoptic surface maps. These maps were examined for frontal conditions in the eastern Gulf of Mexico. The eastern Gulf of Mexico area is defined as being the location within the area limited by 21°N and 31°N parallels and 80°W and 90°W meridians. This area has been used by Fernandez-Partagas in characterizing the frontal conditions over the eastern Gulf of Mexico and surrounding land areas (SUSIO, 1975). These show the passage of cold fronts on December 30 and 31, 1975, January 3 and 4, 7 and 8, 14 and 15, 20 and 23, 26 and 28, January 30 and February 1, 6 and 7, 18 and 19, 22 and 23, 26 and 27, 1976. There were warm fronts on the 6th and 7th and 12th and 13th of January and on the 19th and 20th of February. There were occluded fronts on the 16th and 17th of January and the 25th, 26th, 28th, and 29th of February in the Miami area. Based on these maps there were six cold, two warm, and two occluded fronts in January and six cold, one warm, and two occluded fronts in February.

Fernandez-Partagas' study (SUSIO, 1975) was based on data over a ten-year period. If the 1976 cold front distributions are compared with the statistics from that study in which frontal disturbance was defined as the approximate number of consecutive maps on which an individual warm or cold front could be identified in the sample area, there is an increase in the number of cold fronts and a decrease in the frontal passage time through the area from the mean. Similar statistics for the warm fronts indicate that the frontal duration of the warm fronts is markedly increased over the norm.

To put it another way, only 14 days out of 31 (45%) in January and 9 out of 29 (31%) in February were under the influence of cold fronts. Cursory examination of the weather charts for November and December, 1975, also indicate that this was an unusual winter season.

If one examined the surface charts, this means that 63% of the time the winds would be moving over the subject area from either a north-northeast, east-southeast or southerly direction. These particular directions of flow would result in wind stress from the shore outward to the Continental Shelf over the Transects II through I. Northeasterly and easterly winds would have had the same effect on Transect III. It is in these areas that the isothermals and isohaline were so well defined and extended out nearly to the edge of the shelf or across the shelf. Wind stressing from this direction would cause the transport of surface water off the shelf areas with a resulting inflow of water along the bottom of the shelf. Under these conditions, not only would the isothermal and isohaline layers be present, but the water temperatures themselves should be colder than normal.

As an indication of the mixing of the water column, except for the intrusion of 35.8 ^{o}/oo water on the shelf (Figure 34), the thermocline was either at the bottom or very near the bottom throughout Transects IV, III, and I. On Transect II it was out to Master Station 1207 with two surface shallow thermoclines between Master Stations 1205 and 1206 and around 1207.

The historical data on the four transects (Chart I) have been examined for the winter months in regard to their distributions and the range of temperatures across the shelf.

The result of these indicated that the winter of 1976 was not unique on Transect IV but was colder by one degree on Transect III, two degrees on Transect II, and three degrees on Transect I; further, that the temperatures in 1976 were colder or just as cold as the lowest temperatures observed in the historical past.

Although February was the month of maximum thermocline depths, the thermocline depths particularly on Transect I were abnormally deep. The depth of the thermocline, the coldness of the water, the reports from the diving program on the Florida Middle Grounds, and the transmissometer readings as shown in Figure 59 indicate that the water column had been well mixed with a corresponding disturbance of the bottom surface. It is interesting to note that the transmissometer readings were lower in the winter months than those taken directly after the hurricane on Transect II (Figure 43) indicating that the unusual winter conditions might have had a greater effect on the bottom than storm (hurricane) effects.

The well mixed character of this water would indicate that on Transects III, II, and I those values measured at ten meters can represent the values both at the surface and the bottom. Further, these values represent the combined influence of the shelf circulation patterns.

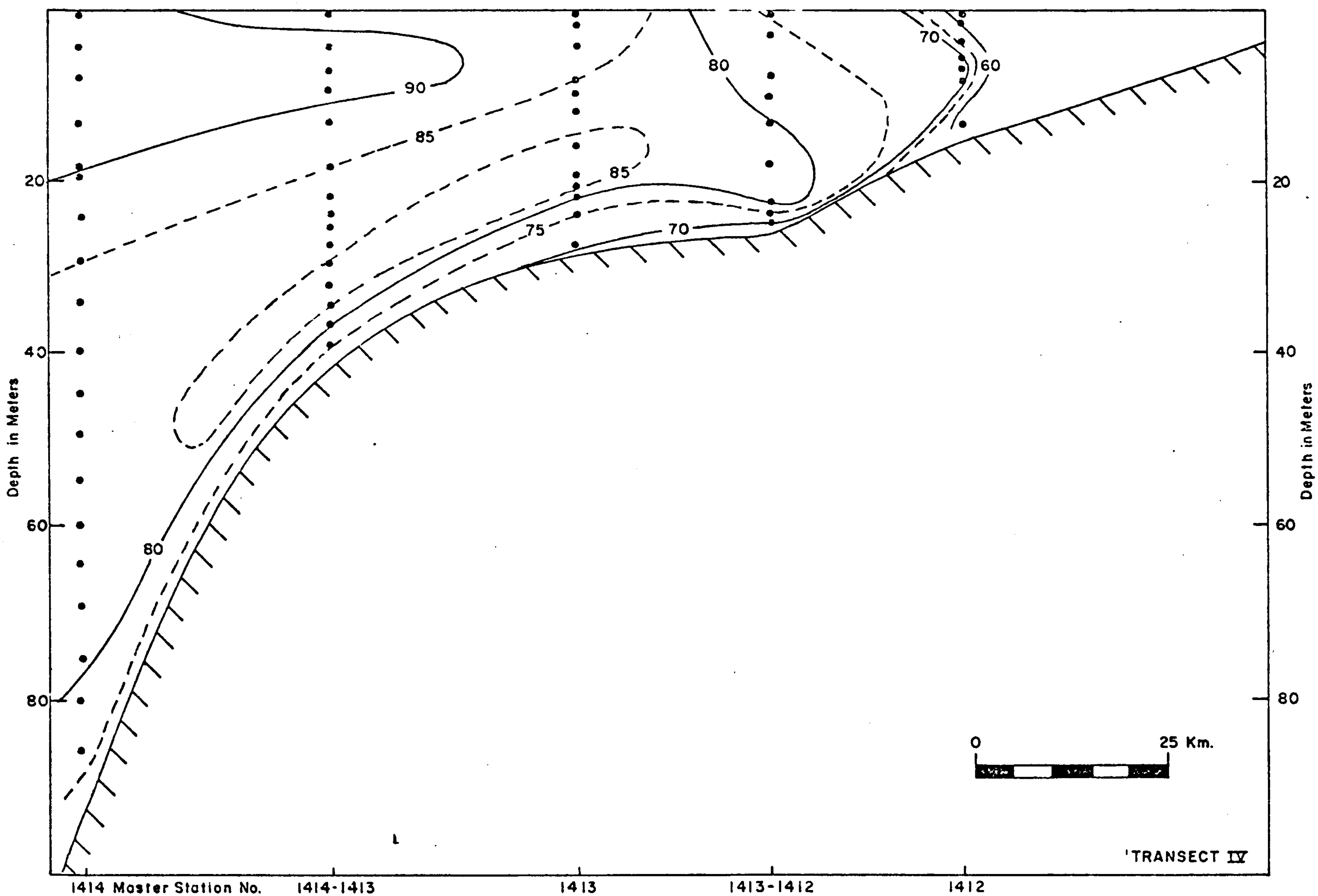


Figure 59. Vertical Distribution Transmission (T%) SEPTEMBER 9-10, 1975

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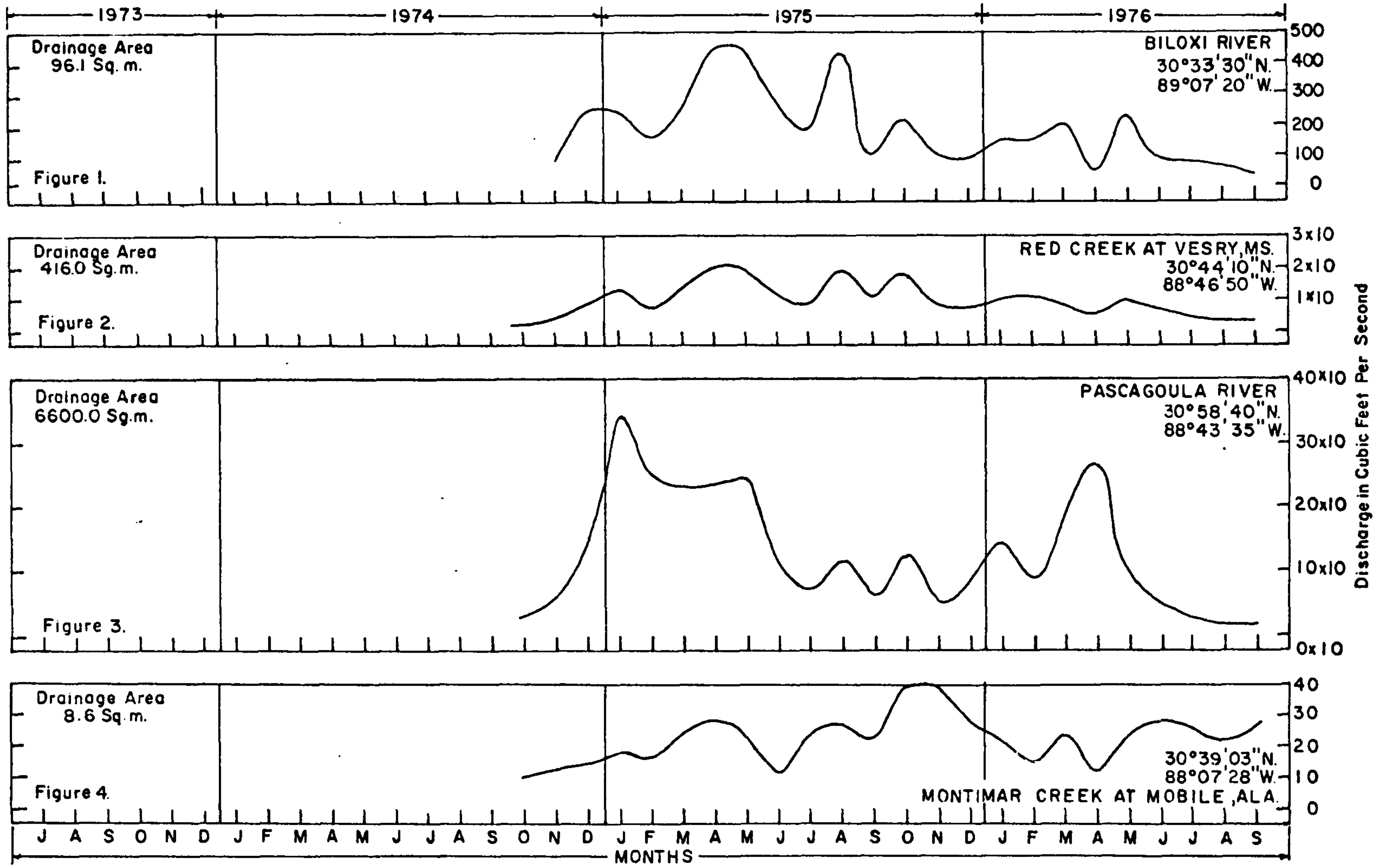
APPENDICES

APPENDIX I

Run-off Discharges From U. S. Geological Survey
Data in the MAFLA Area
from
July 1973 - September 1976



Figures 1, 2, 3 and 4. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values

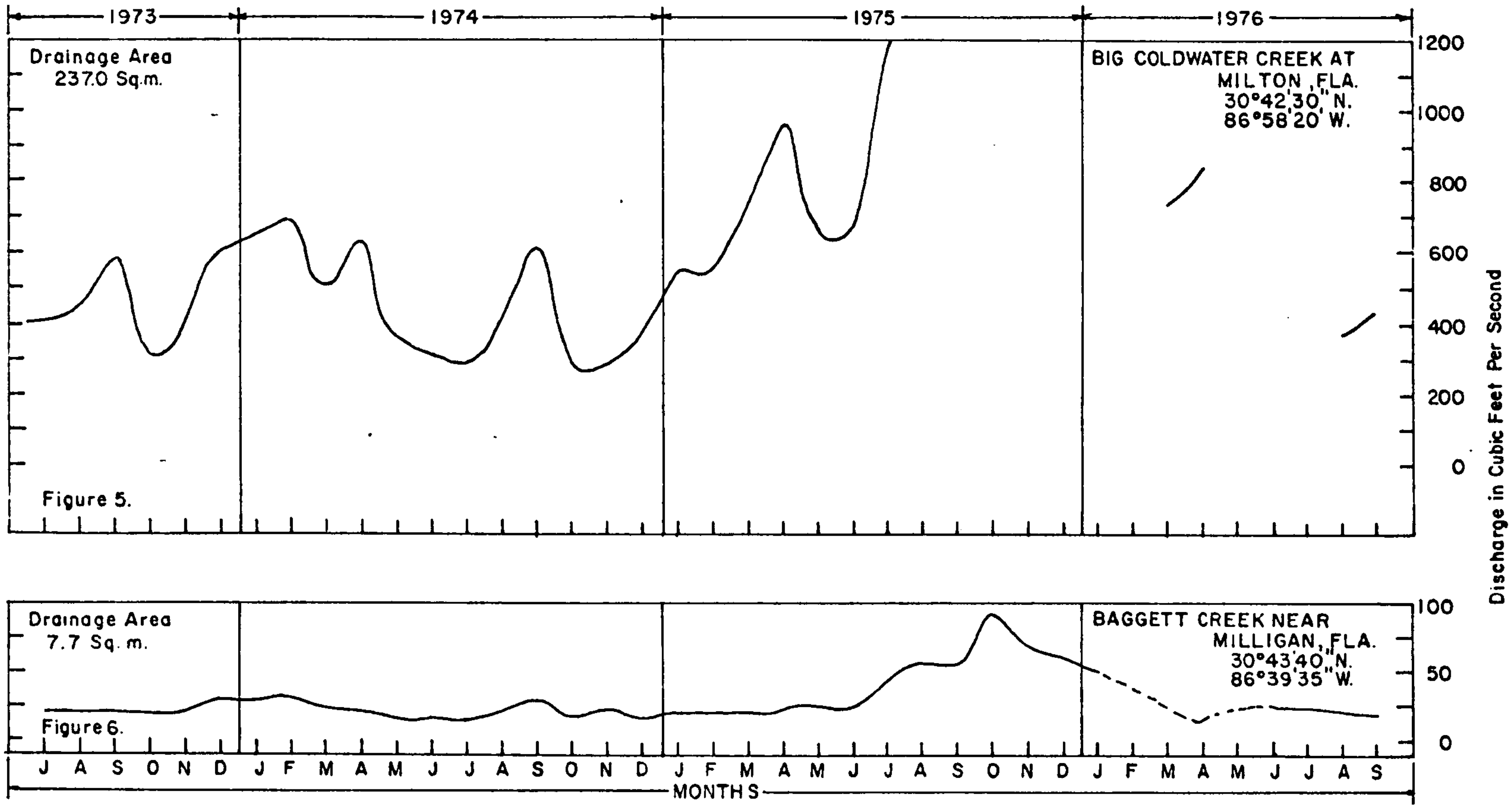


Figure 5 and 6 Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values

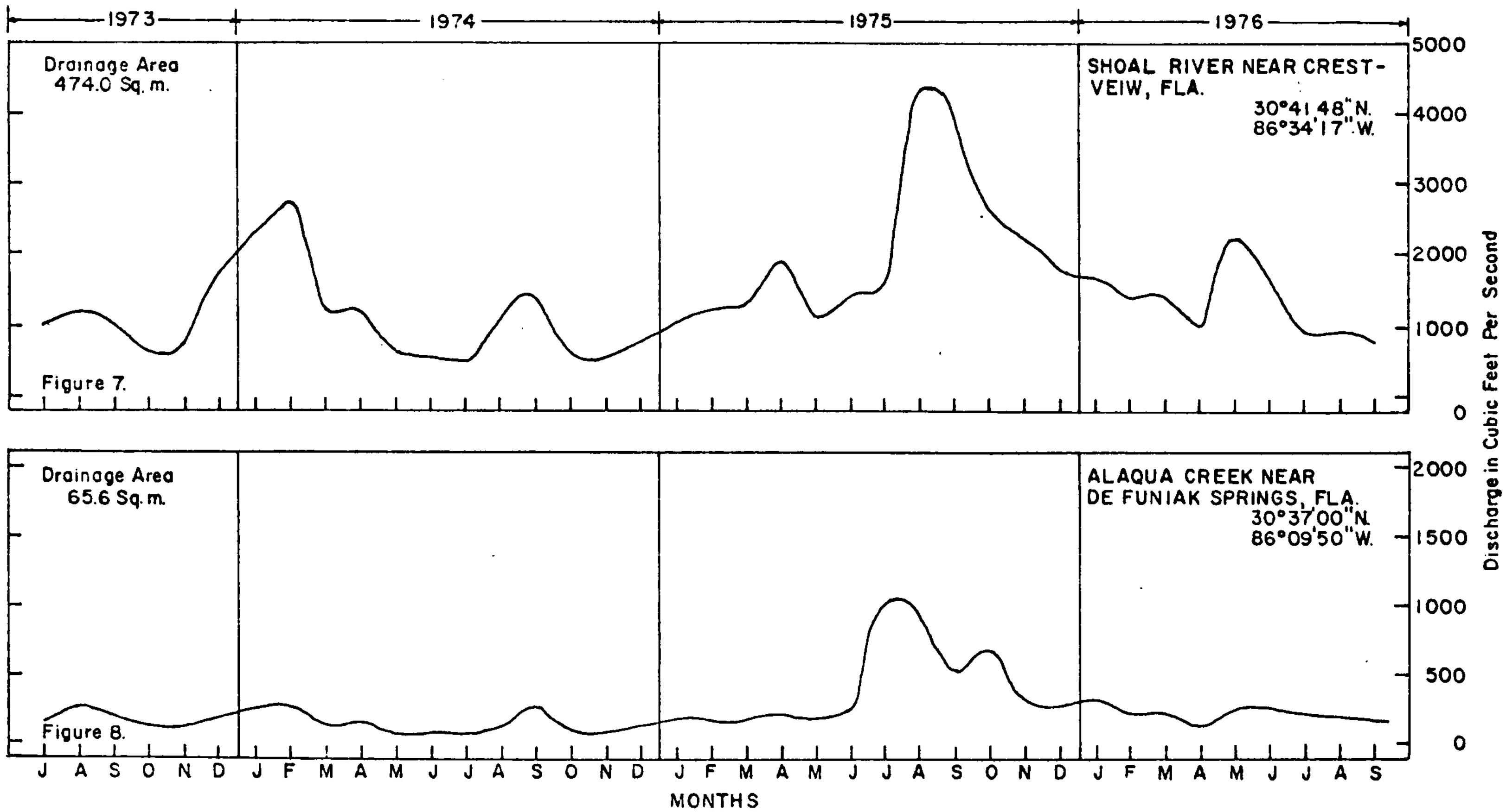


Figure 7and 8. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values

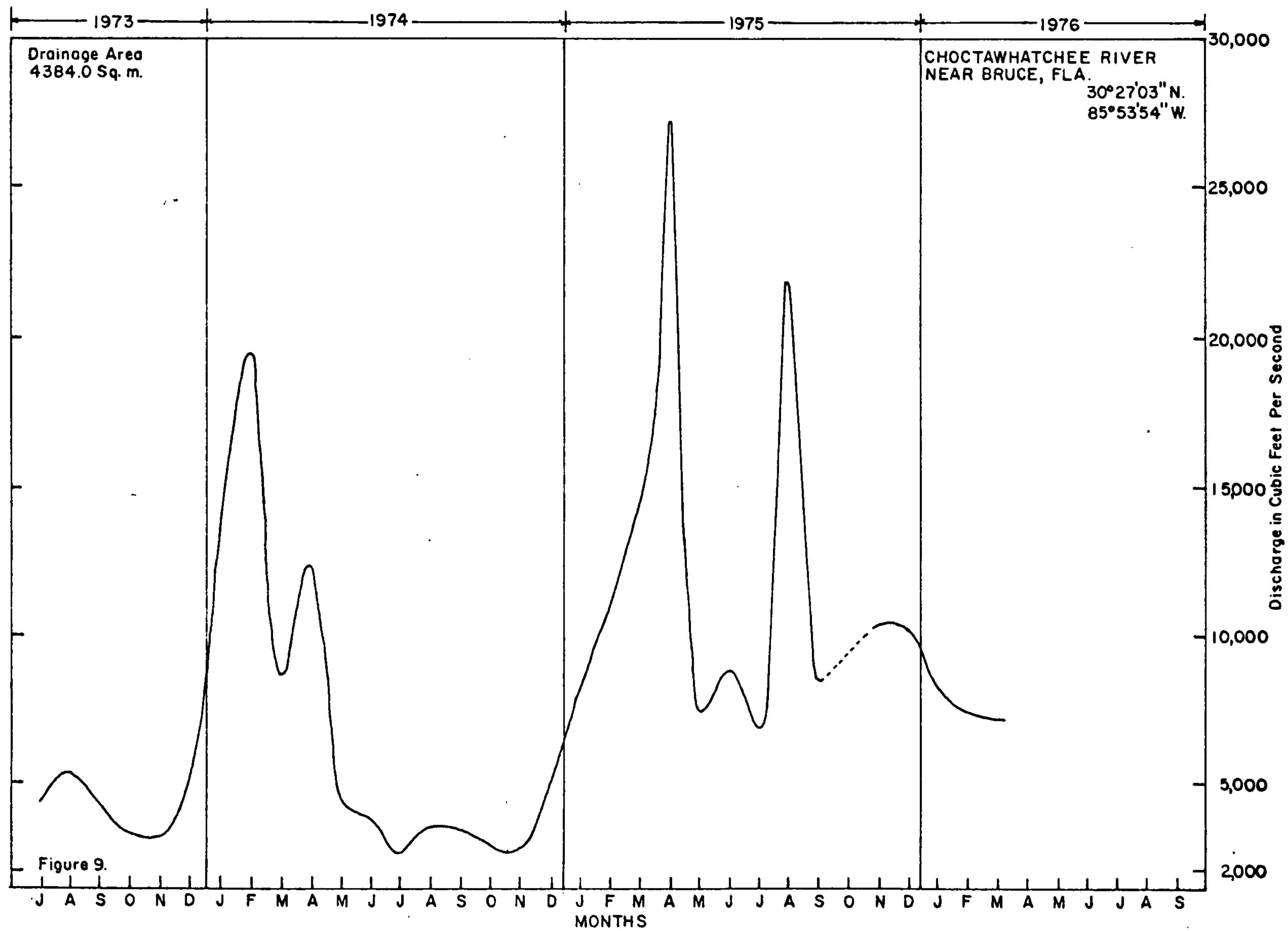
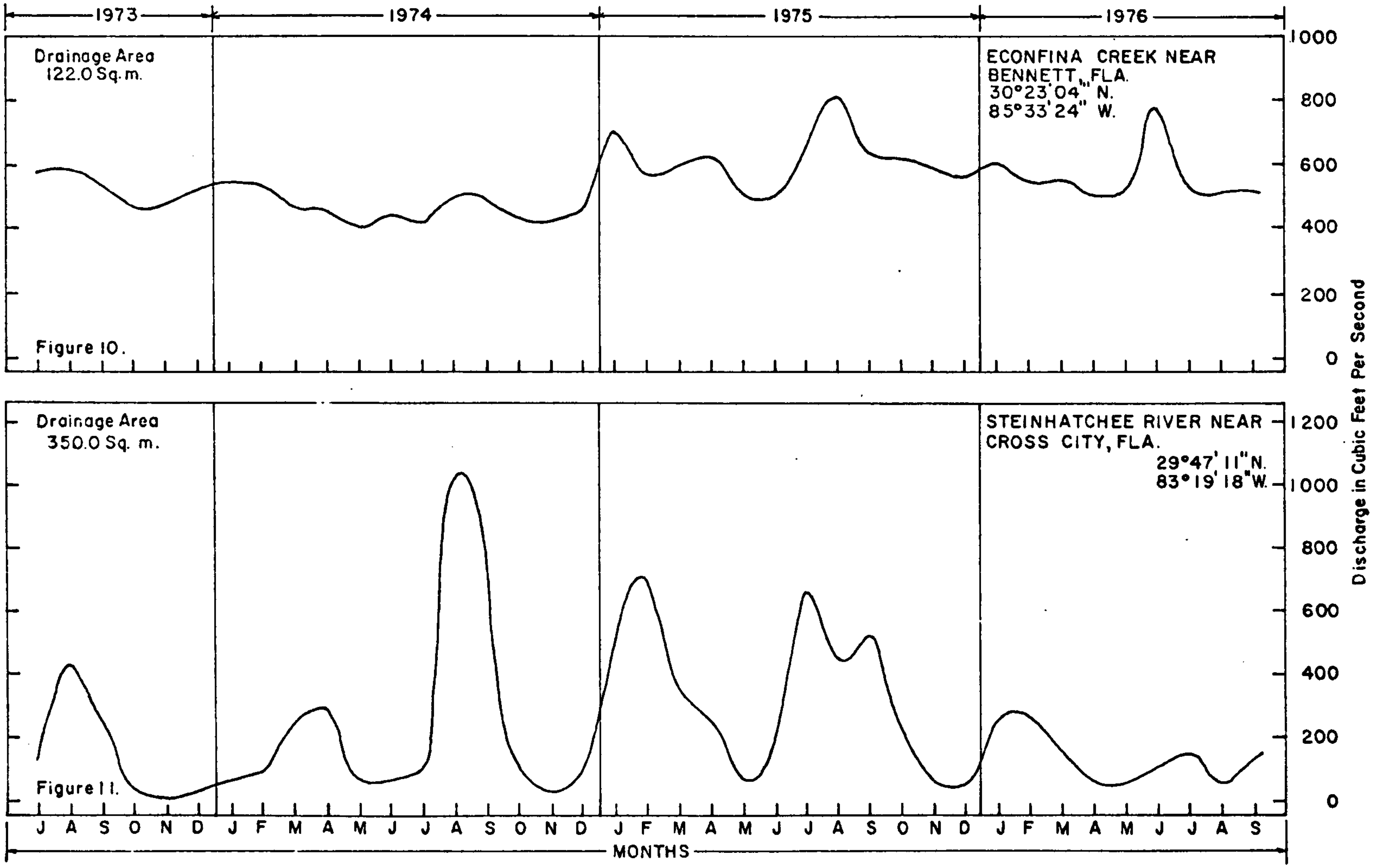
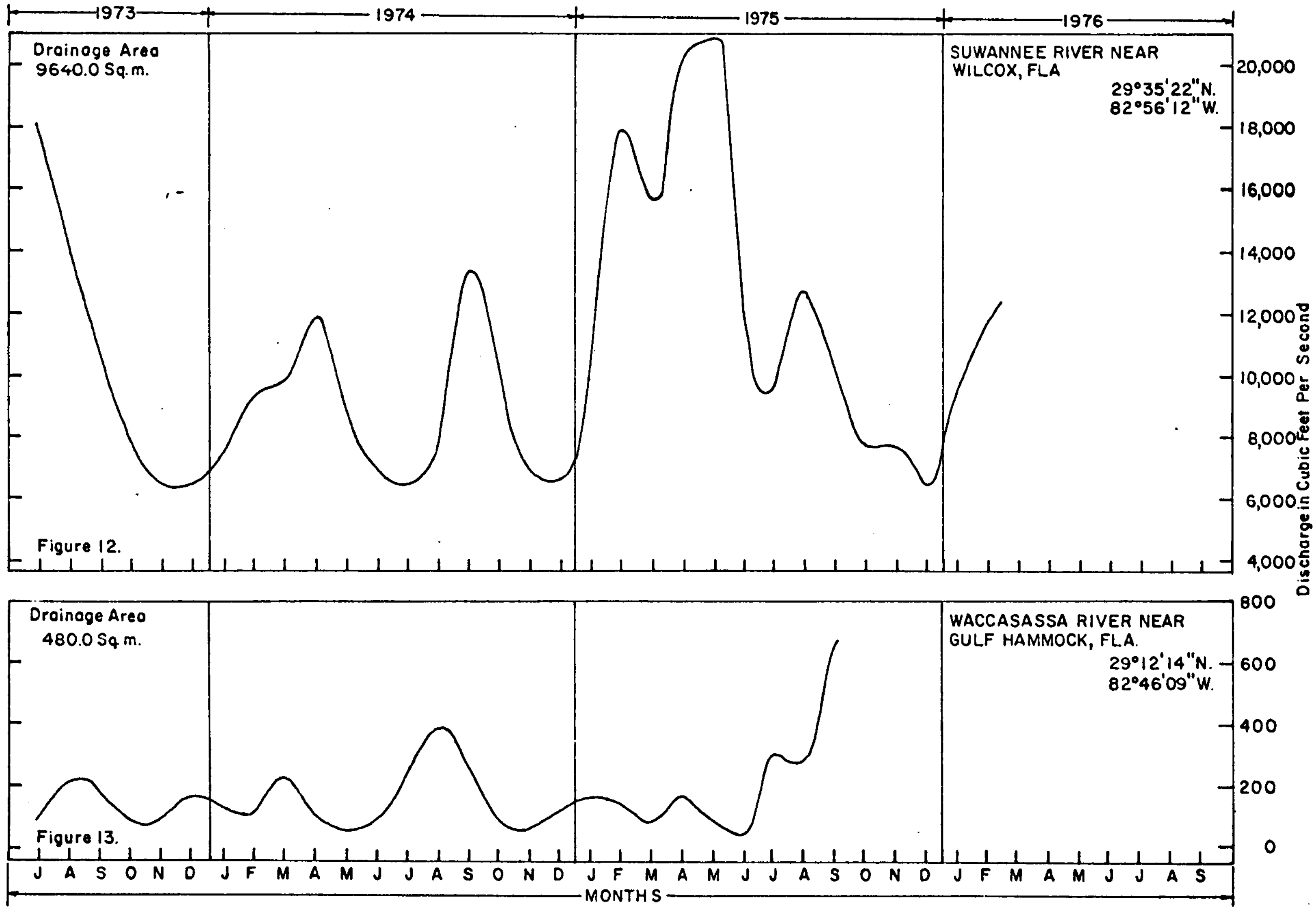


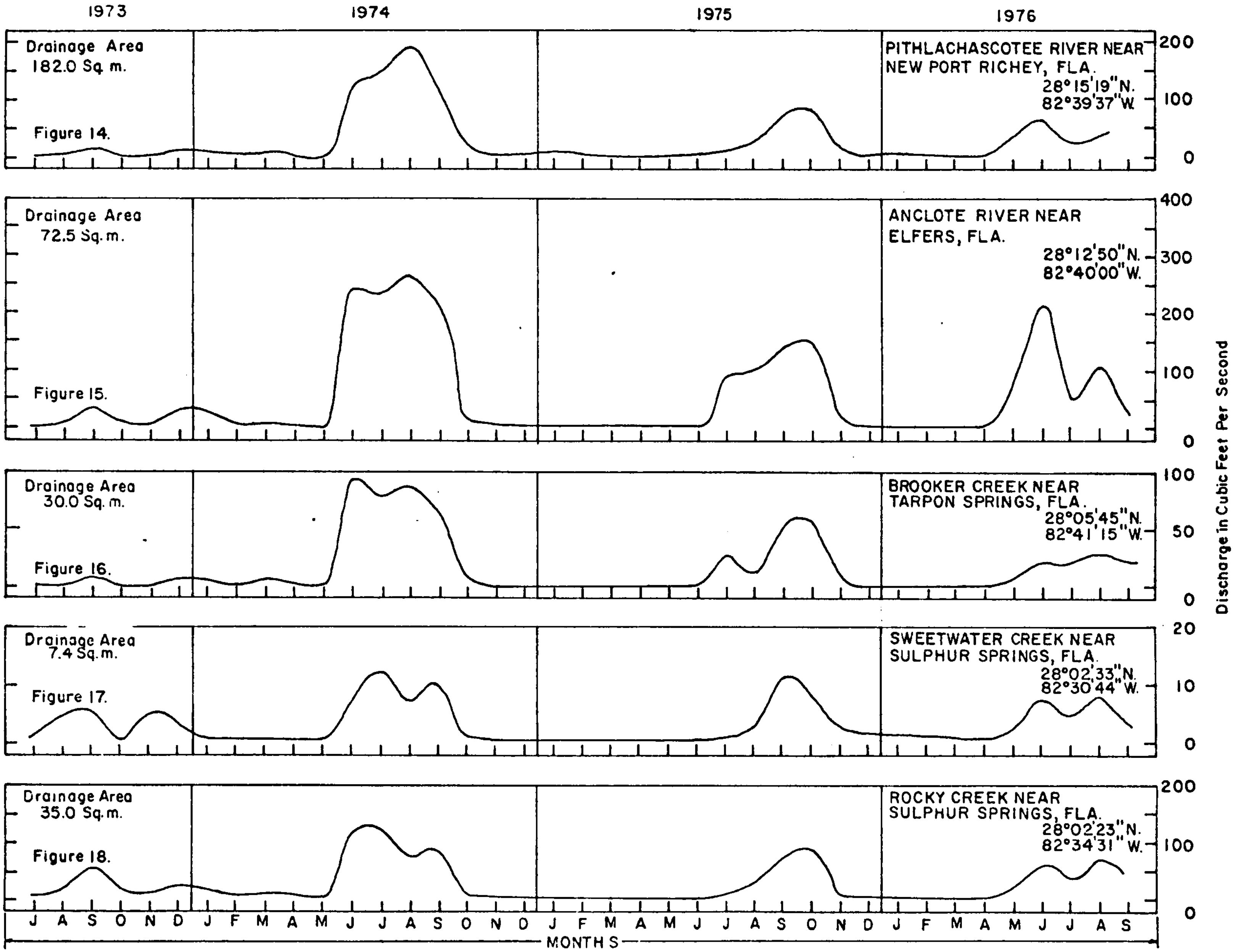
Figure 9. Run-off Discharge in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values



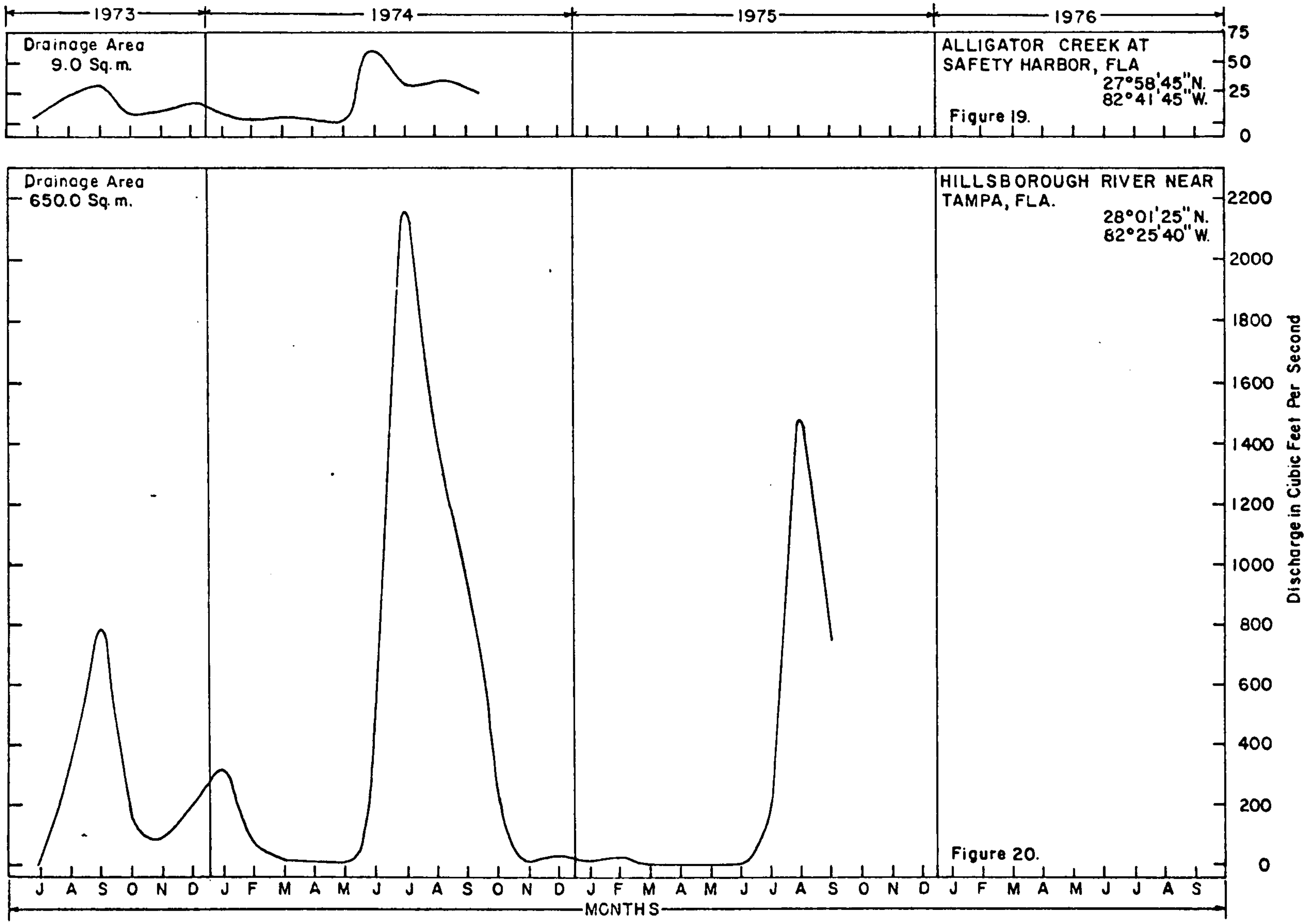
Figures 10 and 11. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values



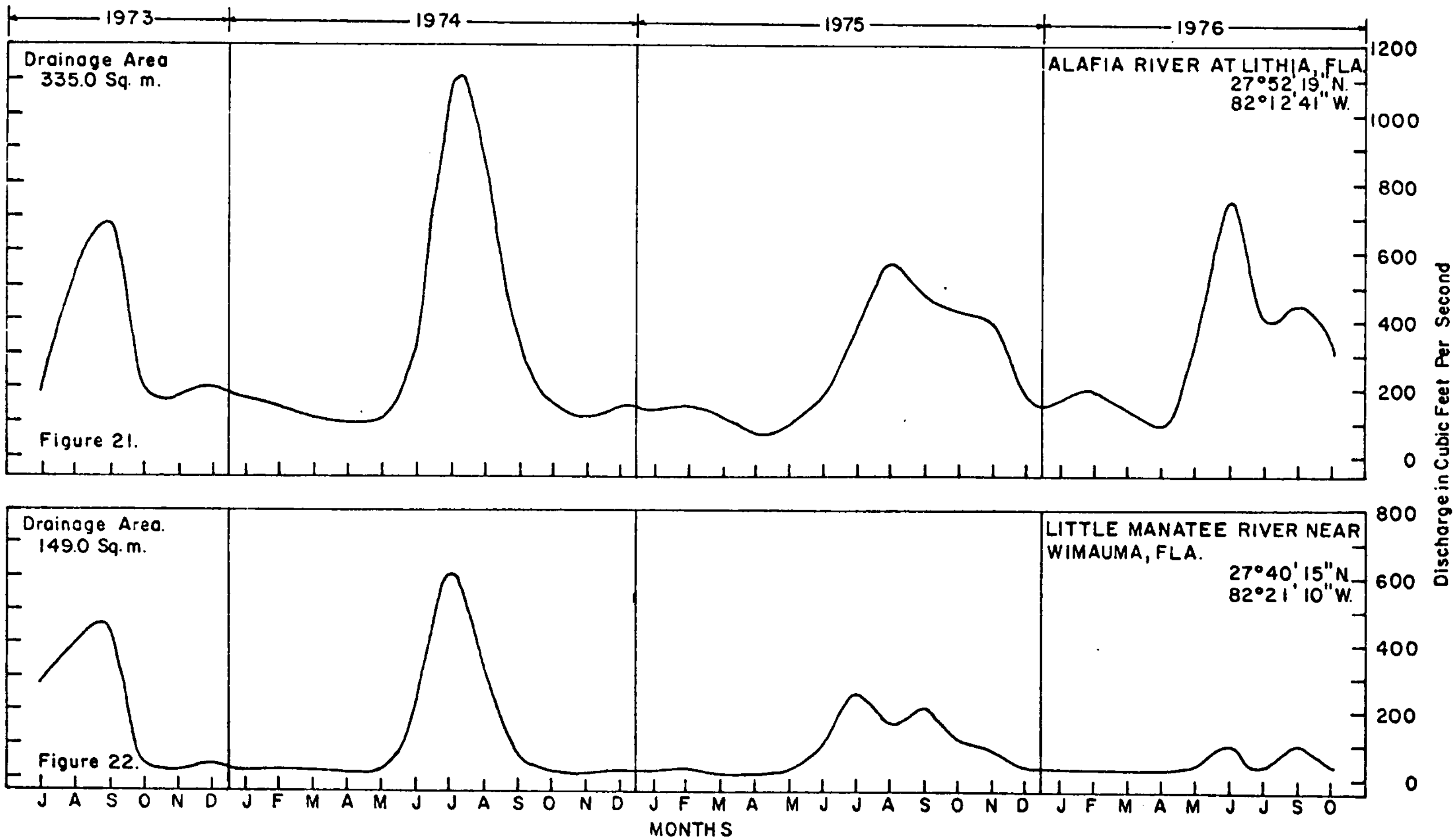
Figures 12 and 13. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values



Figures 14, 15, 16, 17, and 18. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values



Figures 19 and 20. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values



Figures 21 and 22. Run-off Discharges in Cubic Feet Per Second, Water Year OCTOBER 1973 to SEPTEMBER 1976 - Based on Mean Values

APPENDIX II

T-S Curves for Transect I - IV for the
Summer, Fall, and Winter BLM 1975-76
Sampling Program

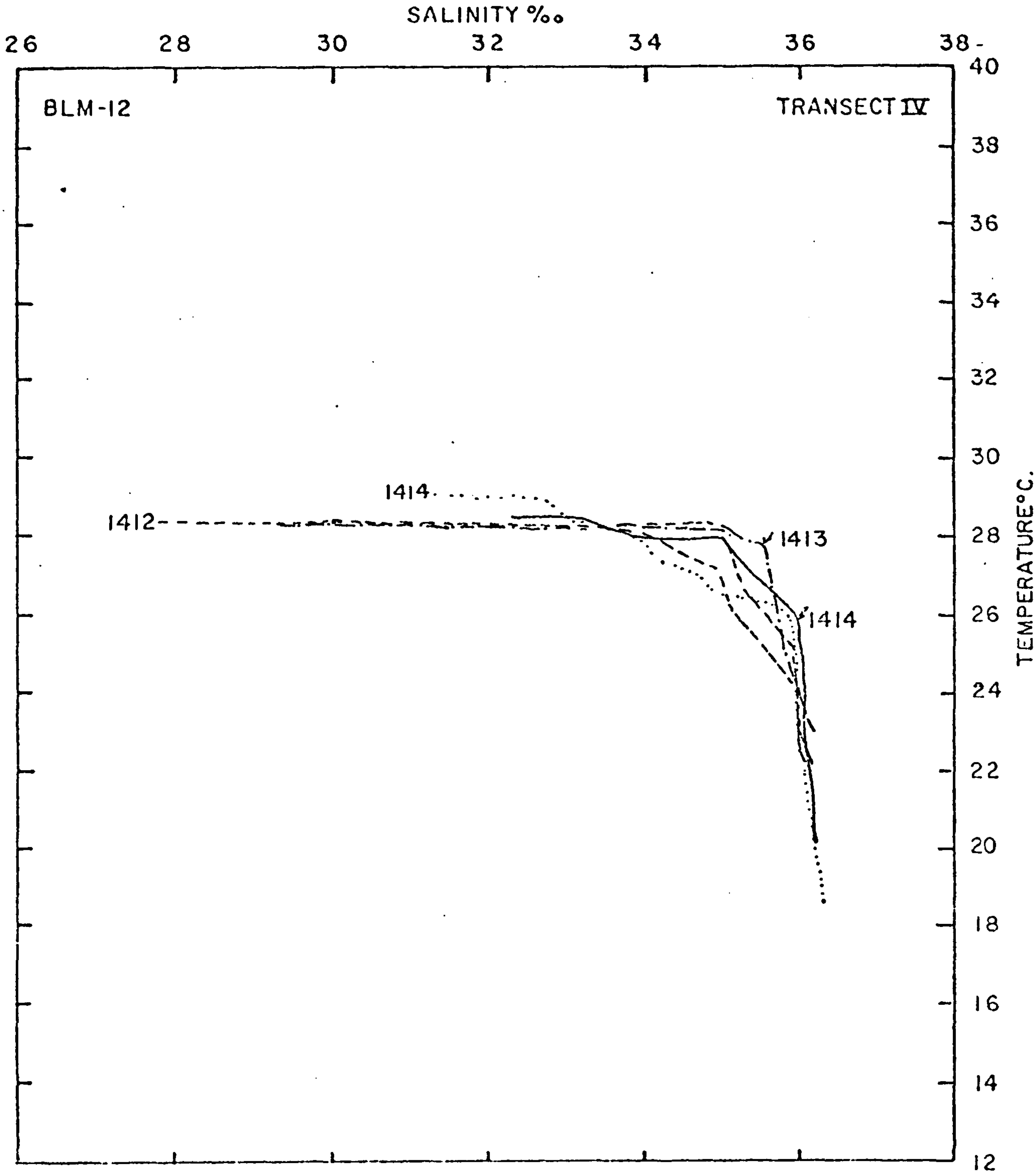


Figure I. Temperature-Salinity (TS) Curves along TRANSECT IV

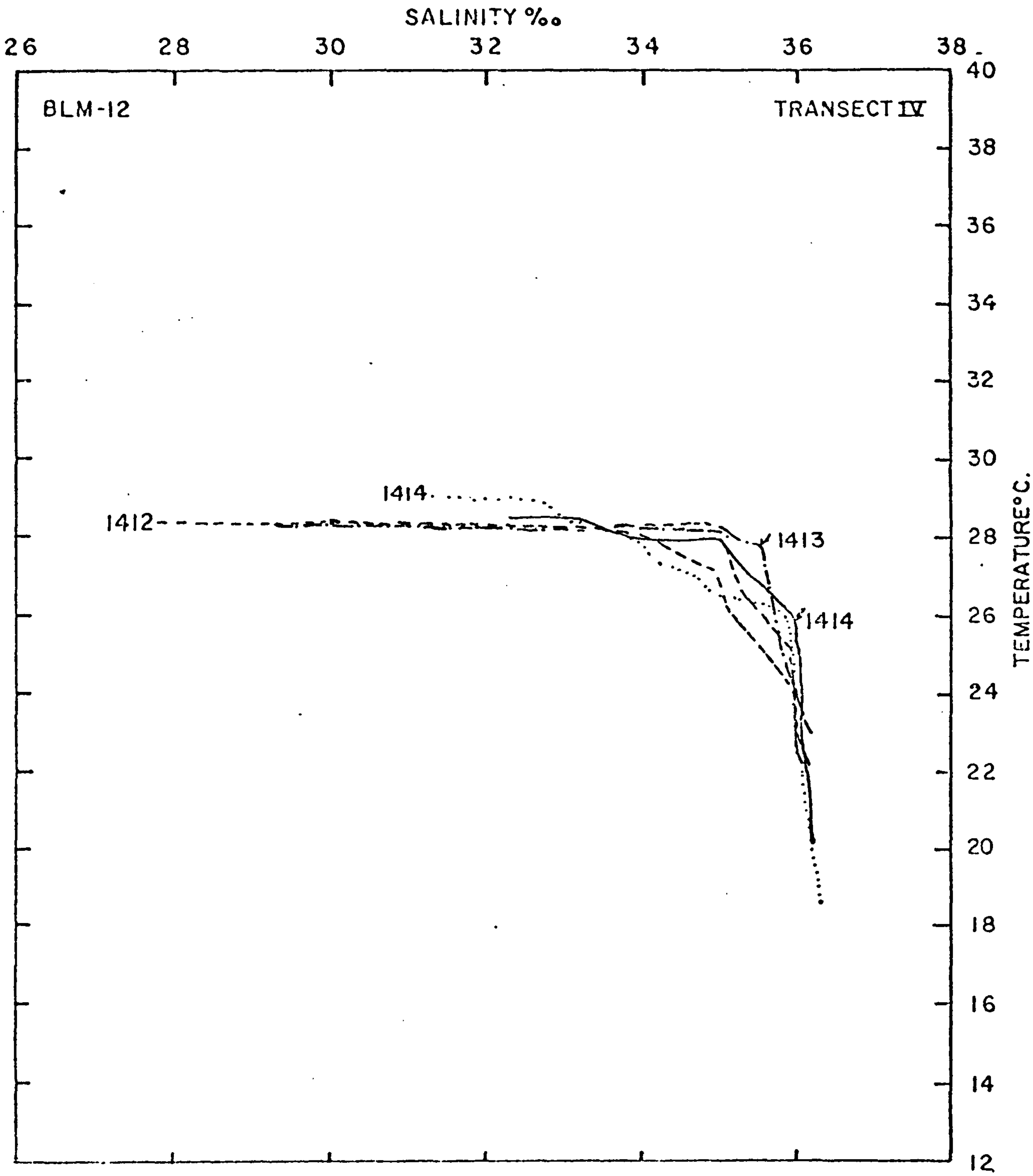


Figure I. Temperature-Salinity(TS) Curves along TRANSECT IV

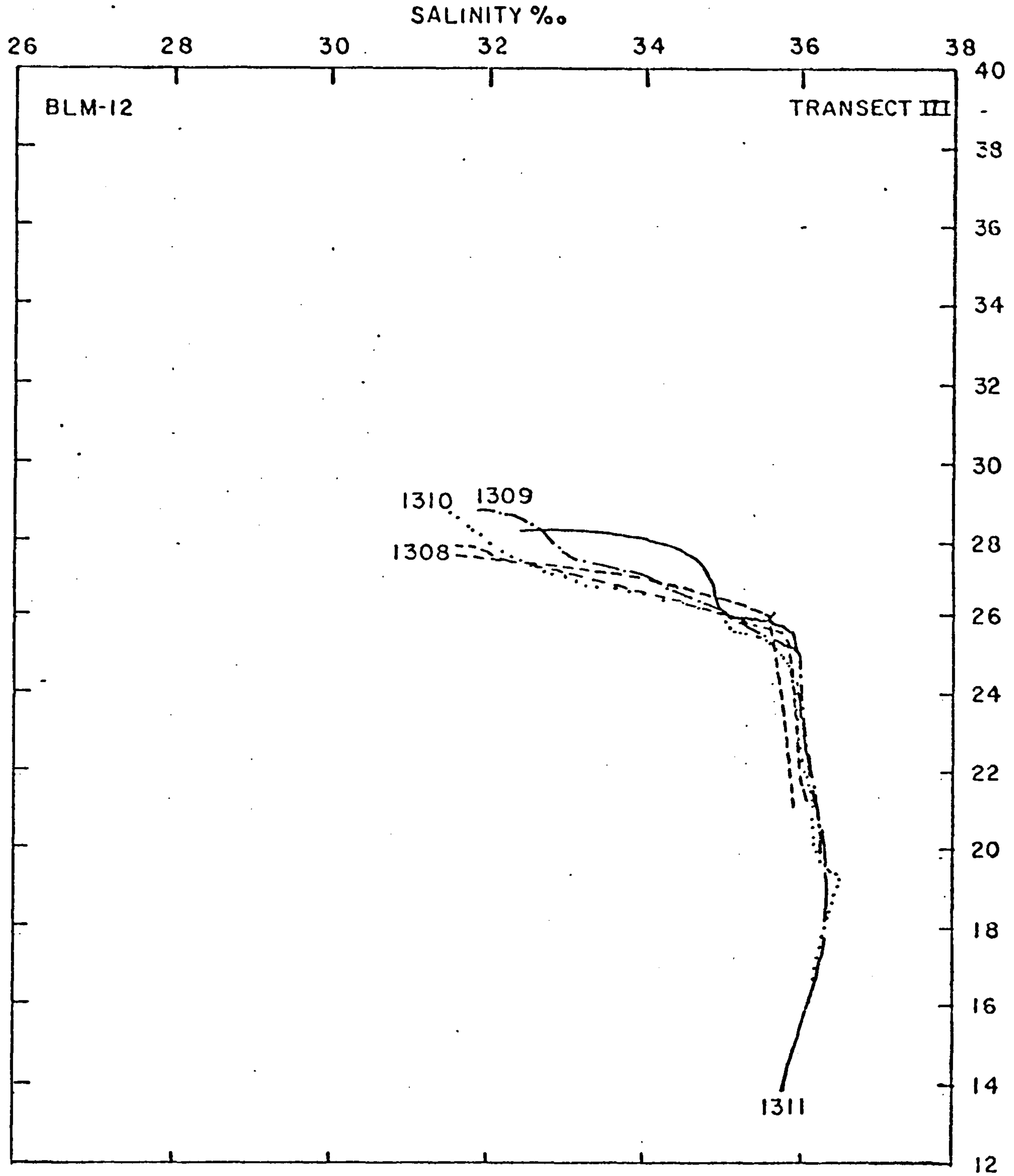


Figure 2. Temperature - Salinity (TS) Curves TRANSECT III

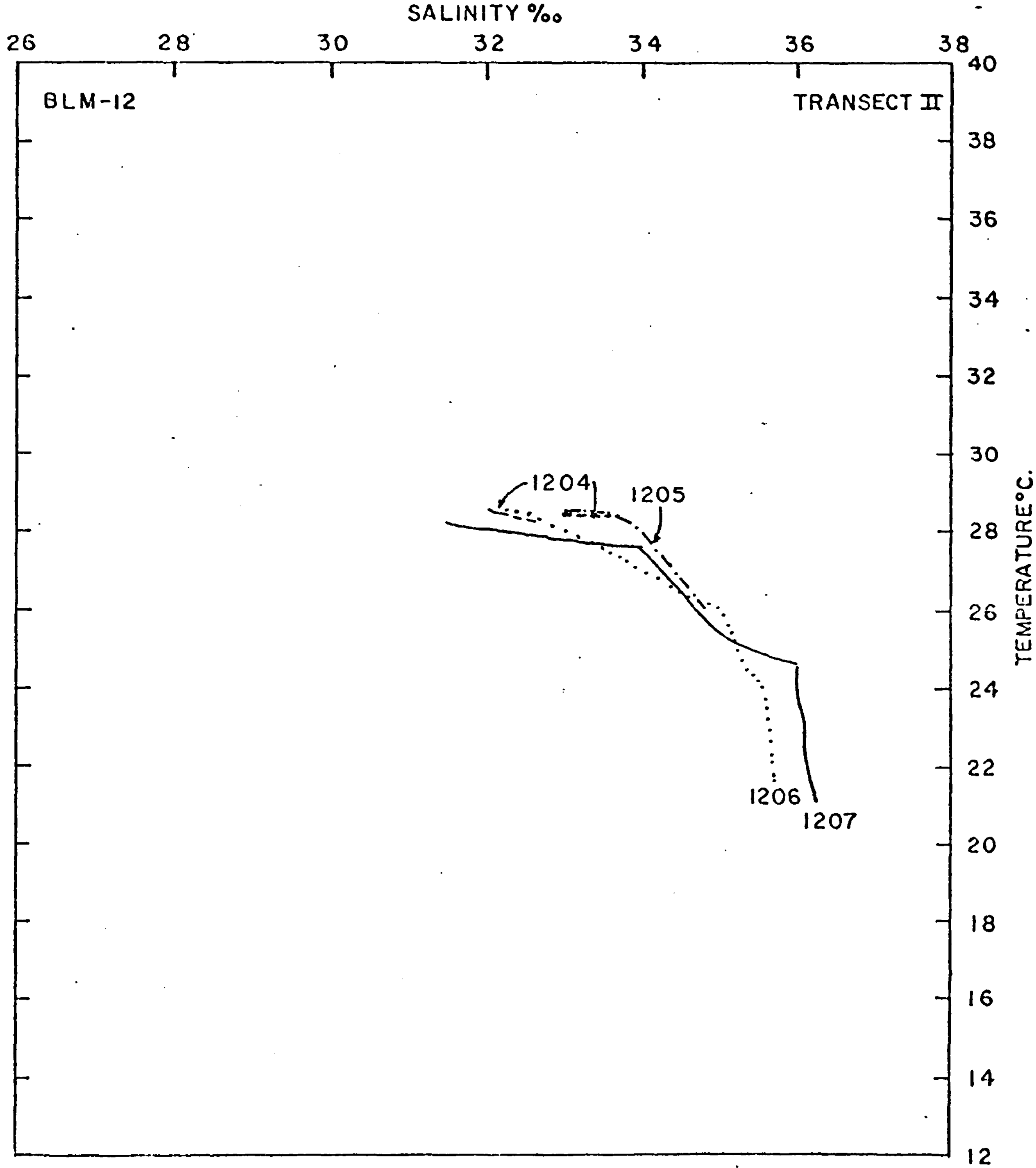


Figure 3. Temperature - Salinity (TS) Curves along TRANSECT II

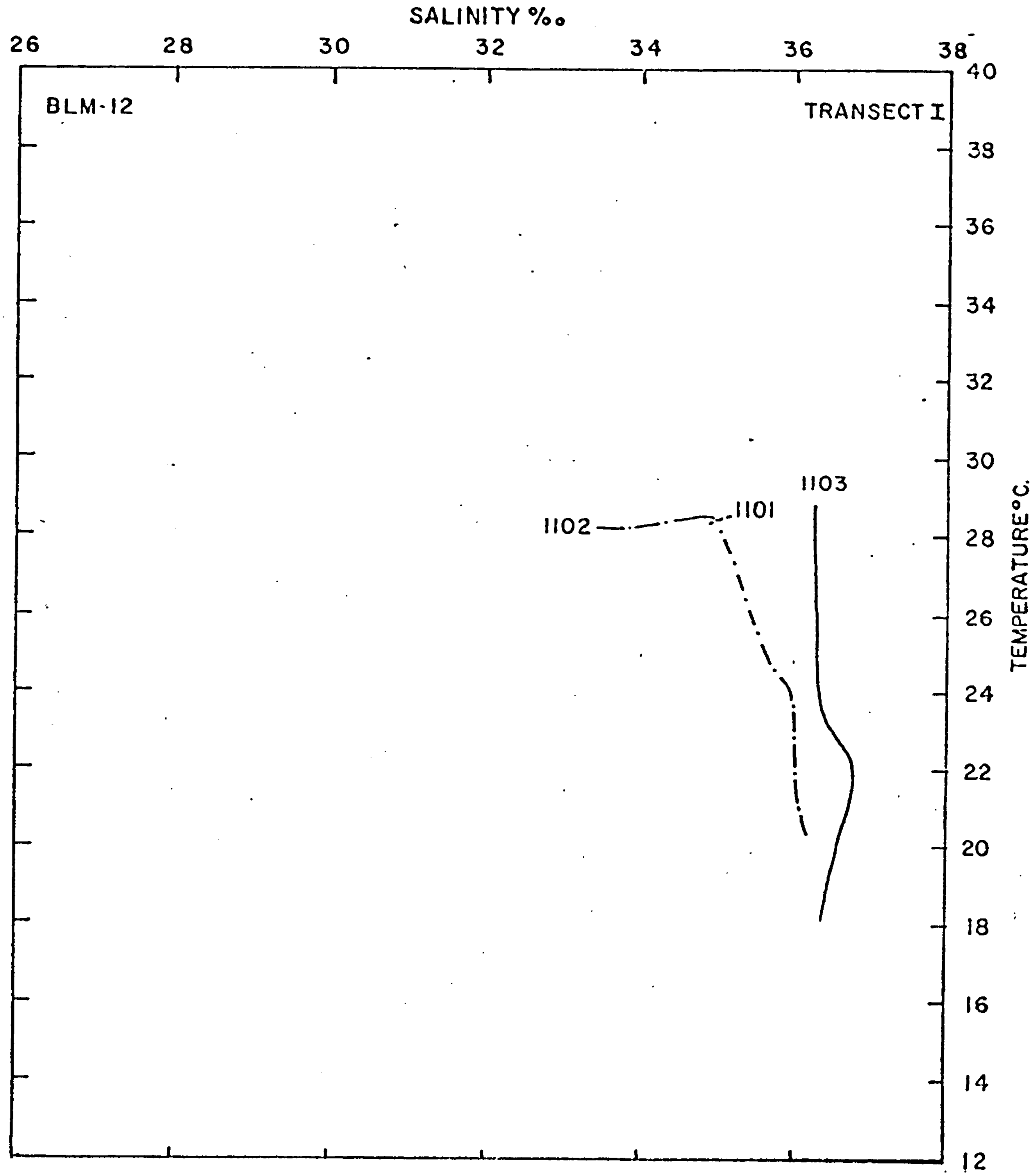


Figure 4. Temperature-Salinity (TS) Curves along TRANSECT I

APPENDIX III

Horizontal Distribution of Salinity $^{o}/oo$
at the Surface, 10 Meters, and Bottom
During
September 7 - October 2, 1975

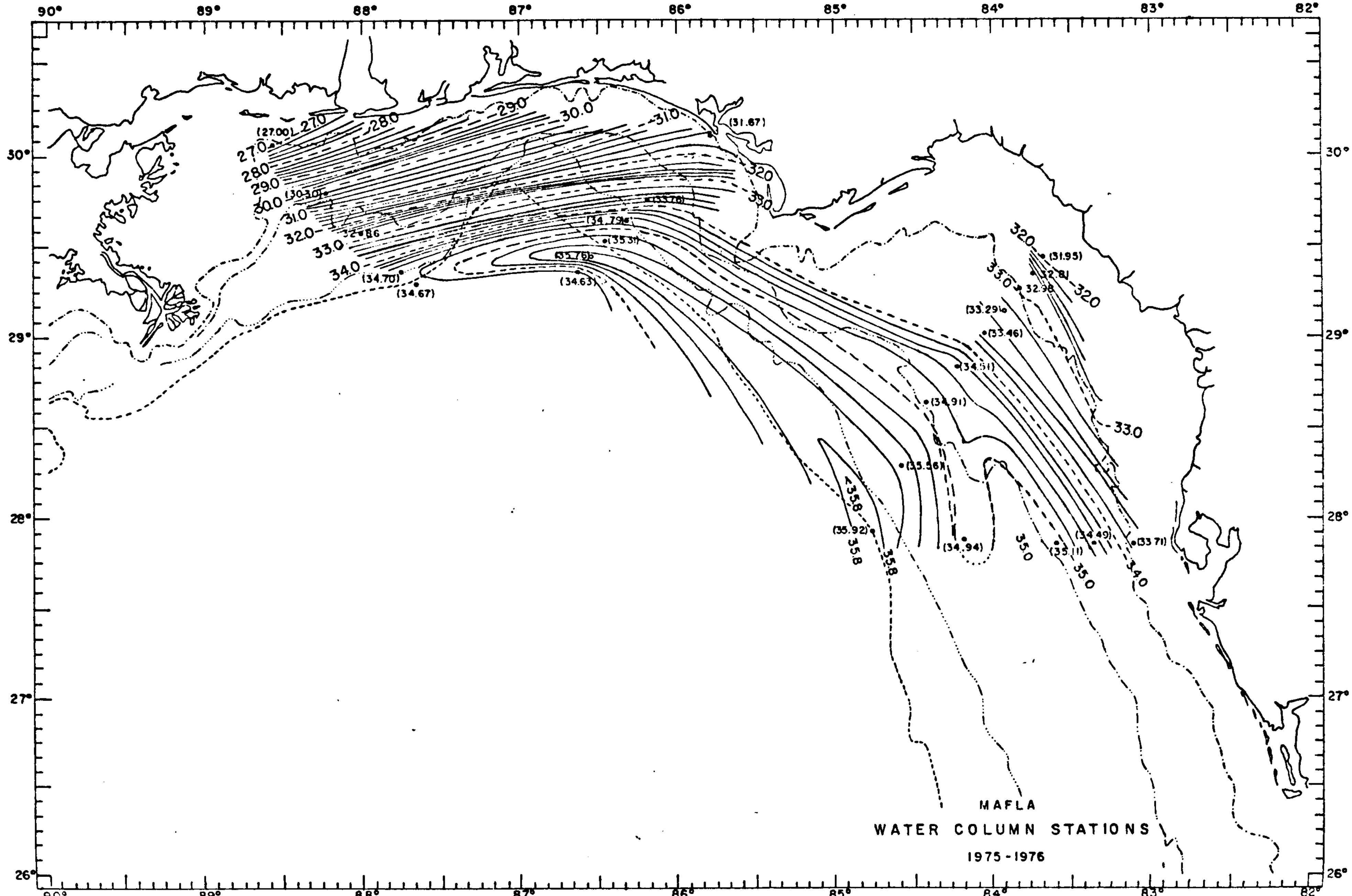


Figure 1. Surface Distribution Salinity ‰ BLM-20 SEPTEMBER 7 - OCTOBER 2, 1975

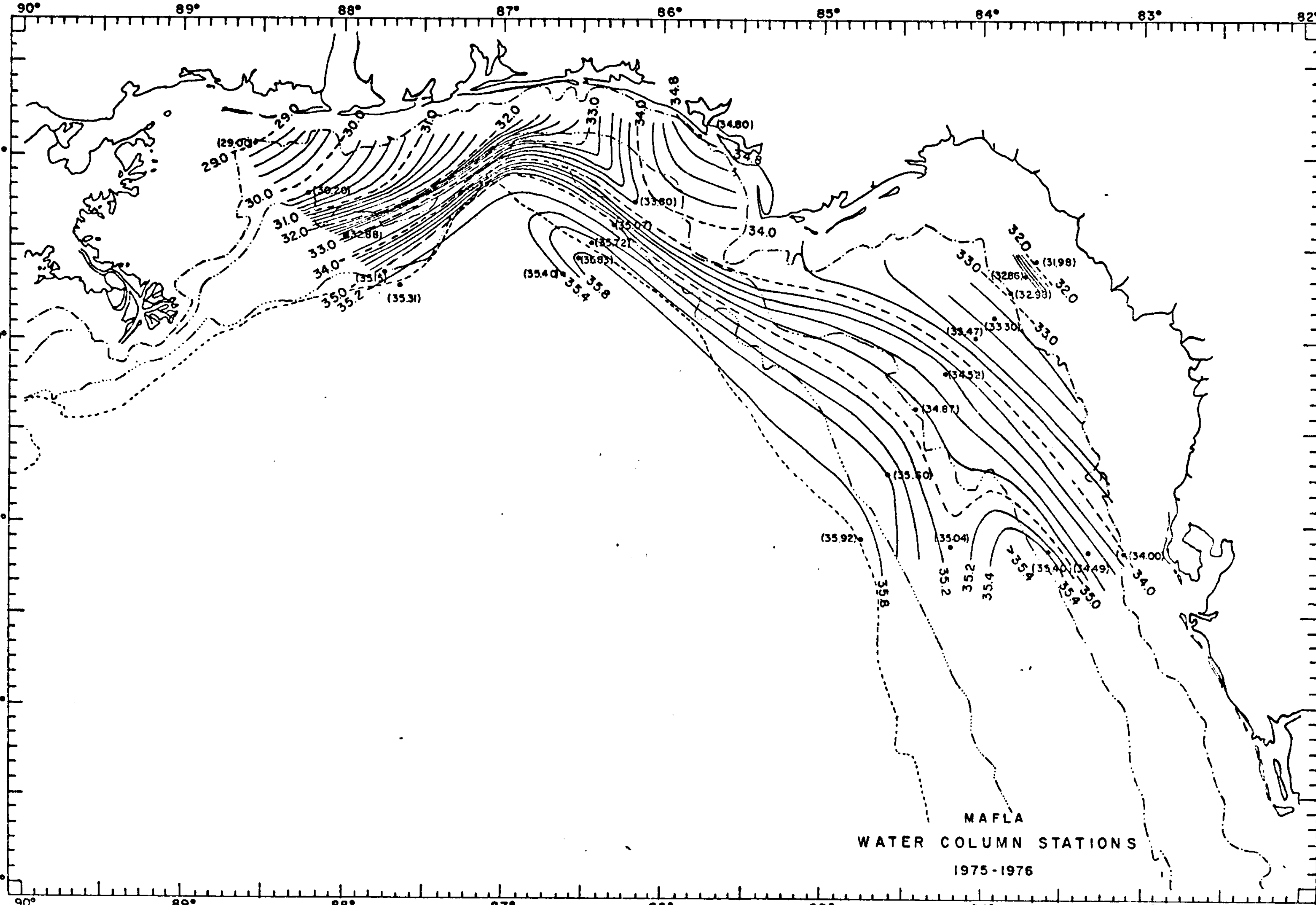


Figure 2. 10 Meter Distribution Salinity ‰ BLM-20 SEPTEMBER 7-OCTOBER 2, 1975

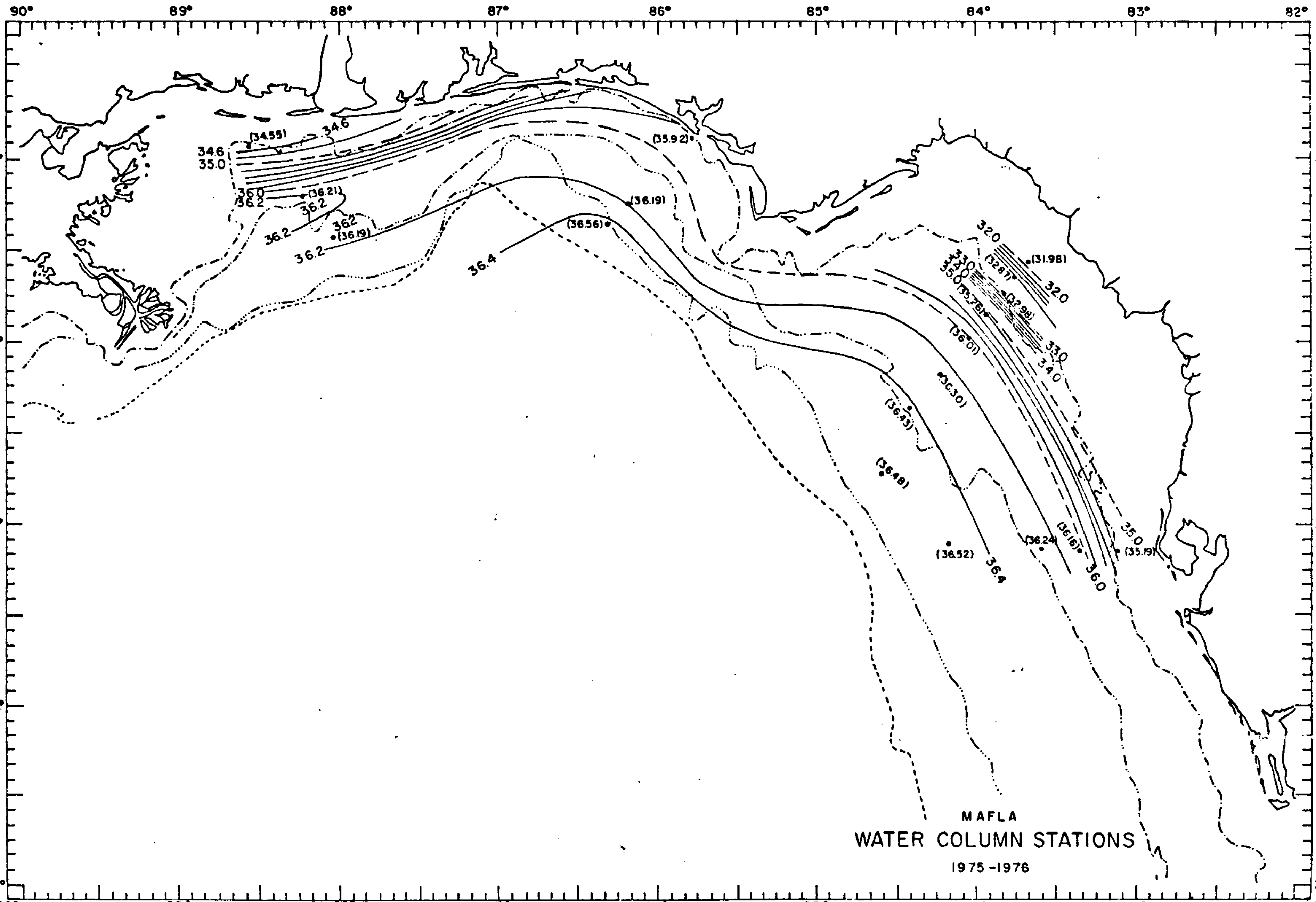


Figure 3. Bottom Distribution Salinity ‰ BLM-20 SEPTEMBER 7-OCTOBER 2, 1975.

BLM MAFLA DEMERSAL FISH SURVEY 1975-1976

Robert L. Shipp

See Stephen A. Bortone

90° W
40° N
PIEDMONT
95° W
35° N
MISS-AL
GULF COASTAL PLAIN
TEXAS-LOUISIANA SHELF
WESTERN GULF RISE
30° N
100° W
EAST MEXICO SHELF
25° N
100° W
EAST MEXICO