PARTICLE SIZES OF SANDS COLLECTED FROM THE BED OF THE AMAZON RIVER AND ITS TRIBUTARIES IN BRAZIL DURING 1982-84

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CONVERSION FACTORS

International System (SI) units used in this report may be converted to inch-pound units by using the following conversion factors:

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.28	foot
kilometer (km)	1.609	mile
liter (L)	0.2642	gallon (U.S.)
gram (g)	0.03527	ounce

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ABSTRACT

One hundred and nine samples of sand were collected at 28 cross sections of the Amazon River (Rio Solimões-Amazonas) and its tributaries between November 1982 and March 1984. Samples were collected with a US BM-54 sampler and were analyzed by standard sieving methods. Median diameters mostly ranged from 0.125 to 0.35 millimeter, with an overall median size of about 0.25 millimeter. Cross-channel variations in sand-particle size at individual cross sections were substantially greater than the slight downriver decrease in particle size that occurs through the 1,950-kilometer study reach. Sand waves on the bed of the Rio Amazonas at Óbidos have amplitudes as large as 10 to 12 meters.

INTRODUCTION

Samples of sand were collected from the bed of the Amazon River (Rio Solimões-Amazonas)[1/] and the lower reaches of some of the larger tributaries between November 1982 and March 1984 during cruises of research vessel Amanaí, in the 1,950-km reach of the river between Vargem Grande and Óbidos, Brazil. This report: (1) Describes the shipboard procedures for collecting and preserving the sand samples and the laboratory procedures for determining particle sizes; (2) lists the particle-size data; (3) gives a brief, noninterpretive description of the spatial variations in particle size; and (4) shows examples of the large sand waves that cover much of the bed of the Rio Solimões-Amazonas. Similar information for samples collected from the Rio Solimões-Amazonas and its tributaries during 1976-77 is given in two earlier reports by Nordin and others (1977, 1979). Information on suspended sediment collected from the Amazon River and its tributaries during 1982-84 is contained in the companion report by Meade (1985).

[1/] In Brazil, the Amazon River mainstem is called "Rio Solimões" between the Peru-Brazil border and Manaus, and "Rio Amazonas" between Manaus and the Atlantic Ocean.

The collection and analysis of the samples described in this report were ancillary activities of the first phase of the CAMREX program (Carbon in the Amazon River Experiment), funded mainly by Grant DEB-801-7522 from the U.S. National Science Foundation. CAMREX was initiated, organized, and led by Jeffrey E. Richey of the College of Ocean and Fisheries Science and the Quaternary Research Center of the University of Washington, Seattle. Other support for the program was provided by the following Brazilian organizations: Instituto Nacional de Pesquisas da Amazônia (INPA; Henrique Bergamin, Director), Centro de Energia Nuclear na Agricultura (CENA; Eneas Salati, Director) of the Universidade de São Paulo, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). We thank these people and organizations for their support. For their help in collecting the samples, our special thanks go to Captain Miguel R. de Souza, Engineer Adamor M. da Silva, and the crew of INPA research vessel Amanaí, and to Thomas Dunne and Allan Devol of the University of Washington. River-stage data were supplied by José Rayol and S. C. Conceição of Companhia de Pesquisas de Recursos Minerais (CPRM) and J. R. G. Natividade of Departamento Nacional de Aguas e Energia Elétrica (DNAEE).

SAMPLING LOCATIONS AND EQUIPMENT

The sand samples were collected at 13 cross sections of Rio Solimões, at 6 cross sections of Rio Amazonas, and at 9 cross sections of 7 major tributaries. The cross sections are shown in Figure 1 and listed, in downstream order, in table 1. The thalweg distances in table 1 are referred to Iquitos, Peru, so that the sample locations can be compared directly with those listed in the earlier reports of bed-material size (Nordin and others, 1977, 1979). Latitude and longitude of the midpoints of most of the cross sections were taken from the navigational charts of the Brazilian Navy (2d edition; scale 1:100,000). For cross sections of tributary rivers for which navigational charts were unavailable, coordinates were taken from side-looking radar mosaics (scale 1:250,000) produced by PROJETO RADAMBRASIL from imagery collected in 1971-72. Coordinates taken from these two sources usually agree within 0.5 minute.

Three or more samples of bed material were collected at most cross sections, usually at positions corresponding to 0.25, 0.5, and 0.75 of the channel width. Samples were collected during more than one cruise at several of the cross sections. The samples were collected during three periods of rising river stage and during one period immediately after the annual peak stage (fig. 2). The river discharges at the times of sampling are listed by Richey and others (in press).

All samples were collected with a standard US BM-54 sampler (Guy and Norman, 1970, p. 15) that was lowered to the bed of the river and retrieved by means of a hydraulic winch (Nordin and others, 1983, p. 1148-1150). The BM-54 sampler collects about 0.5 L of material off the top 5 cm of the river bed and brings it to the surface in a closed semicircular cavity. To avoid the large wire angles and the attendant sampling difficulties associated with the great depths and strong current velocities of the river, the boat was allowed to drift downriver with the current while the sampler was being lowered to the river bed.

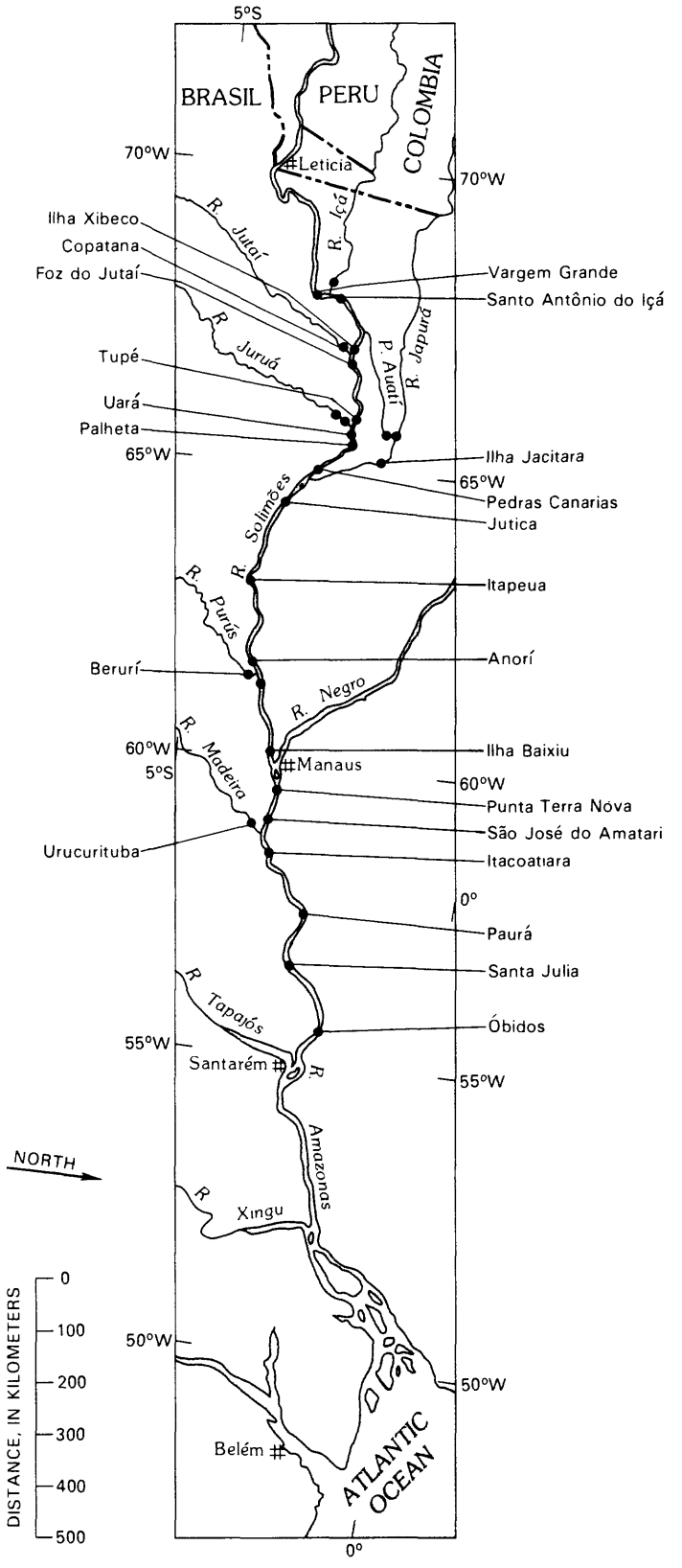

Figure 1. Locations from which bed-material samples were collected in 1982-84. Amazon River mainstem in Brazil is called "Rio Solimões" upriver of Manaus, and "Rio Amazonas" between Manaus and the Atlantic Ocean.

Table 1. Sampled sections on the Rio Solimões-Amazonas and its tributaries, listed in downstream order. (km, kilometer; DNAEE, Departamento Nacional de Aguas e Energia Elétrica)

River and sampling section	Thalweg distance below Iquitos, Peru (km)	South latitude	West longitude	Brazilian Naval chart (and year published)	RADAM Mosaic	Fluvial setting
Rio Solimões at Vargem Grande	881	3°16.7′	67°55.7′	4113A (1980)		17 km above mouth of Rio Içá. Near crest of bend; right bank concave.
Rio Içá, 20 km above mouth	--	3°06.4′	68°06.8′	4113A (1980)		Midpoint of meander limb.
Rio Solimões below Santo Antônio do Içá	909	3°02.2′	67°53.4′	4113A (1980)		DNAEE section; 14 km below mouth of Rio Içá. Straight reach.
Rio Solimões at Ilha Xibeco	1065	2°43.1′	66°55.6′	4112B (1980)		22 km above mouth of Rio Jutaí. Midpoint of meander limb; downriver of large island.
Rio Jutaí at Copatana	--	2°50.7′	66°55.8′		SA19ZB	DNAEE section; 20 km above mouth.
Rio Solimões below Foz do Jutaí	1100	2°41.1′	66°39.4′	4112A (1980)		13 km below mouth of Rio Jutaí. Straight reach.
Rio Solimões below Tupé	1266	2°30.0′	65°50.5′	4111B (1979)		17 km above mouth of Rio Juruá Crest of gentle bend; left bank concave.
Rio Juruá, 23 km above mouth	--	2°44.5′	65°46.4′		SA20YA	Crest of bend; left bank concave.
Rio Juruá, 16 km above mouth	--	2°41.9′	65°47.5′		SA20YA	Straight reach.
Rio Solimões at Uará	1302	2°39.4′	65°35.0′	4111B (1979)		19 km below mouth of Rio Juruá. Crest of gentle bend; right bank concave.
Rio Solimões at Palheta	1327	2°30.4′	65°25.6′	4111B (1979)		44 km below mouth of Rio Juruá. Downriver limb of broad bend; right bank concave.
Rio Solimões at Pedras Canarias	1499	3°05.7′	64°55.0′	4111A (1979)		14 km above main mouth of Rio Japurá. Straight reach.
Rio Japurá, 3 km above Paraná Auatí	--	1°48.5′	65°43.5′		SA20VC	Straight braided reach.
Paraná Auatí, 17 km above Rio Japurá	--	1°57.3′	65°43.8′		SA20VC	Fairly straight reach.
Rio Japurá at Ilha Jacitara	--	1°55.0′	65°16.4′		SA20VC	180 km above mouth. Below crest of bend; left bank concave.

Rio Solimões at Jutica	1573	3°34.8′	64°17.6	4109B (1979)		Straight reach.
Rio Solimões below Itapeua	1750	4°01.8′	62°59.8′	4108B (1979)		5 km below DNAEE section. Fairly straight reach (meander limb).
Rio Solimões at Anorí	1944	3°48.3′	61°37.9′	4108A (1979)		22 km above mouth of Rio Purús. Below crest of gentle bend; right bank concave.
Rio Purús below Berurí	--	3°51.2′	61°23.0′		SA20ZD	22 km above mouth. Straight reach, 3 km below crest of 90° bend.
Rio Solimões, 22 km below Rio Purús	1988	3°35.8′	61°18.3′	4107B (1979)		Fairly straight reach, between two large islands.
Rio Solimões at Ilha Baixiu	2146	3°17.8′	60°03.1′	4107A (1979)		30 km above confluence with Rio Negro. Straight reach.
Rio Amazonas at Punta Terra Nova	2196	3°03.7′	59°44.0′	4106B (1970)		20 km below Solimões-Negro confluence. Dunes at this locality described by Sioli (1965).
Rio Amazonas above São José do Amatari	2292	3°14.2′	59°00.3′	4106A (1970)		30 km above mouth of Rio Madeira. Crest of broad bend; left bank concave.
Rio Madeira at Urucurituba	--	3°32.5′	58°54.8′	4501A (1982)		28 km above mouth. Straight reach; downriver of large island.
Rio Amazonas at Itacoatiara	2367	3°09.7′	58°26.0′	4106A (1970)		45 km below mouth of Rio Madeira. Below crest of broad bend; left bank concave.
Rio Amazonas at Costa do Paurá	2542	2°23.0′	57°26.8′	4105A (1970)		Crest of large bend; left bank concave.
Rio Amazonas at Santa Julia	2686	2°25.0′	56°27.7′	4104B (1972)		Downriver limb of large bend; right bank concave.
Rio Amazonas at Óbidos	2827	1°56.2′	55°30.5′	4104A (1972)		DNAEE section. Below crest of broad bend; left bank concave (see Figure 5).

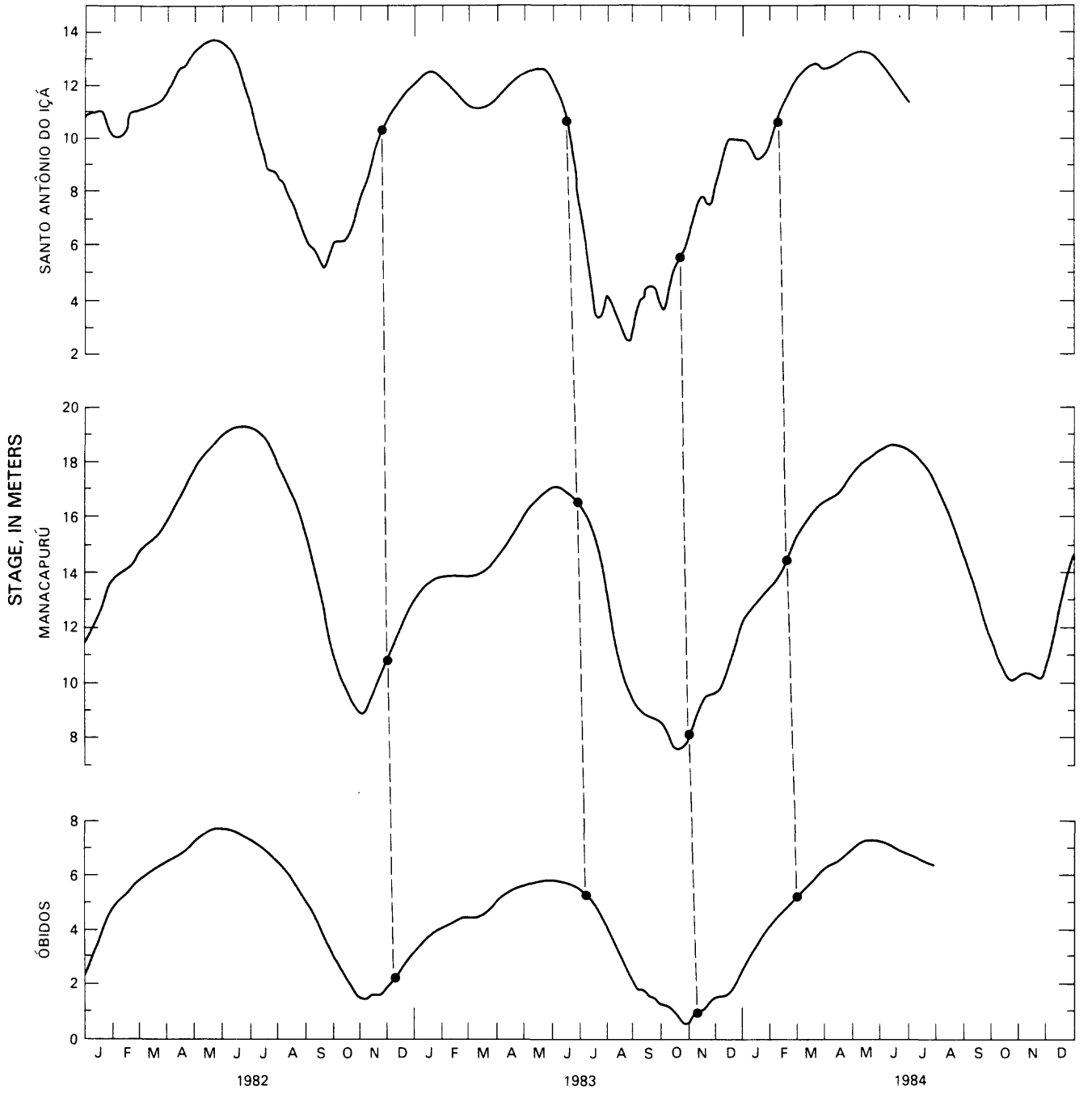

Figure 2.--Daily river stages at three gages on the Rio Solimões-Amazonas, showing (by solid circles and dashed lines) dates of four cruises during which bed-material samples were collected, 1982-84. Stage data were provided by J. Rayol, S. C. Conceição, J. R. G. Natividade and by local observers: Antônio and Analisa Fereira (Santo Antônio do Içá), Raimundo A. de Oliveira (Manacapurú), Francisco S. and Raimundo S. Nunes (Óbidos). The Manacapurú gage is about 60 km upriver of Ilha Baixiu. River stages are not referenced to the same datum at all three gages.

PROCESSING OF SAMPLES

All samples were emptied directly from the sampler into plastic bags. Most of the excess water was poured out of the bags; we were careful not to elutriate micas and small mineral grains in the process. Most samples were partially dried aboard ship by leaving them on deck for several hours in the sun. They were then wrapped for shipment to the laboratory.

Particle sizes were determined in the sediment laboratory of the Department of Geological Sciences at the University of Washington in Seattle. The sand samples were dried in their plastic bags for 2 to 3 days in an oven at 50° C. Each sample was then poured over a splitter and divided until a representative fraction of 50 to 100 g was available for particle-size analysis. All samples were sieved through a standard set of 20-cm sieves. Each sample was shaken mechanically on a Ro-tap[2/] machine for 15 minutes, and the weight of the material retained in each sieve and in the pan was recorded to the nearest 0.01 g.

PARTICLE-SIZE DETERMINATIONS

Results of the particle-size analyses of 109 sands from the bed of the Rio Solimões-Amazonas and its tributaries are listed in table 2. Median diameters of 83 percent of the samples fall into the categories of fine sand (0.125 to 0.25 mm) and medium sand (0.25 to 0.5 mm). The average of all 109 median diameters is about 0.25 mm.

DOWNRIVER AND CROSS-RIVER CHANGES IN PARTICLE SIZE

Nordin and others (1980, 1981) reported no overall downriver change in the particle sizes of sands collected during 1977 from the bed of the Rio Solimões-Amazonas. However, when they considered only the sands from a single hydraulic environment (crossings between meanders), they discerned a slight decrease in median size in the downriver direction. When our results are plotted on the same scale, using only the samples collected at midriver in each mainstem cross section, a slight downstream decrease in median size also is discernible (fig. 3).

The slight downriver decrease in median size, however, is much less than the local cross-channel change in particle size at many individual cross sections. Cross-channel changes in particle size are most obvious at sections located on channel bends (fig. 4, left). Even more pronounced changes have been observed at bends on tributary channels (fig 4, right). Perhaps some mechanism analogous to that described in a meander of a small river (Dietrich and Smith, 1984) is causing strong cross-channel gradients of sand-particle size in bends of these large rivers.

[2/] Trade name is used for identification purposes only, and does not imply any endorsement by the U.S. Geological Survey or the University of Washington.

Table 2. Particle size, determined by sieving, of sands collected from bed of the Rio Solimões-Amazonas and its tributaries. (DNAEE, Departamento Nacional de Aguas e Energia Elétrica)

Location in cross section (Fraction of distance between left and right banks)	Date of sampling	Depth of water (meters)	Percent finer than indicated size, in millimeters											Median diameter (millimeters)
			0.063	0.088	0.125	0.177	0.250	0.350	0.500	0.707	1.00	1.41	2.00	2.80	
RIO SOLIMÕES AT VARGEM GRANDE															
0.2	02/14/84	15	2.0	2.6	12.6	67.1	98.7	100							0.16
0.25	11/27/82	15	0.2	2.0	27.6	95.5	96.5	99.9	100						.14
0.25	10/26/83	10	2.0	2.1	24.0	69.7	96.9	99.9	100						.15
0.4	02/14/84	22	1.0	1.0	7.9	55.0	93.9	99.8	100						.17
0.5	11/27/82	23	0.3	0.6	1.5	8.5	46.5	93.8	99.7	100					.26
0.5	10/26/83	20	1.0	1.1	2.1	3.7	18.8	86.4	98.1	99.9	100				.30
0.65	02/14/84	27	1.0	1.1	8.7	43.8	89.4	99.6	99.9	100					.19
RIO IÇÁ, 20 KILOMETERS ABOVE MOUTH															
0.25	11/28/82	10	1.0	2.2	11.6	55.2	83.5	98.5	99.9	100					.17
0.5	11/28/82	16	0.0	0.2	0.7	4.7	22.5	85.5	99.7	100					.29
0.75	11/28/82	17		0.0	0.1	0.4	1.4	15.5	72.5	96.4	99.4	99.8	99.9	99.9	.44
RIO SOLIMÕES BELOW SANTO ANTÔNIO DO IÇÁ (DNAEE SECTION)															
0.15	11/29/82	23		0.0	5.6	50.0	97.3	99.7	99.9	100					.18
0.25	11/29/82	19		0.0	0.4	2.8	21.5	48.5	90.8	99.6	99.9	100			.36
0.5	11/29/82	12	0.0	0.1	1.7	11.7	46.3	95.2	99.8	100					.26
0.75	11/29/82	21	0.0	0.2	0.8	6.2	47.2	98.6	100						.26
RIO SOLIMÕES AT ILHA XIBECO															
0.25	11/30/82	26		0.0	0.2	1.4	9.7	53.7	89.6	98.7	99.5	99.7	99.7	99.8	.34
0.5	11/30/82	19	2.0	2.0	13.3	63.1	97.3	99.8	99.9	100					.16
0.75	11/30/82	22	0.0	0.1	5.9	61.3	98.1	99.9	99.9	100					.17
RIO JUTAÍ AT COPATANA (DNAEE SECTION)															
0.2	11/30/82	22	0.0	0.2	3.8	11.4	31.9	81.1	96.8	99.5	99.9	100			.29
0.75	11/30/82	11	0.0	0.1	0.3	1.4	14.8	66.2	92.6	98.1	98.9	99.2	99.2	99.4	.32
RIO SOLIMÕES BELOW FOZ DO JUTAÍ															
0.25	11/30/82	21	1.0	1.1	7.9	44.2	94.9	99.9	100						.18
0.5	11/30/82	32		0.0	2.0	13.6	62.4	98.1	100						.23
0.75	11/30/82	17	0.0	0.4	3.6	16.4	40.4	90.3	98.9	99.9	100				.27

RIO SOLIMÕES BELOW TUPÉ

0.25	12/01/82	26	1.0	1.1	3.9	15.0	43.6	97.9	99.9	100					.26
0.5	12/01/82	26		0.0	0.4	3.2	11.8	40.8	81.2	95.5	98.3	99.1	99.7	99.9	.38
0.75	12/01/82	25		0.0	0.6	3.2	10.6	24.1	64.9	96.0	99.2	99.5	99.5	99.6	.44

RIO JURUÁ, 23 KILOMETERS ABOVE MOUTH

0.25	02/18/84	18	0.0	0.1	0.6	1.5	2.7	8.3	24.2	46.6	74.3	88.2	94.6	97.0	.74
0.5	02/18/84	14	1.0	1.2	3.7	30.1	75.6	98.6	100						.21
0.75	02/18/84	10	0.0	0.2	4.0	38.1	61.7	94.6	99.6	100					.21

RIO JURUÁ, 16 KILOMETERS ABOVE MOUTH

0.25	12/01/82	13	0.2	0.3	0.9	5.2	12.4	54.3	85.5	97.1	99.3	99.7	99.8	99.9	.34
0.5	12/01/82	13	0.3	0.4	1.3	20.3	43.0	82.0	96.6	99.5	99.8	100			.27
0.75	12/02/82	12	0.2	0.4	1.2	25.6	29.2	82.8	97.2	99.7	100				.29

RIO SOLIMÕES AT UARÁ

0.25	12/02/82	22	0.0	0.1	0.7	2.0	5.7	51.1	94.9	99.7	99.9	99.9	100		.35
0.5	12/02/82	30	0.0	0.2	0.8	2.5	10.8	30.6	58.6	94.3	99.1	99.7	99.9	100	.45

RIO SOLIMÕES AT PALHETA

0.25	07/01/83	12	1.5	2.3	16.2	70.6	95.0	99.8	99.9	99.9	100				.16
0.5	07/01/83	29	0.0	0.1	0.7	5.3	36.4	78.1	91.6	96.2	98.2	99.3	99.8	100	.28
0.8	07/01/83	27	0.0	0.1	0.4	2.5	14.0	52.8	81.0	92.1	97.6	99.2	99.8	100	.34

RIO SOLIMÕES AT PEDRAS CANARIAS

0.25	12/02/82	22	1.0	1.4	6.4	35.1	76.6	97.9	99.9	100					.20
0.5	12/02/82	20	1.0	1.4	4.7	19.2	48.3	90.6	99.5	100					.25
0.8	12/02/82	26	1.0	4.1	20.1	65.5	79.2	87.8	98.4	99.9	100				.16

RIO JAPURÁ, 3 KILOMETERS ABOVE PARANA AUATÍ

0.25	06/24/83	15		0.0	0.3	2.6	20.4	56.8	78.1	91.1	96.8	99.0	99.8	100	.33
0.5	06/24/83	13	1.0	1.5	4.2	15.9	42.2	76.8	91.0	97.0	98.9	99.7	100		.27
0.8	06/24/83	8		0.0	0.8	4.9	16.9	41.6	63.2	80.4	90.3	95.7	98.2	99.2	.41

PARANA AUATÍ, 17 KILOMETERS ABOVE RIO JAPURÁ

0.5	06/24/83	15		0.0	0.4	4.8	46.2	93.0	99.3	99.7	99.8	99.8	100		.26
0.5	02/11/84	12	3.8	3.8	4.1	5.8	32.0	84.6	98.5	99.8	99.9	100			.28

Table 2. Particle size, determined by sieving, of sands collected from bed of the Rio Solimões-Amazonas and its tributaries--continued.

Location in cross section (Fraction of distance between left and right banks)	Date of sampling	Depth of water (meters)	Percent finer than indicated size, in millimeters												Median diameter (millimeters)
			0.063	0.088	0.125	0.177	0.250	0.350	0.500	0.707	1.00	1.41	2.00	2.80	
RIO JAPURÁ AT ILHA JACITARA															
0.25	06/23/83	28			0.0	0.1	0.4	2.2	12.2	37.3	61.7	81.3	92.5	96.3	0.86
0.25	02/10/84	27			0.0	0.1	0.3	2.7	25.8	63.3	85.6	94.9	98.8	99.6	.63
0.5	06/23/83	26		0.0	0.1	0.9	10.5	78.4	96.7	99.7	99.9	99.9	100		.31
0.5	02/10/84	25		0.0	0.1	0.5	3.1	63.4	95.7	99.5	99.9	100			.33
0.75	06/23/83	18		0.0	4.3	46.3	98.0	100							.18
0.75	02/10/84	21	2.0	2.0	10.0	43.4	87.6	99.6	100						.19
RIO SOLIMÕES AT JUTICA															
0.25	12/03/82	19	1.0	4.8	35.2	92.9	99.9	100							.14
0.5	12/03/82	25	1.0	2.2	9.5	36.9	77.3	99.5	99.9	100					.20
0.75	12/03/82	8	0.0	0.1	0.7	5.0	43.9	94.4	99.2	99.9	100				.26
RIO SOLIMÕES BELOW ITAPEUA															
0.25	12/05/82	40	2.5	20.0	60.1	92.1	99.3	99.9	99.9	100					.12
0.25	02/22/84	36	3.9	21.4	76.2	98.0	99.9	100							.11
0.5	12/05/82	43	0.0	1.5	15.1	83.0	99.1	99.8	99.9	100					.15
0.5	11/03/83	40	0.0	0.1	8.8	78.1	99.6	99.9	99.9	100					.16
0.5	02/22/84	44	23.8	39.3	83.2	99.0	99.8	99.9	100						.10
0.75	12/05/82	43	0.0	0.8	5.8	28.0	76.9	96.4	99.9	100					.21
0.75	11/03/83	38	5.6	5.6	5.7	5.9	7.1	48.4	97.2	99.9	100				.35
0.75	02/22/84	46		0.0	0.2	1.3	14.5	62.1	96.5	100					.32
RIO SOLIMÕES AT ANORÍ															
0.25	12/06/82	23	2.9	3.4	6.2	16.5	57.9	98.8	100						.24
0.5	12/06/82	29		0.0	0.7	4.2	25.3	64.5	86.2	94.6	98.4	99.7	99.9	100	.31
0.75	12/06/82	31		0.0	1.6	6.8	22.8	67.4	95.3	98.5	99.6	99.9	99.9	100	.31
0.85	12/06/82	29	0.0	0.2	1.3	3.3	7.8	19.8	37.7	71.2	90.2	97.0	99.2	99.9	.58
RIO PURÚS BELOW BERURÍ															
0.25	12/06/82	30	8.1	10.8	18.2	91.6	98.0	99.1	99.3	99.5	99.7	99.8	99.9	100	.15
0.25	02/23/84	31	2.9	3.3	36.6	93.6	99.8	100							.14
0.5	12/06/82	35	1.8	2.1	2.7	24.1	68.6	99.4	99.9	100					.22
0.5	02/23/84	39	1.0	1.1	1.9	29.5	88.4	99.8	100						.20
0.75	12/06/82	37	2.0	2.2	2.5	3.6	3.9	44.9	92.9	99.3	99.9	100			.36

RIO SOLIMÕES, 22 KILOMETERS BELOW RIO PURÚS

0.25	12/06/82	36	0.0	0.1	0.1	16.9	20.9	78.4	98.8	99.6	99.9	100			.30
0.5	12/06/82	39	0.2	0.6	3.0	12.0	64.1	97.6	100						.23
0.75	12/06/82	7	0.2	0.9	4.4	8.3	56.8	99.5	100						.24

RIO SOLIMÕES AT ILHA BAIXIU

0.2	12/07/82	19	0.0	0.2	2.8	9.4	45.3	96.4	99.8	100					.26
0.5	12/07/82	29		0.0	1.2	10.7	55.1	95.4	99.5	99.9	100				.24
0.75	12/07/82	41	0.0	0.5	2.1	6.9	30.5	79.1	93.1	96.3	97.9	98.8	99.5	99.7	.29

RIO AMAZONAS AT PUNTA TERRA NOVA

0.25	12/09/82	74		0.0	0.2	0.6	4.5	81.1	98.9	99.9	100				.31
0.5	12/09/82	13	0.9	1.5	5.9	23.0	75.6	99.8	100						.21
0.75	12/09/82	12		0.0	1.7	32.7	77.7	99.4	99.9	99.9	100				.20

RIO AMAZONAS ABOVE SÃO JOSÉ DO AMATARI

0.5	12/10/82	63	1.0	2.0	17.8	53.2	74.2	84.2	93.7	97.6	98.7	99.4	99.9	100	.17
0.65	12/10/82	48	1.0	2.3	11.1	31.1	51.1	87.2	94.9	97.9	99.1	99.7	99.9	100	.24
0.85	12/10/82	29		0.0	0.2	0.4	13.6	75.3	98.4	99.9	100				.31

RIO MADEIRA AT URUCURITUBA

0.25	12/11/82	21	9.2	34.2	82.0	93.2	95.5	99.4	100						.10
0.25	07/11/83	19	2.0	3.0	24.2	51.2	76.6	97.8	99.8	100					.17
0.25	11/11/83	16	9.1	14.1	63.7	97.3	98.7	99.6	99.8	99.9	100				.11
0.3	03/01/84	35	0.0	0.5	4.1	21.0	46.7	93.7	99.7	100					.26
0.45	03/01/84	36	1.0	1.0	7.4	17.8	34.8	66.1	81.1	89.5	94.6	97.8	99.4	100	.30
0.5	12/11/82	33	13.0	54.5	88.3	98.0	98.7	99.7	99.9	100					.08
0.5	07/11/83	40	2.0	2.0	2.5	9.7	39.5	87.8	97.8	99.1	99.5	99.7	99.9	99.9	.27
0.5	11/11/83	34	6.3	7.4	10.8	18.7	44.6	93.2	99.3	99.7	99.8	99.8	99.9	100	.26
0.75	12/11/82	18	11.8	59.8	93.3	99.1	99.2	99.7	99.9	99.9	100				.08
0.75	07/11/83	20	0.0	0.8	20.0	79.3	96.4	99.6	99.9	100					.14
0.8	03/01/84	25	2.0	13.0	54.0	97.2	99.9	100							.12

RIO AMAZONAS AT ITACOATIARA

0.25	12/11/82	52	0.4	1.8	9.6	50.9	86.2	99.4	99.9	100					.18
0.5	12/11/82	38	1.6	1.7	38.7	94.5	97.1	99.8	99.9	100					.16
0.75	12/11/82	30	15.6	55.2	92.2	99.7	99.8	100							.08

RIO AMAZONAS AT COSTA DO PAURÁ

0.25	12/12/82	62	3.8	4.0	5.2	15.7	53.3	88.1	98.1	99.5	99.8	99.9	100		.24
0.5	12/12/82	44	2.0	2.1	21.7	71.4	98.2	99.8	99.9	100					.15
0.75	12/12/82	37	43.5	70.0	97.9	99.8	99.9	100							.07

Table 2. Particle size, determined by sieving, of sands collected from bed of the Rio Solimões-Amazonas and its tributaries--continued.

Location in cross section (Fraction of distance between left and right banks)	Date of sampling	Depth of water (meters)	Percent finer than indicated size, in millimeters												Median diameter (millimeters)
			0.063	0.088	0.125	0.177	0.250	0.350	0.500	0.707	1.00	1.41	2.00	2.80	
RIO AMAZONAS AT SANTA JULIA															
0.15	12/14/82	18	1.0	4.2	27.7	94.9	99.9	100							0.14
0.75	12/14/82	50	0.0	0.1	3.1	20.4	41.6	99.4	100						.26
RIO AMAZONAS AT ÓBIDOS (DNAEE SECTION)															
0.2	03/04/84	53		0.0	0.1	1.1	3.9	15.1	56.6	90.2	98.3	99.6	100		.48
0.25	12/13/82	53	0.1	0.5	3.3	46.3	86.9	98.2	99.8	99.9	100				.18
0.25	11/15/83	60		0.0	0.5	6.7	19.5	39.4	67.0	87.9	95.8	98.7	99.7	100	.41
0.5	12/13/82	53	1.9	8.2	25.2	81.5	94.7	99.5	99.9	99.9	100				.15
0.5	11/15/83	52	11.8	12.3	63.2	93.3	99.5	100							.12
0.5	03/04/84	56	3.8	18.1	74.7	98.9	99.7	99.8	99.9	100					.11
0.75	03/04/84	56	3.1	18.3	84.4	99.4	99.9	100							.11
0.8	12/13/82	45	42.6	80.7	98.4	99.8	99.8	100							.08

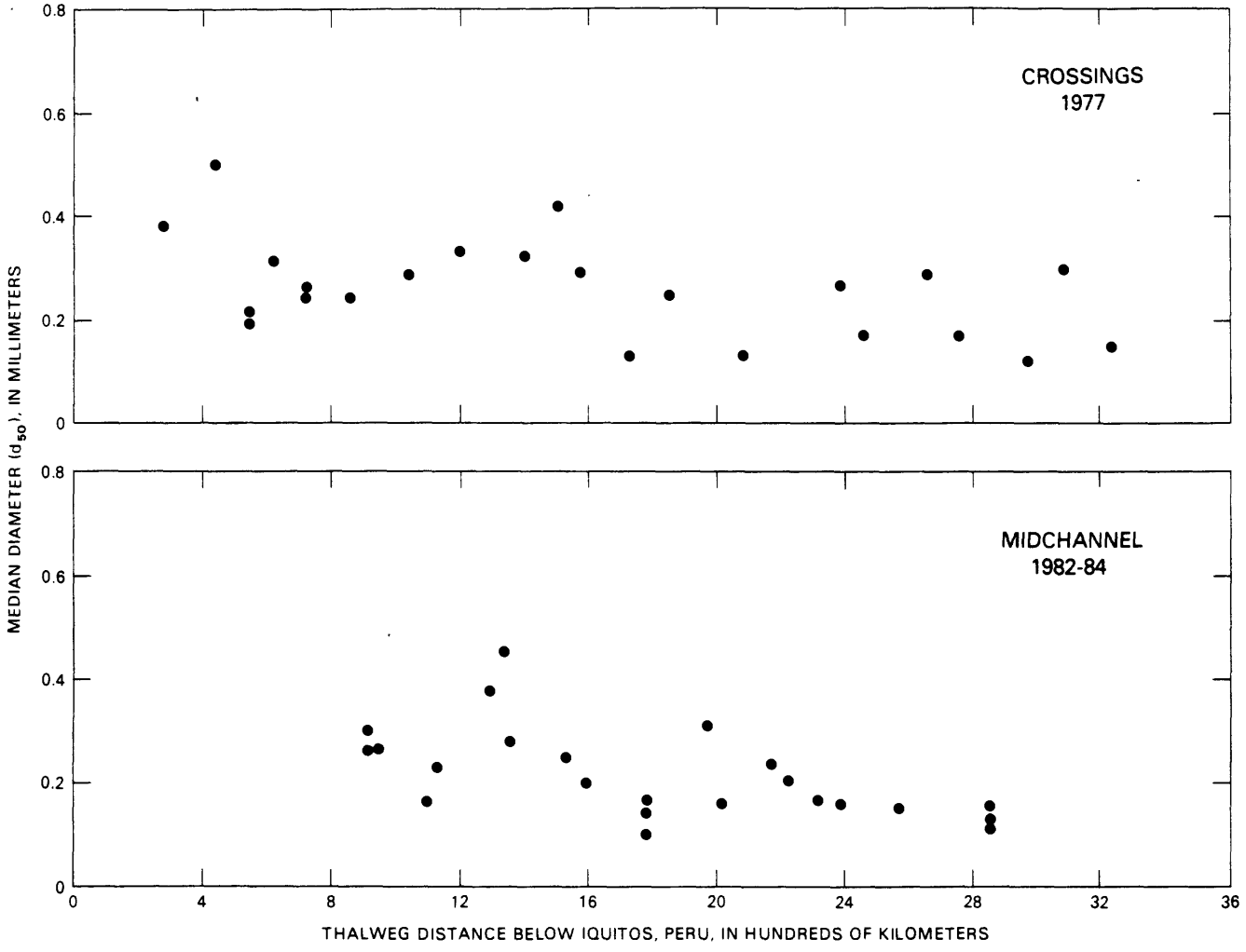

Figure 3. Downriver changes in median particle size of sands on bed of Rio Solimões-Amazonas. Upper graph: at crossings between meanders, 1977 (Nordin and others, 1980, 1982). Lower graph: at midchannel, 1982-84 (this report, table 2).

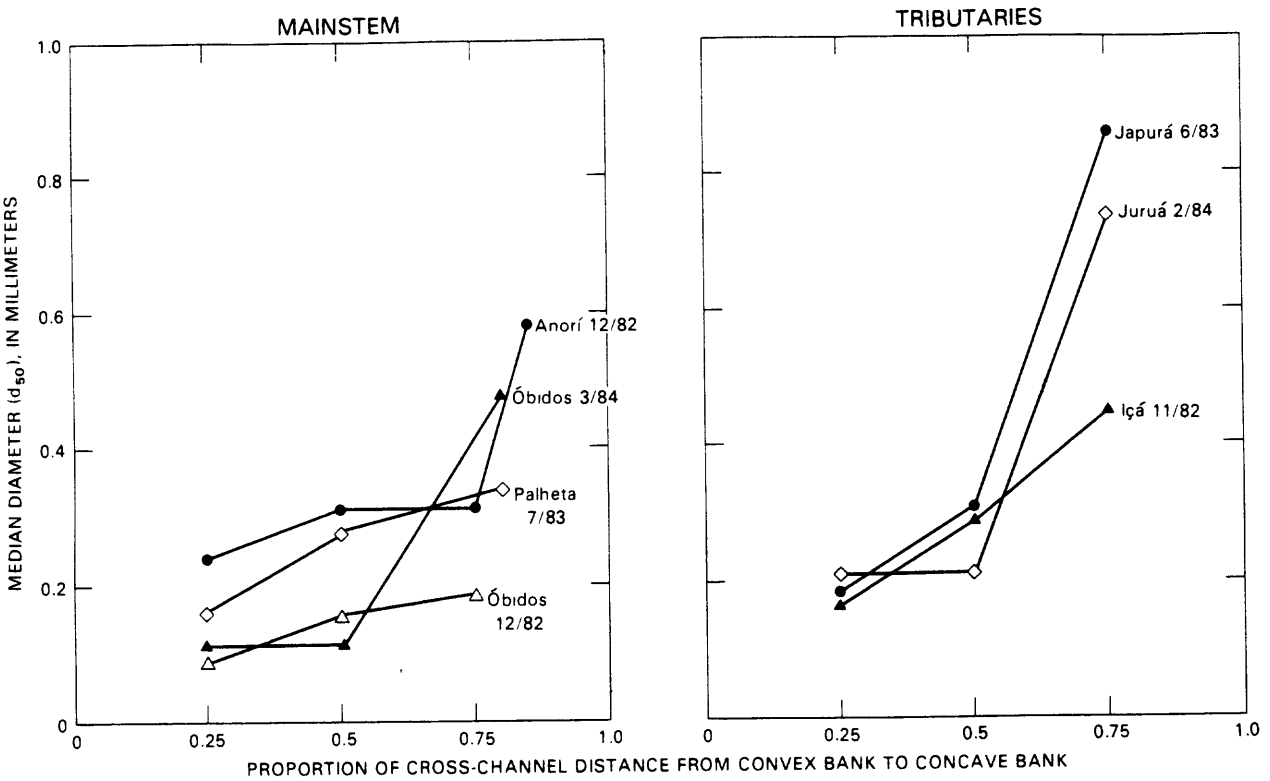

Figure 4. Cross-channel changes in median particle size of sands collected at bends in Rio Solimões-Amazonas (left graph) and in selected tributaries (right graph), 1982-84.

SAND WAVES

Sand-wave size also increases from the convex bank to the concave bank in bends of the Rio Solimões-Amazonas and its tributaries. Sand waves of varying sizes are prevalent on the bed of the river (Nordin and others, 1979, table 1). On bends of the river, sand waves generally have greater amplitudes on the outer part of the bend (nearer the concave bank) than on the inner part (nearer the convex bank). Sand waves observed in March 1984 at the Óbidos section, on the downriver limb of a large bend, are shown in figure 5. On the right side of the channel, the sand waves (if there were any) were too small to resolve at this scale; those in midchannel had amplitudes of 4 to 5 m; those along the left side of the channel had amplitudes of 10 to 12 m. Sand waves with amplitudes of 8 to 12 m have been reported previously on the bed of Rio Amazonas by Sioli (1965) and Irion (1976, p. 72).

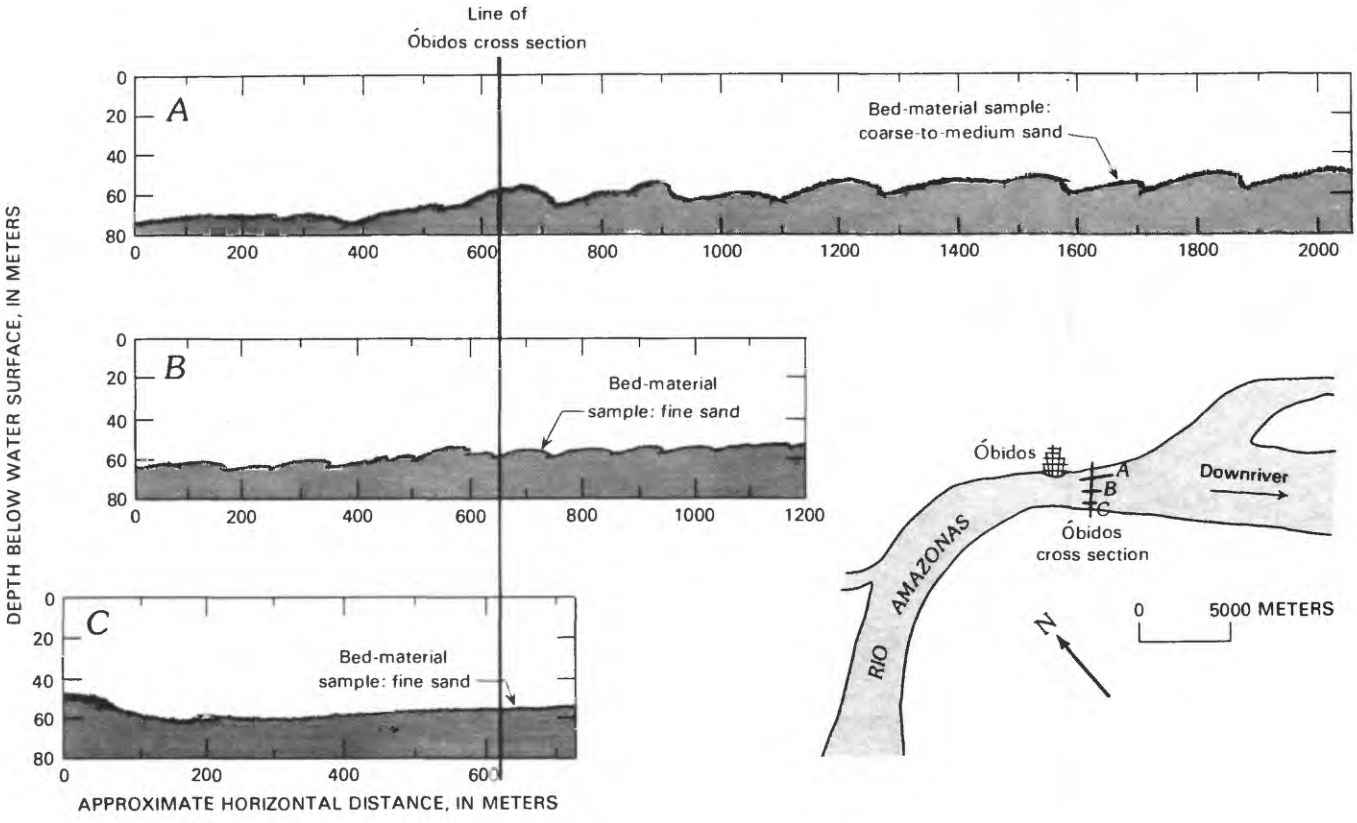

Figure 5. Sand waves on bed of Rio Amazonas at Óbidos, measured by sonic depth sounder on March 4, 1984. A, near left bank. B, midchannel. C, near right bank. Downriver direction is to right in all profiles. Profiles were collected while the research vessel was allowed to drift downriver. Locations of bed-material samples, indicated by arrows, are exact.

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