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## MANUSCRIPT REPORT SERIES

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## ABSTRACT

Fifty-one sediment samples were obtained from the Nanaimo Delta and analysed. The major sedimentary facies are gravel and well-sorted sands. These facies are associated with the two major distributaries of the Nanaimo River. Short-term variations occur in the sediment-size distribution.

## INTRODUCTION

The Nanaimo Delta is a protected bay-head delta located on the east coast of Vancouver Island near the city of Nanaimo. The area is bounded on the west and south by Vancouver Island and on the east by an outcrop of tilted sandstone strata forming barrier islands. To the north, part of the delta is protected by the Nanaimo Harbour and Protection Island, with the remainder open to Northumberland Channel. The tidal flats are mainly the subaqueous top-set beds being produced by the Nanaimo River.

The purpose of this study is to describe the properties of the top 1 cm of sediment in conjunction with a concurrent investigation of the meiofauna of the Nanaimo Delta. In December of 1975 and February-March of 1976 a total of 51 sediment samples were collected and texturally analysed.

The samples are described and inferences on their texture and distribution are given in this report.

This study was sponsored by the Pacific Biological Station and carried out jointly by staff of Pacific Biological Station and the Department of Geological Sciences, University of British Columbia. We wish to acknowledge the assistance of T. Brown, B. Kask and B. Windecker.

## MATERIALS AND METHODS

### 1. Field techniques

In December 1975 a series of seven samples was taken on the delta in conjunction with biological sampling. In February-March a more complete program to determine a sedimentological facies distribution was undertaken. The tidal flats, an area of approximately 3 sq mi, was divided into a quarter-mile grid pattern; the cross section of grid lines being chosen for sample stations. With the aid of aerial photographs and hydrographic charts additional stations were added to achieve greater accuracy in areas with more complex bottom features and to duplicate the December 1975 stations. Relocation of some stations was necessary due to congestion of log booms across the delta. The station positions are given in Fig. 1.

Locating the sample stationson the delta flats was achieved by positioning the boat at or between series of numbered dolphins placed across the area by the logging companies. Sightings on docks and prominent points of land were of help and some sextant shots were tried. Poor visibility within the small area of the tidal flats made greater use of the sextant impossible.

Fifty-one cores were obtained from the delta at high tide by scuba divers using short plastic core barrels. The barrels, each 15 cm long and 7 cm in diameter, were bevelled on one end for ease in penetrating the sediment. Rubber stoppers were placed in the top of the core barrel before extraction to hold sediment in the barrel. After removal from the bottom, the open end of the cores were capped, stored on board the boat and transported to the University of B.C. for analysis.

2. Experimental techniques

In the laboratory sediment samples were processed for standard textural analysis by means of sieving (Royse, 1970) and a sedigraph 5,000-particle-size analyzer for the under 0.065 mm fractions. Subsamples were prepared for future studies which might be initiated. In addition these subsamples were divided into over and under 0.5 mm size fractions and photographed. Subsamples of minus 0.0625 mm material from stations 20, 22, 23, 44, 75 and 84 were separated and prepared for analysis by a scanning electron microscope.

## RESULTS

The results of the study of sediment texture distribution across the delta are summarized in Table 1 and in the sedimentological maps, Fig. 4-8 . The complete results including tabulations and plots of sediment size distribution, photographs of over and under 0.5 mm size fraction and scanning electron micrographs are on file at the University of B.C. and Pacific Biological Station and may be obtained from the authors. (Riemer, 1976)

1. Sediment types

The major textural sediment types based on millimeter sizes are given in Table I. This data plotted on a ternary diagram, gravel and sand vs silt vs clay, shows the sand-gravel fraction dominant in the majority of samples (Fig. 2). The silt fraction is the third most important and clay the least. There is no more than 10% clay in any sample except station 25 and 22 associated with the salt marsh. A second ternary diagram (Fig. 3) grouping the silt and clay fractions into mud results in a more representative distribution of sediment types. This distribution was used to produce a facies map (Fig. 4) of the delta.

The most conspicuous features on the tidal flats are the locations of the main river channels and secondary outwash channels. Coarse sediments are associated with the river channels and tributaries fingering across the delta. The interchannel areas are generally well-sorted sands influenced by meandering of outwash channels and tidal reworking. Finer muddy sediments are extensions of the salt marshes and form a region of poorly sorted material between the main river channels at the head of the delta. The long gravel bar found in the centre of the tidal flats is an annomaly with regard to the present sedimentation regime. It is separated from either main channel flow and forms a topographic high on the tidal flats. Although present processes seem to be reworking the material around the bar, it appears to be a relic feature.

2. Relative proportions of the major sediment types

From Table I, it can be seen that gravel is present in all but three samples and ranges between 88.46% and 0.02%. The distribution of gravel is contoured by percent in Fig. 5. The main areas of gravel deposition are the river channels along the west and east banks. Branches from the east channel fan out through the centre of the delta but gravel concentrations are decreased to 10% by midway, with exception to the gravel bar.

Sand, the most abundant textural class in most samples ranges between 97.6% and 4.46%. Highest concentrations are found at the northeast section of the delta and within two tongues, one extending almost to the west bank and another south toward the mouth of the east channel. This channel appears to have a marked influence on sand distribution (Fig. 6). The very high sand values are from well-sorted sediments which are probably under-going tidal and storm reworking.

Silt is also present in all the samples but in generally smaller amounts than sand or gravel and ranges between 87.89% and 0.15%. Its distribution across the delta is in the form of two plumes (Fig. 7); one fanning out between the two main river channels toward the north, the other hugging close to the west bank forming what appears to be a reciprocal to the gravel concentrations in Fig. 5. Examination of the scanning electron micrographs show that a large percentage of silt-size particles are tests of marine plankton.

Clay is the least significant in terms of percentage. It ranges between 15.4% and 0.03% but has a broad distribution across the delta (Fig. 8). The highest concentrations are around the tidal marshes and perimeters extending seaward between the main river channels. A second concentration follows the same southward plume as the silt along the west bank.

## TEMPORAL VARIATIONS

The seven samples taken in December 1975 were repeated in February 1976. The purpose was to study the effects of the seasonal changes of the delta on the top cm of sediment. The dominant change from December to February is a shift to a coarser mean grain size. Increases in both gravel and sand occur at all seven stations with resulting decreases in silt and clay. These changes may reflect a period of high river discharge during January and February moving coarser material across the delta. Individual changes could also be caused by the shift in position of one of the many tidal outwash channels, or in an inaccurate repositioning of sample stations. Within the highly active delta area a distance of a few m could result in a very different value.

Inhomogenieties can be observed below the sediment surface in cross sections or cores. These features provide good evidence for temporal changes but provide no time scale. Results from samples repeated in July and September 1976 may indicate short-term changes.

## DISCUSSION AND CONCLUSIONS

The sedimentological maps show a dispersal pattern relating to the outflow of the Nanaimo river channels and the action of tidal currents. Two major distributary channels are floored by gravel and coarse sand which locally accumulates to form bars where the channels widen. Gravel is concentrated at the mouth of the river channels and decreases seaward. Silt and clay increase correspondingly. Downstream transportation of silt and clay may be retarded by the inflow of tidal currents which appear to be strongest along the west bank. High concentrations of silt and clay occur in the pockets around the frontal portions of the salt marsh. These regions, largely floodplain deposits with an abundance of marine organism and fecal pellets, are isolated from the high energy of the river. Sand blankets the whole delta, but reaches highest concentrations where reworking has produced a well-sorted sandy bottom. This type of bottom was observed by divers during the collection of samples to have well-developed sand waves.

Variations and changes of the delta surface with time are evident. The stratigraphic record on a small scale shows an actively changing environment. Longer cores and a continued seasonal sampling program will be necessary to acquire an understanding of these changes and the processes which most influence them.

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Royse, Jr., and F. Chester. 1970. An Introduction to Sediment Analysis. Ariz. State Univ., Tempe, Arizona.

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Shepard, F. P. 1954. Nomenclature based on sand-silt ratios: J. Sediment Petrol., v. 24, pp. 151-158.

Table I. Sediment textural statistics for the Nanaimo Delta.[a]

| Sta. no. | %gravel | %sand | %silt | %clay | %mud | S/M | Median | Mean | S.D. |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 0.80 | 67.43 | 26.95 | 4.82 | 31.77 | 2.12 | 3.35 | 3.53 | 1.83 |
| 9 | 1.47 | 91.29 | 5.23 | 2.00 | 7.24 | 12.62 | 0.84 | 1.20 | 1.82 |
| 10 | 10.71 | 74.52 | 12.17 | 2.60 | 14.77 | 5.05 | 1.81 | 1.93 | 2.35 |
| 20 | 1.96 | 77.12 | 11.09 | 9.83 | 20.92 | 3.69 | 2.92 | 3.47 | 2.94 |
| 21 | 20.54 | 55.68 | 20.45 | 3.33 | 23.79 | 2.34 | 1.91 | 1.95 | 3.05 |
| 5 | 12.18 | 51.92 | 29.24 | 6.66 | 35.91 | 1.45 | 2.79 | 2.79 | 2.95 |
| 22 | 23.10 | 44.82 | 16.68 | 15.40 | 32.08 | 1.40 | 2.34 | 2.84 | 4.54 |
| 23 | 1.00 | 27.82 | 61.22 | 9.96 | 71.18 | 0.39 | 5.25 | 5.20 | 2.22 |
| 24 | 0.00 | 4.46 | 87.89 | 7.65 | 95.54 | 0.05 | 5.79 | 5.94 | 1.26 |
| 25 | 0.00 | 41.05 | 31.24 | 27.71 | 58.95 | 0.70 | 4.80 | 6.08 | 3.32 |
| 26 | 0.21 | 36.96 | 58.43 | 4.40 | 62.83 | 0.59 | 4.73 | 4.72 | 1.68 |
| 27 | 88.46 | 11.36 | 0.15 | 0.03 | 0.19 | 61.30 | -3.96 | -3.18 | 1.47 |
| 28 | 71.11 | 22.86 | 3.38 | 2.65 | 6.03 | 3.79 | -2.73 | -1.63 | 3.12 |
| 29 | 57.75 | 37.12 | 4.16 | 0.97 | 5.13 | 7.24 | -1.69 | -0.75 | 2.62 |
| 30 | 1.57 | 90.62 | 5.47 | 2.34 | 7.81 | 11.60 | 1.82 | 2.09 | 1.73 |
| 31 | 0.74 | 83.82 | 12.98 | 2.47 | 15.45 | 5.43 | 2.76 | 3.04 | 1.68 |
| 7 | 0.95 | 90.17 | 6.53 | 2.35 | 8.89 | 10.15 | 2.70 | 2.71 | 1.58 |
| 32 | 0.06 | 92.92 | 6.18 | 0.84 | 7.02 | 13.23 | 2.66 | 2.77 | 1.10 |
| 33 | 0.00 | 97.60 | 1.80 | 0.60 | 2.40 | 40.66 | 1.63 | 1.75 | 1.09 |
| 8 | 0.02 | 77.63 | 18.92 | 3.44 | 22.36 | 3.47 | 3.49 | 3.62 | 1.45 |
| 34 | 1.66 | 86.78 | 4.85 | 6.71 | 11.56 | 7.51 | 2.49 | 2.92 | 2.94 |
| 35 | 0.18 | 59.43 | 37.97 | 2.42 | 40.40 | 1.47 | 3.64 | 3.77 | 1.67 |
| 36 | 0.23 | 94.58 | 4.30 | 0.88 | 5.19 | 18.23 | 1.56 | 1.76 | 1.35 |
| 37 | 70.39 | 23.34 | 4.83 | 1.44 | 6.28 | 3.72 | -3.64 | -1.84 | 3.23 |
| 38 | 61.63 | 37.57 | 0.56 | 0.24 | 0.79 | 47.34 | -3.01 | -1.39 | 2.21 |
| 39 | 70.74 | 28.12 | 0.98 | 0.16 | 1.14 | 24.66 | -3.03 | -2.05 | 2.34 |
| 40 | 1.49 | 78.45 | 18.66 | 1.40 | 20.06 | 3.91 | 2.46 | 2.57 | 1.88 |
| 41 | 10.64 | 66.99 | 19.69 | 2.68 | 22.37 | 2.99 | 2.32 | 2.34 | 2.60 |
| 42 | 37.12 | 37.57 | 21.01 | 4.31 | 25.32 | 1.48 | 1.53 | 1.24 | 3.86 |
| 43 | 79.14 | 18.21 | 2.23 | 0.42 | 2.65 | 6.87 | -3.14 | -2.32 | 2.29 |
| 44 | 0.51 | 32.97 | 58.53 | 7.99 | 66.52 | 0.50 | 4.86 | 4.72 | 2.23 |
| 45 | 5.62 | 85.05 | 6.35 | 2.98 | 9.33 | 9.12 | 1.55 | 1.83 | 2.09 |
| 46 | 7.93 | 55.46 | 28.19 | 8.42 | 36.61 | 1.51 | 3.27 | 3.47 | 3.02 |

Table I (continued)

| Sta. no. | %gravel | %sand | %silt | %clay | %mud | S/M | Median | Mean | S.D. |
|---|---|---|---|---|---|---|---|---|---|
| 47 | 2.65 | 84.00 | 11.48 | 1.87 | 13.35 | 6.29 | 2.40 | 2.53 | 1.80 |
| 48 | 6.54 | 32.47 | 51.83 | 9.15 | 60.99 | 0.53 | 4.70 | 4.40 | 2.79 |
| 49 | 44.54 | 49.84 | 4.52 | 1.10 | 5.62 | 8.87 | -0.56 | -0.57 | 2.77 |
| 50 | 8.37 | 89.06 | 1.59 | 0.90 | 2.56 | 34.78 | 0.69 | 0.66 | 1.66 |
| 51 | 4.26 | 90.89 | 3.49 | 1.36 | 4.85 | 18.74 | 0.93 | 1.09 | 1.67 |
| 11 | 0.36 | 96.90 | 2.75 | 0.00 | 2.75 | 35.27 | 1.42 | 1.46 | 0.89 |
| 52 | 2.71 | 95.99 | 0.86 | 0.44 | 1.30 | 73.71 | 1.18 | 1.18 | 1.20 |
| 74 | 11.23 | 46.64 | 37.92 | 4.21 | 42.13 | 1.11 | 3.43 | 3.23 | 3.01 |
| 75 | 5.54 | 78.80 | 13.79 | 1.88 | 15.67 | 5.03 | 2.51 | 2.45 | 2.07 |
| 76 | 17.32 | 74.52 | 6.85 | 1.30 | 8.15 | 9.14 | 0.69 | 0.93 | 2.16 |
| 77 | 0.94 | 95.00 | 3.74 | 0.32 | 4.06 | 23.40 | 1.25 | 1.42 | 1.33 |
| 78 | 28.53 | 50.01 | 19.09 | 2.37 | 21.46 | 2.33 | 1.02 | 1.29 | 3.05 |
| 79 | 2.43 | 87.90 | 8.61 | 1.07 | 9.68 | 9.08 | 1.27 | 1.51 | 1.69 |
| 80 | 18.77 | 62.99 | 14.59 | 3.65 | 18.24 | 3.45 | 1.57 | 1.69 | 2.96 |
| 81 | 0.26 | 61.06 | 35.98 | 2.71 | 38.69 | 1.58 | 3.54 | 3.62 | 1.72 |
| 82 | 2.10 | 90.41 | 7.27 | 0.23 | 7.50 | 12.06 | 2.02 | 2.06 | 1.41 |
| 83 | 2.92 | 91.71 | 3.97 | 1.40 | 5.37 | 17.09 | 1.05 | 1.30 | 1.63 |
| 84 | 1.64 | 69.94 | 26.42 | 1.99 | 28.41 | 2.46 | 2.94 | 3.41 | 1.89 |

[a]Sta. no. = station number; % = weight percent; gravel(>2.0mm), sand(<2.0>0.0625mm), silt(<0.0625>0.0039mm), clay(<0.0039mm); mud = silt + clay; S/M = sand to mud ratio; median, mean, standard deviation (S.D.) are probability extrapolated moment measures in phi units.

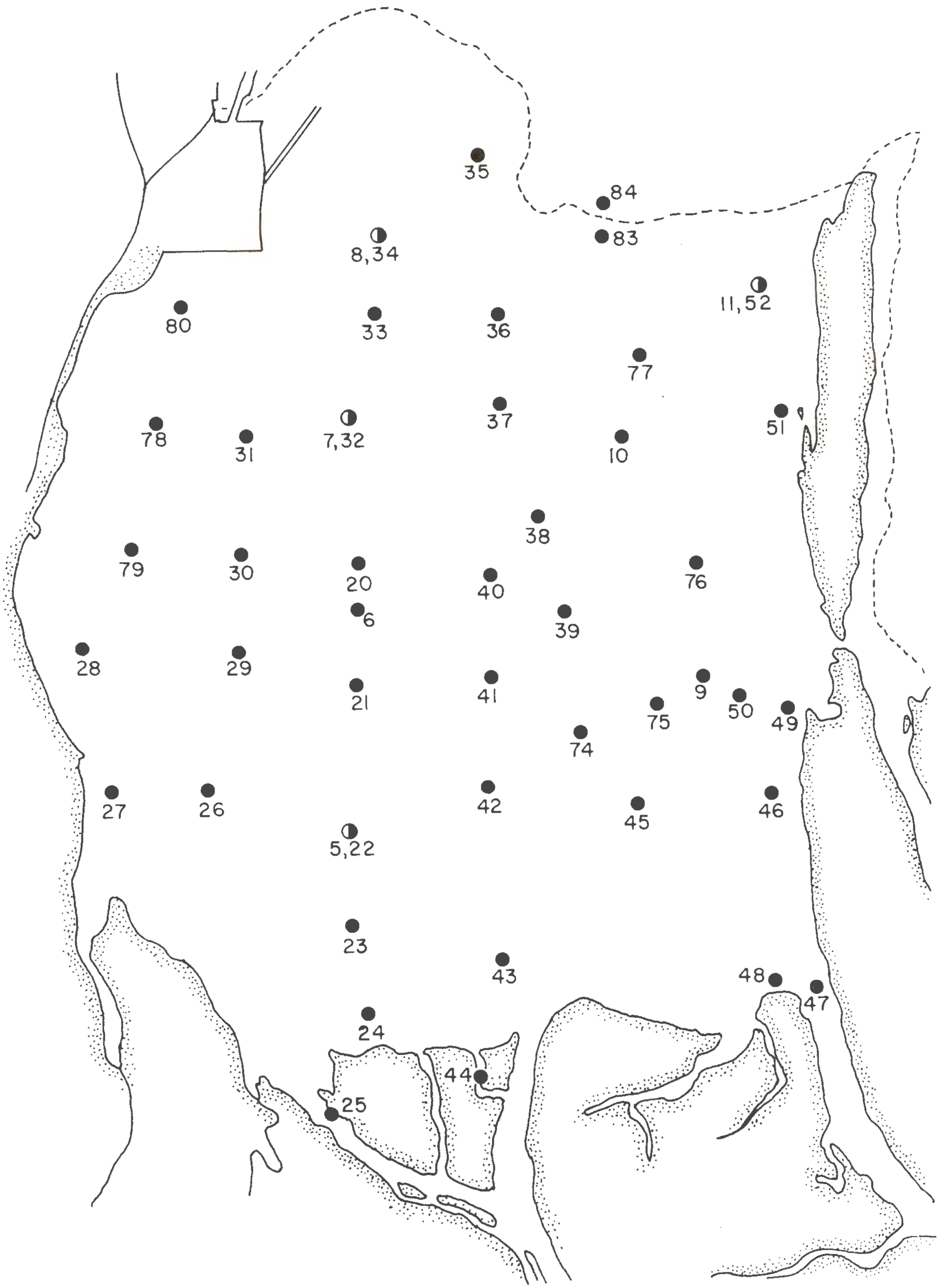


Fig. 1. Locations of stations on the Nanaimo Delta. Shaded circles represent December 1975 samples; open circles represent January-February 1976 samples.

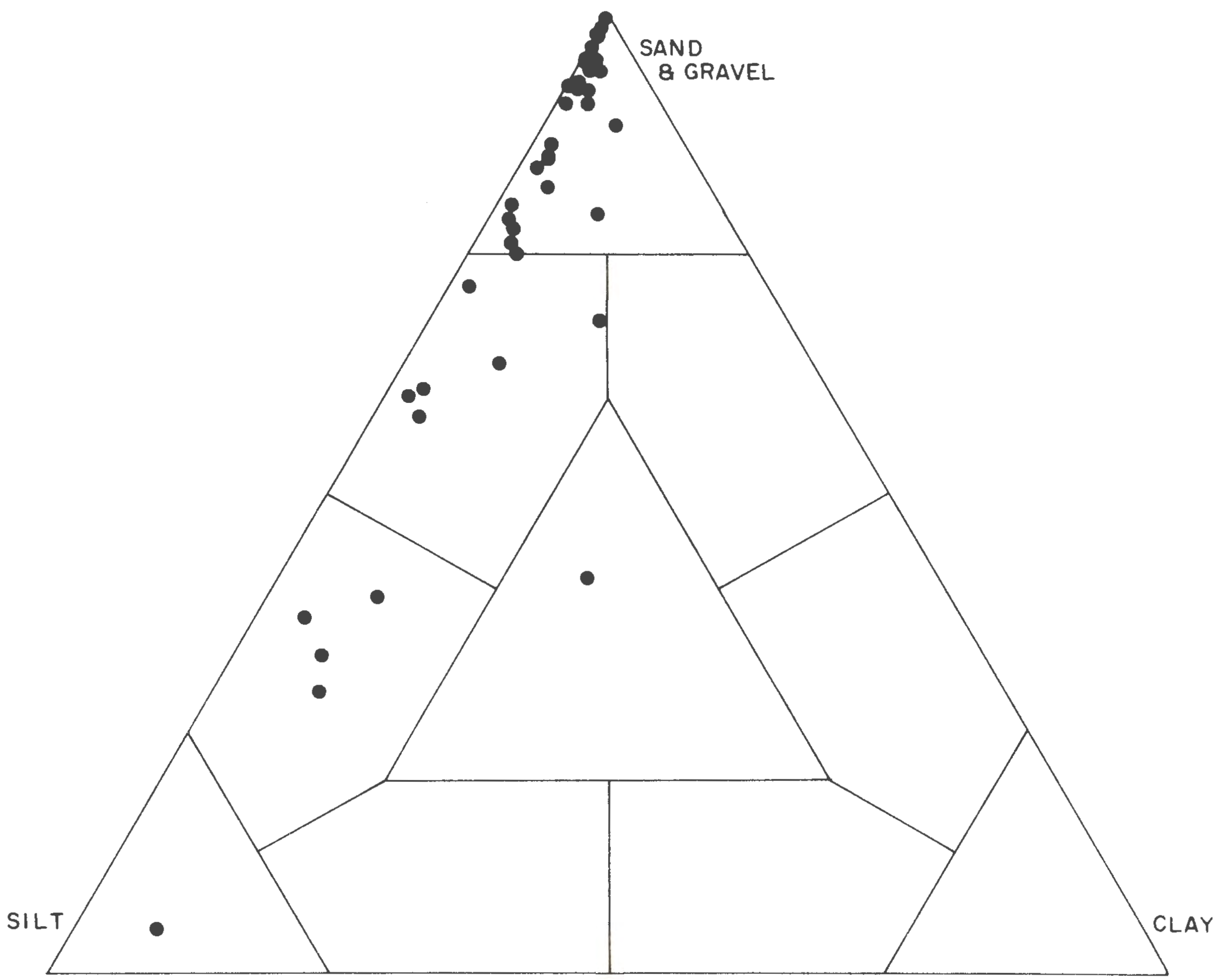


Fig. 2. Ternary diagram showing contributions of sand and gravel, silt and clay to sediment composition.

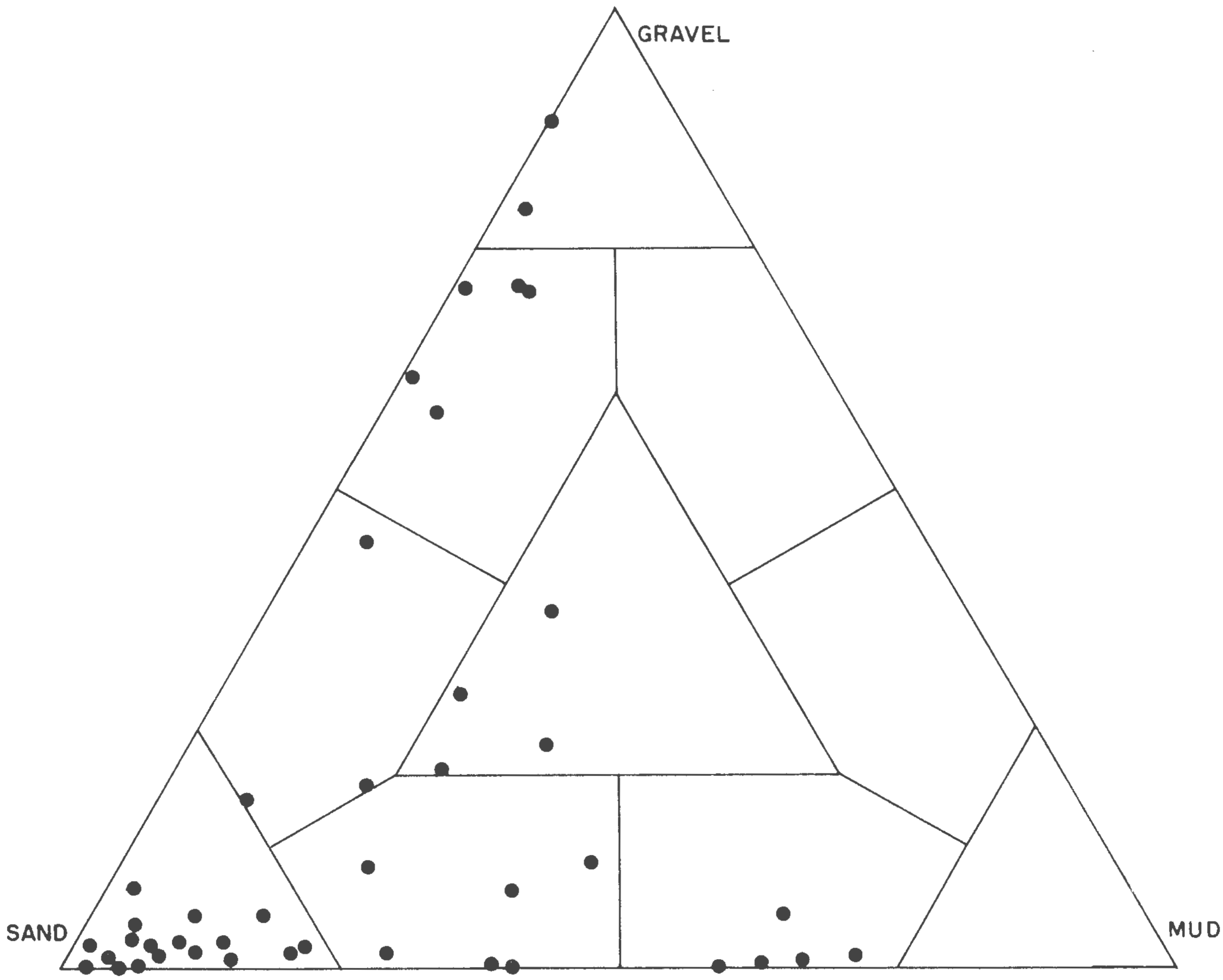


Fig. 3. Ternary diagram showing contributions of sand, gravel, and mud to sediment composition.

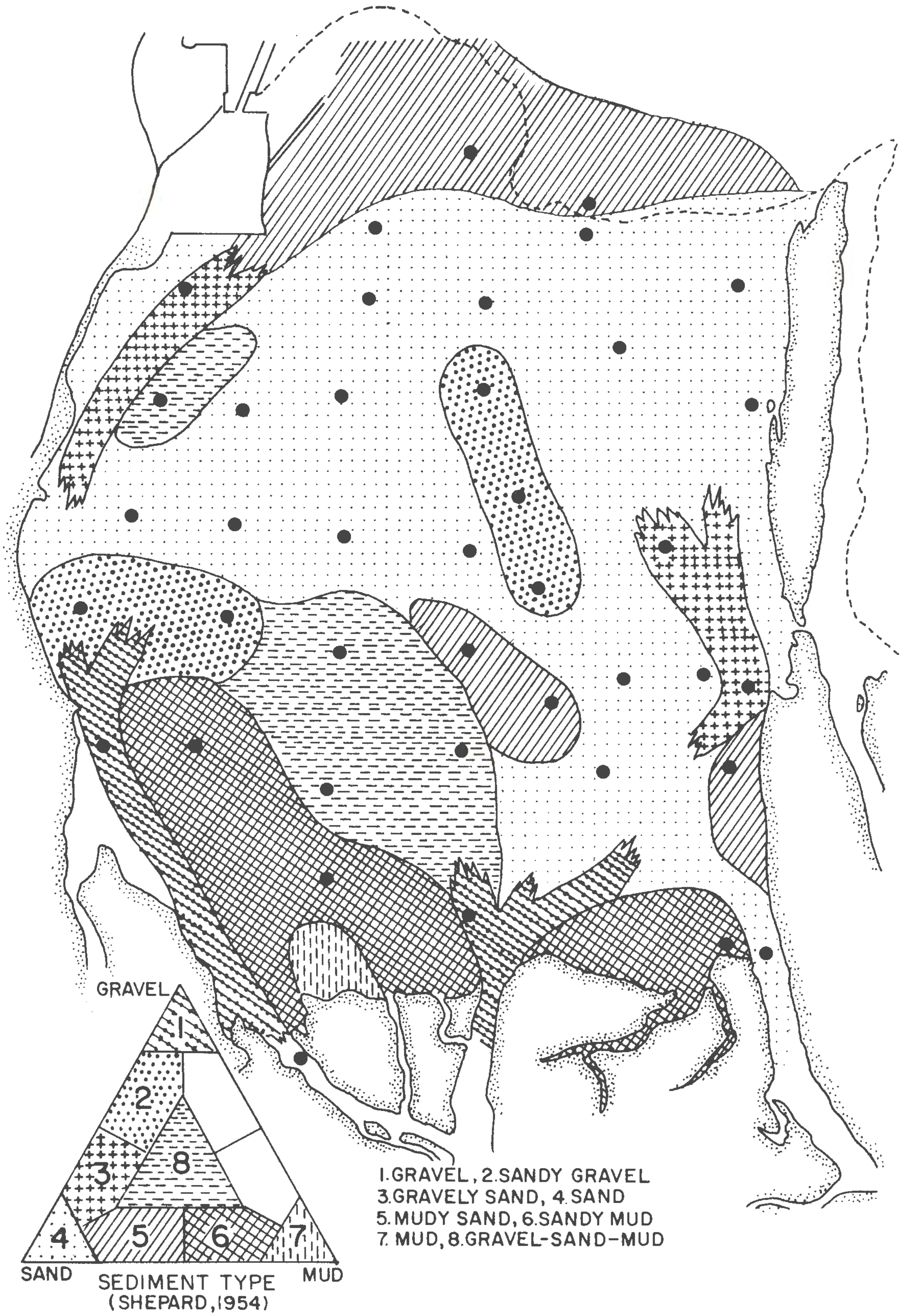


Fig. 4. Sediment facies map. Sediment types after Shepard, 1954.

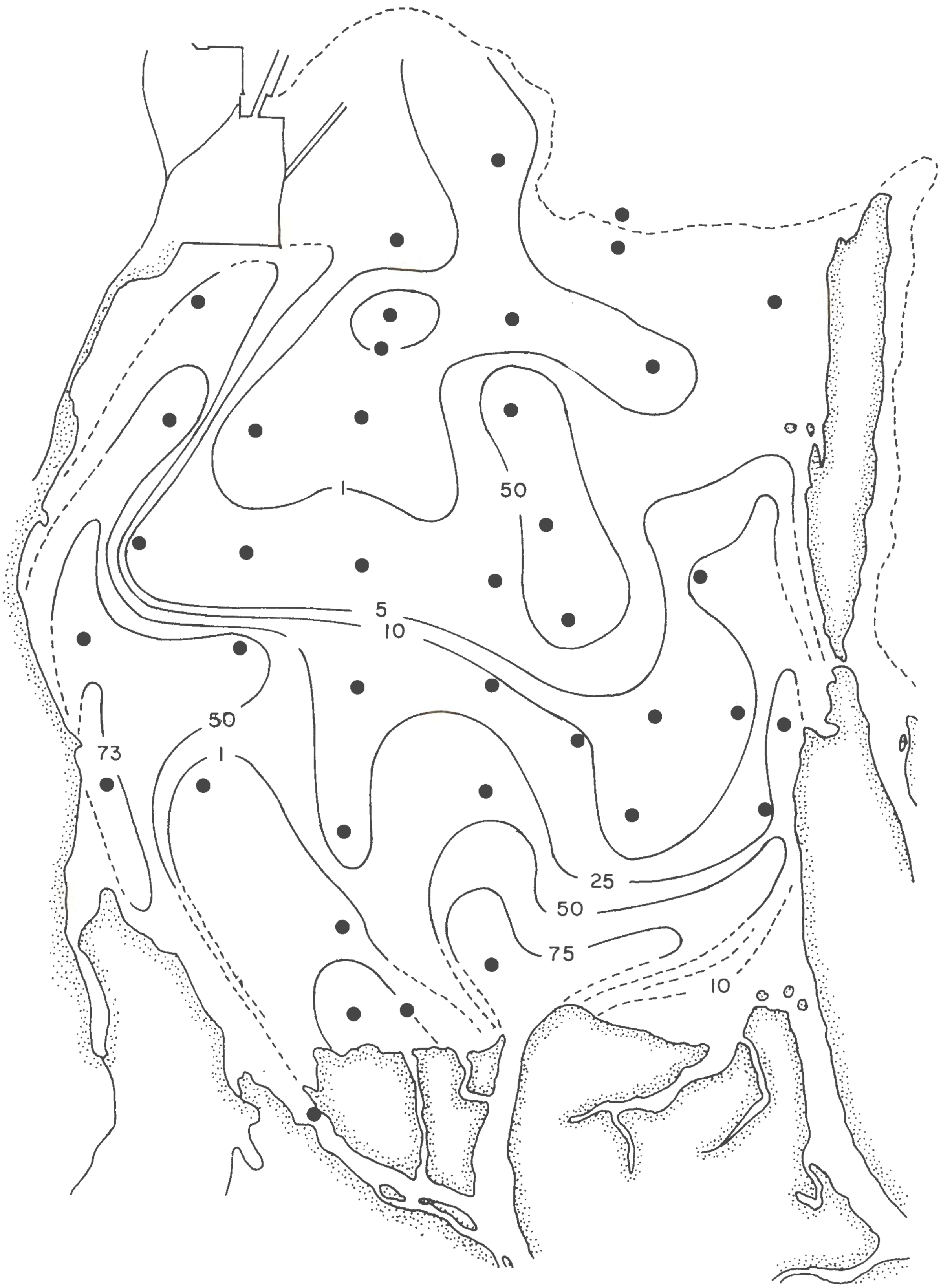


Fig. 5. Gravel distribution (percent).

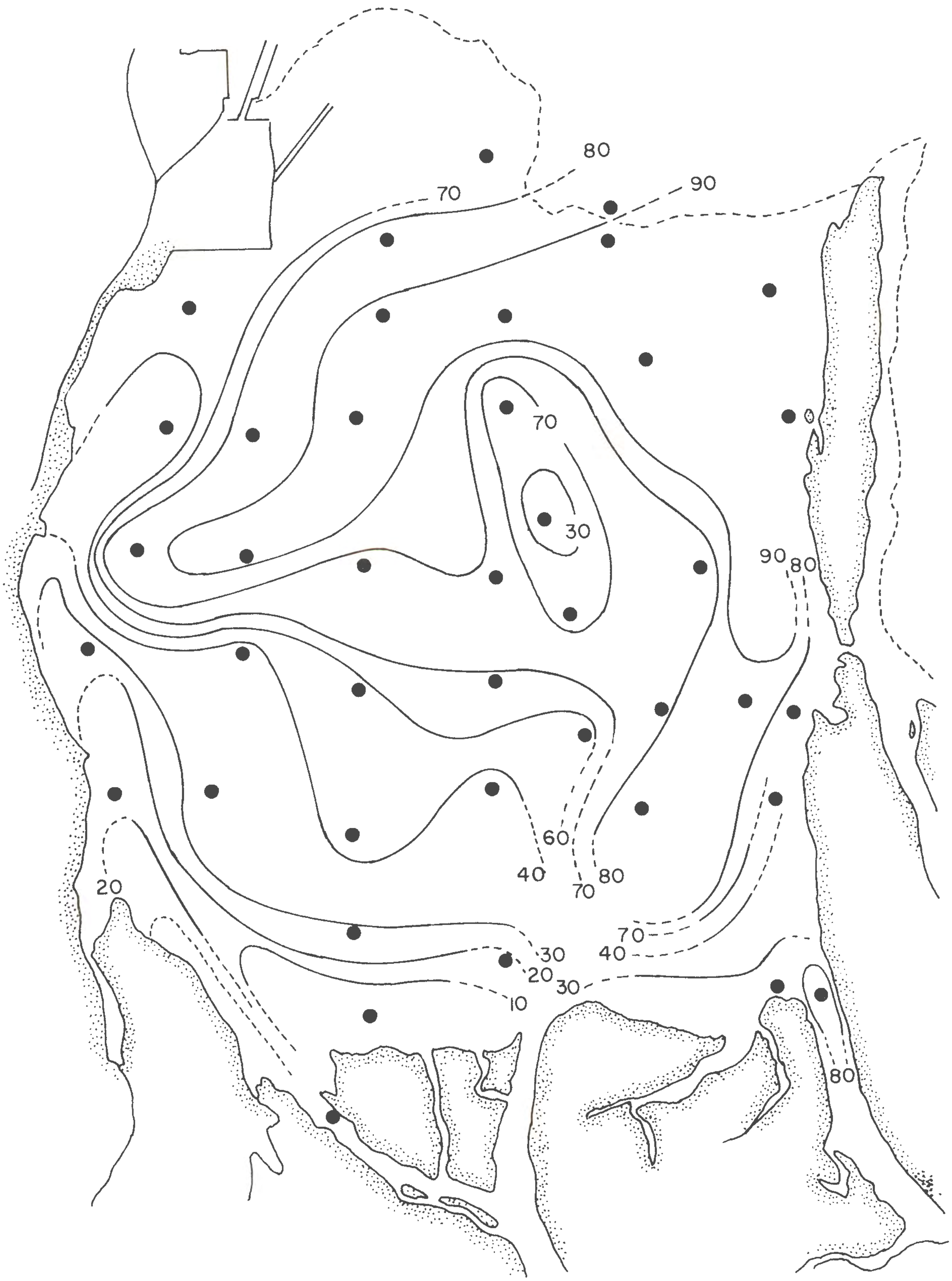


Fig. 6. Sand distribution (percent).

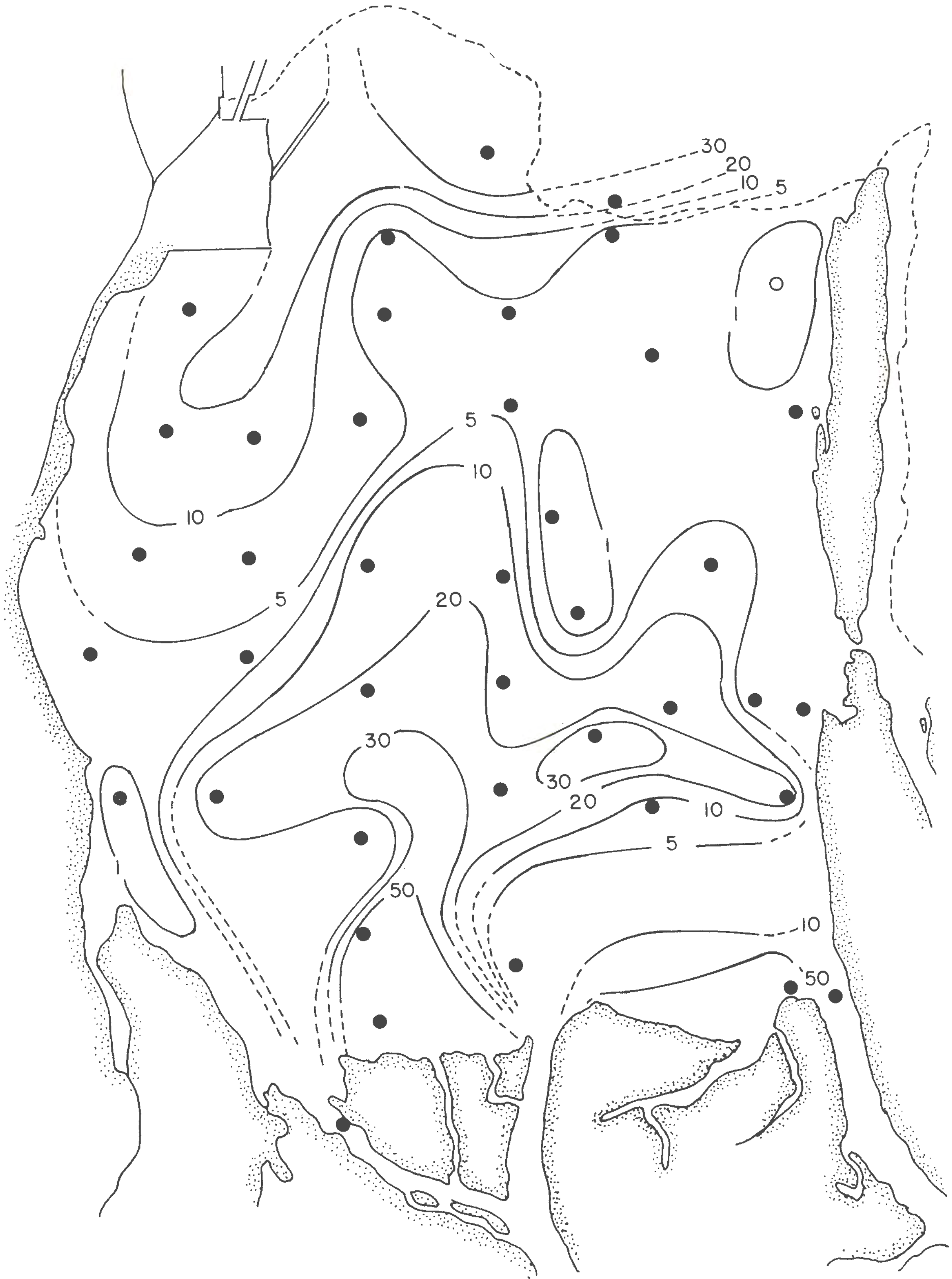


Fig. 7. Silt distribution (percent).

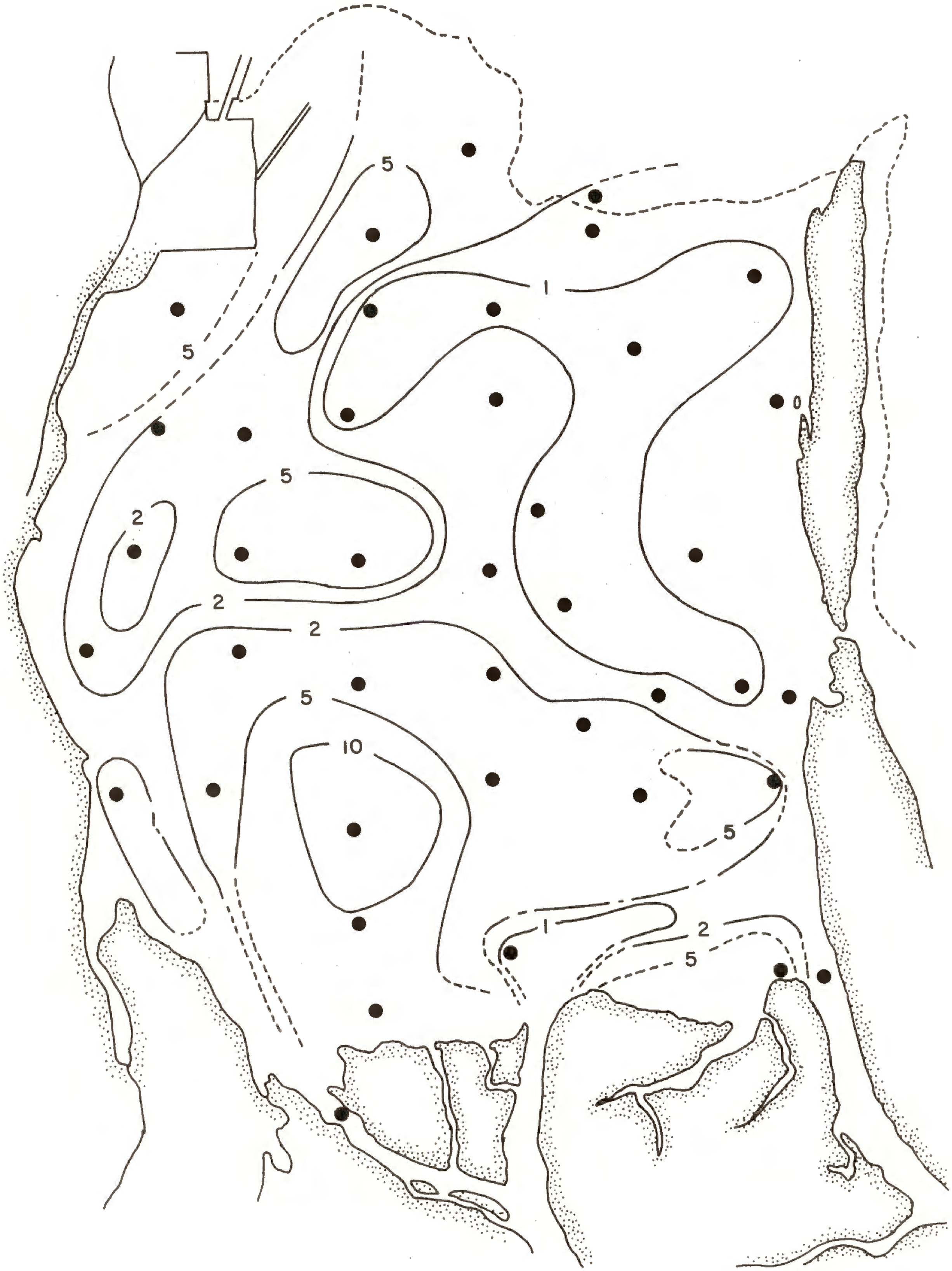


Fig. 8. Clay distribution (percent).