Hydrologic-morphometric characteristics of delta branches

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SUMMARY: The hydrological and morphological characteristics of non-tidal delta branches are considered. The analysis of factors determining the variability of these characteristics in time and in space is made. The hydrometric and hydromorphometric methods of calculation of these characteristics are examined. The first method is based on graphical relationships of branch characteristics in individual cross sections with water discharge at the top of the delta (or in individual branches) and sea level near the delta front. In the second method hydro-morphometric relationships connecting all characteristics of delta branches at bankfull discharge are used.

The theoretical inference of these relationships is drawn. The parameters of these relationships are determined by analysis of the observational data.

The hydro-morphometric relationships may be used for determination the tendency towards evolution of the delta branches.

RéSUMÉ : Il s'agit des résultats des recherches de caractéristiques hydrologiques et morphologiques des chenaux des deltas sans marée. L'analyse des facteurs, qui déterminent les variations de ces caractéristiques dans le temps et dans l'espace a été effectué. Les méthodes hydrométriques et hydrologiques de calcul des caractéristiques hydrologiques-morphologiques ont été examinées.

La première méthode est fondée sur la liaison des caractéristiques des chenaux sur certaines sections avec le débit de l'eau en amont du delta (ou dans certains chenaux) et avec le niveau de la mer dans la partie maritime de l'embouchure. Ce sont les relations hydrologiques-morphologiques liant toutes les caractéristiques des chenaux de delta avec le débit de pleine section, qui sont utilisées dans la deuxième méthode. La déduction théorique de ces relations est donnée et leurs paramètres sont trouvés par l'arrangement des données d'observation. Les relations hydrologiques-morphométriques peuvent être également utilisées pour la détermination de la tendance de l'évolution des chenaux de delta.

Recent pressure on the water and land resources of large river deltas has stimulated interest in studying, calculating and predicting the hydrologic-morphometric characteristics of delta branches.

The main hydrologic-morphometrical characteristics of delta branches are:

\[
\begin{align*}
Q & \quad \text{water discharge;} \\
H & \quad \text{water level;} \\
Z & \quad \text{mean elevation of bottom;} \\
J & \quad \text{water surface slope;} \\
v & \quad \text{mean flow velocity;} \\
\omega & \quad \text{cross-section area;} \\
B & \quad \text{channel width;} \\
h & \quad \text{mean depth;} \\
R & \quad \text{sediment discharge;} \\
s & \quad \text{mean sediment concentration;} \\
D & \quad \text{mean diameter of bottom sediments;} \\
n & \quad \text{Manning's coefficient of roughness.}
\end{align*}
\]

Characteristics listed above may be referred to some cross sections in branches or to stretches of the branches (in this case the characteristics are averaged according to the stretch length).

Hydrologic-morphometric characteristics are determined by the following equations:
Hydrologic-morphometric characteristics of delta branches

(a) equation of continuity
\[ \frac{\partial Q}{\partial x} + \frac{\partial h}{\partial t} = 0 \]  

(b) equation of motion
\[ - \frac{\partial H}{\partial x} = J = \frac{1}{g} \frac{\partial v}{\partial t} + \alpha \frac{\partial v}{\partial x} + \frac{v|v|}{C^2 h} \]  

where:
C is Chezy's coefficient
\[ C = \frac{h^2}{n} = k_1 \left( \frac{h}{D} \right)^p \]  

(c) equation of water discharge
\[ Q = ov = Bhv, \]  

(d) equation of flow capability for transport (of sediment discharge) according to A.N. Gostunsky
\[ R = sQ = k_2 g^{1/2} \frac{v}{Cw} = k_2 g^{1/2} \frac{v^3}{C^2 hw} \]  

where:
\[ w = \text{fall velocity of sediments} \]
\[ w = k_3 \sqrt{g D} \]  

(e) equation of river bed deformation
\[ \frac{\partial R}{\partial x} + \gamma_s B \frac{\partial z}{\partial t} = 0, \]  

(f) equation of stable channel sizes with bankfull discharge according to M. A. Velikanov
\[ \frac{B^m D \cdot 1-m}{h} = k_4 \]  

In these equations:
\[ \gamma_s \] is sediment specific weight;
\[ \alpha \] Coriolis' coefficient;
\[ g \] acceleration of gravity;
\[ k_1, k_2, k_3, \text{ and } k_4 \] coefficients;
\[ \gamma \text{ and } m \] parameters (\( \gamma \) changes from 1/2 to 1/8, \( m \) from 1/2 to 1, while \( \gamma = 1/6, m = 2/3 \) occur most frequently).

All hydrologic-morphometric characteristics of branches change both in time and in space. The main factors determining their variability are—hydrological conditions at upper and lower boundaries of delta (water discharge and sea level) and channel processes in branches (erosion and accretion of bed), specific river mouth processes, connected with interaction between sea and river waters and development of delta, and local conditions (hydrological, structure, man-made constructions, and so on).

Variations in time can be of two types: reversible and non-reversible. If the variation is reversible then, after finishing the phenomenon cycle (for example, flood, tide, surge),
all characteristics return to the values they had before the cycle. During non-reversible changes uni-directional processes take place.

According to their duration, the variations of branch characteristics may be of the following types:

1. Long-term variations connected with long-term oscillations of water and sediment discharges because of natural or artificial causes, long-term elevation or lowering of base level (sea level); with non-reversible channel processes (erosion and accretion) in branches, with non-reversible mouth processes (lengthening of branches, scouring of some and silting of others because of discharge re-distribution between branches and breaking of natural levees, and with hydrotechnical arrangements).

2. Seasonal variations connected with seasonal variations of discharge and sea level and with reversible channel processes in branches.

3. Short-term variations resulted from short-term floods, flushes of water into lower pools of dams, from variations of sea level because of tides, surges, breezes and seiches.

*Changes in space.* The reasons for hydrologic-morphometric characteristics changing a one-branched river mouth are:

1. **Hydraulic form of river and reservoir level association.** With large water discharges in the river and with low sea levels, the channel sizes are decreased but velocity and slope are increased in the downstream direction. With small discharges in the river and with high sea levels the reverse picture may be observed.

2. Changes of channel process type. Usually, towards the mouth, the channel changes from braided to meandering and then to straight. With each type of channel process the shape and size of channel are different.

3. Local conditions connected with the influence of geological and some other factors changing the natural channel shape.

In a many-branched mouth (in delta branches) to the above mentioned reasons a rather significant reason is added—distribution of water discharge between the branches. Usually in shallow branches all morphometrical characteristics and the flow velocity are less but the slope is greater than those in branches having an abundance of water.

Estimation of hydrologic-morphometric characteristics of delta branches can be made by the following methods: hydrometric, hydraulic and hydrologic-morphometric.

**Hydrometric method** consists in determining graphical (or analytical) relations between branch characteristics from measured data. The advantage of this method is—use of real data; the defect is—the difficulties of obtaining large amounts of information under field conditions and the difficulties of determining relations in a complicated hydrological regime.

Usually, the relations are determined between water level or discharge in the i-th individual cross-section \((H_i, Q_i)\) or at the head of the delta \((H_0, Q_0)\) and other characteristics of branches.

With a steady regime (when short-term changes of \(H\) and \(Q\) are not considered or observational data are averaged to exclude the effect of short-term oscillations) relations of one of the following types are determined:

\[
\omega_i = \omega_i(H_0, H_M), \tag{9}
\]

\[
\omega_i = \omega_i(Q_0, H_M), \tag{10}
\]

\[
\omega_i = \omega_i(H_i, H_M), \tag{11}
\]

\[
\omega_i = \omega_i(Q_i, H_M), \tag{12}
\]
where:

$\omega_i$ is the cross-section area (or any other characteristics of the branch), in the $i$-th cross-section, and

$H_m$ is the averaged sea level (free from short-term oscillations).

FIGURE 1. The relation of water discharge in the Kura mouth on level in some cross-section ($H_i$) and on level at the mouth ($H_m$).

FIGURE 2. The relations between hydrologic-morphometrical characteristics of the Kamisjak branch in the Volga delta and water discharge. The arrow indicates the example of calculation with $Q = 3,400$ m$^3$/s. 1. rising stage; 2. falling stage.
These relations reflect the fact that all branch characteristics depend on discharge at the head of delta and on its distribution between the branches and on sea level. The example of relationships as (12) is shown in figure 1.

The discharge distribution between the branches is characterized by following relations:

\[ Q_i = Q_i(Q_0, H_M), \]  
\[ Q_0 = \Sigma Q_i \pm \Delta Q, \]

where:
- \( \Sigma Q \) is the sum of branch discharges;
- \( \Delta Q \) the value of losses or of water discharge increment in the delta.

In some cases (in large deltas) when seasonal variations of sea level are small or are connected with variations of \( Q_0 \), it is convenient to express the relations (12) as power functions (fig. 2).

\[ \omega_i = aQ_i^x \]

The form of these relations can be determined theoretically by means of the joint solution of Chezy's equation, resulting from (2); of the discharge equation (4) and of the channel cross-profile equation, expressed, for example, by a parabola of type \( B/2 = ch^2 \).

**Figure 3**
It is supposed that the slope $J$ and roughness coefficient $n$ are constant, or they change depending only on $Q$ (this last was confirmed in large deltas).

The relation (9)-(12) and (15) must be in accordance with (3), (13) and (14).

With non-reversible long-term variations of branch channel morphology connected, for example, with variations of base level or with redistribution of discharge between the branches, the above mentioned relations are disturbed. In this case it is necessary to determine them for individual periods, when the morphology of branch channels can be assumed to be invariable.

With a non-steady regime the relations (9)-(12) are complicated; that can be explained by unsynchronous arrival of similar phases of different flow and channel characteristics (fig. 3).

By means of joint solutions of equations (1)-(4) (for the one-dimensional problem) and the time-derivative of characteristics of flow and channel ($\delta H/\delta t$, $\delta v/\delta t$, $\delta s/\delta t$ and so on) the regular and successive occurrence of extreme values of the main characteristics were derived (table 1).

**Hydraulic method** consists of the use of equations (1), (2) and (3); in this case, a minimum of information about the morphometric characteristics of branches is necessary.

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**Figure 3.** Variation of hydrologic-morphometrical characteristics of the Karabelniy branch in the North-Dvina delta for tidal cycle, March 15, 1960. a) variability in time b) relations between branch characteristics and water level; c) relation between branch characteristics and water discharge
TABLE 1.

<table>
<thead>
<tr>
<th>The hydrological phenomenon</th>
<th>Succession of coming of extreme values for hydrologic-morphometrical characteristics of flow and channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flood</td>
<td>$H_M; J_M; s_M; v_M; Q_M; J_m; s_m; v_m; Q_m; H_m;</td>
</tr>
<tr>
<td>2. Tide-ebb-tide without upstream flow</td>
<td>$H_M; Q_M; v_M; J_M; H_m; Q_m; v_m; s_m; J_m; H_M;</td>
</tr>
<tr>
<td>3. Tide-ebb-tide with upstream flow</td>
<td>$H_m; J = 0; Q = v = R = 0, s_m; J_M; s_m; v_m; s_m; J_M; s_M; v_m;</td>
</tr>
<tr>
<td>4. Surge without upstream flow</td>
<td>$H_n; Q_m; v_m; J_m; H_M; J = 0; Q = v = R = 0, s_m; J_m; s_m; v_m;</td>
</tr>
<tr>
<td>5. Surge with upstream flow</td>
<td>$H_m; J = 0; Q = v = R = 0, s_m; J_M; s_m; v_m; s_m; J_M; H_M;</td>
</tr>
<tr>
<td>6. Lowering of the water by the effect of wind without upstream</td>
<td>$H_n; Q_m; v_m; J_m; H_M; Q_m; v_m; s_m; J_M;</td>
</tr>
<tr>
<td>7. Lowering of the water by the effect of wind with upstream</td>
<td>$H_m; J = 0; Q = v = R = 0, s_m; J_M; s_m; v_m; s_m; J_M; H_M;</td>
</tr>
</tbody>
</table>

Note 1.: Symbols: $M$ - maximum; $m$ - minimum; $n$ - initial; $k$ - final.

2. $S$ - mean cross section salinity (in the case when brackish waters penetrate into the mouth). Negative values concern upstream flow.

The advantage of this method is the possibility of analysing any situation, even an unreal one for the modern regime; that is very important for projected hydrotechnical constructions and for forecasting.

The defect of the method is its approximation.

The method of hydraulic calculation with steady regimes consists of determining the fall of the stream $-\Delta H$ between two sections with length $l$ and chosen discharge. The calculation is made using the formula

$$-\Delta H = \frac{Q^2l}{C^2 \bar{w}^2 h},$$

that results from (2). There, the line over the letter denotes averaging over the length of stretch.

Use of (16) requires knowledge of the relations between morphometric characteristics and water level for the cross-sections being considered or for the stretch as a whole.

The calculation is carried out by different methods described in hydraulic theory, for example, by the method of successive approximation.

After calculation of the values of $-\Delta H$ with different $Q$ and levels in an initial cross-section that can be taken as delta front, one can get the relations as $Q_i = Q_i(H_i, H_M)$ and then the relations as (11) or (12) for the branch. After summation of curves, $Q_i = Q_i(H_i, H_M)$ for different branches one can obtain the relation (14) for each $H_M$, then the relations as (13), characterizing discharge distribution between the branches, and finally, the relations as (9) or (10).

Discharge distribution between branches 1 and 2 with the same fall and with length $l_1$ and $l_2$ can be also calculated with the approximate formula

$$Q_1 = \frac{C_1 \bar{w}_1}{C_2 \bar{w}_2} \sqrt{\frac{h_1}{h_2}},$$

$$Q_2 = \frac{C_1 \bar{w}_1}{C_2 \bar{w}_2} \sqrt{\frac{l_1}{l_2}}$$

(17)
With a non-steady regime the approximate methods of calculation with joint solution of the equations (1), (2) and (4) and schematization of the channel shape are used.

With non-reversible channel processes, connected, for example, with base level variation, it is necessary to obtain a joint solution of the equations of motion (2) (without the term in $\delta u/\delta t$), of water discharge (4), of sediment discharge (5), of channel deformation (6) and of the stable channel sizes (7). In this case only tentative calculations can be made by the method of successive approximations in finite-differences.

**Hydrologic-morphometric method** uses, so called, hydrologic-morphometric relations between different characteristics of flow and channel under certain conditions, e.g. with bankfull discharges. These relations can be of four types according to the choice of independent variables. In the relations of the first type $Q$, $J$ and $D$ (or $n$), of the second type—$Q$, $D$, of the third type—$Q$, $D$, $s$ and of the fourth type—$Q$, are used as independent variables. These relations for rivers can usually be obtained empirically, and they can be expressed as power functions. These relations were not used for river deltas.

For the delta branches the values $Q$, $D$ and $s$, namely, the discharge entering the delta (and its distribution between the branches) and river sediments patterns (their size and concentration) can be used as independent variables. All other characteristics of branches ($\omega$, $B$, $h$, $v$, $J$) are dependent variables.

Hydrologic-morphometric relations can be obtained theoretically by means of joint solution of Chezy’s formula, resulting from equation (2), equations of water discharge (3), of sediment discharge (5), and of stable channel sizes (8). These equations and formulae are considered under conditions of channel-forming water discharges, when non-reversible channel processes are not available in the flow and the actual velocity is that all the sediments descending on the stretch pass through it freely. In this case the channel can be considered as stable one. Note that flows close to bankfull discharges or mean maximum discharges can be taken as channel forming discharges.

Solution of equations listed above provides relations such as

$$\omega = A_\omega Q^{\alpha_\omega} D^{\beta_\omega} s^{\gamma_\omega} g^{\delta_\omega} \tag{18}$$

For $B$, $h$, $v$ and $J$ the relations are analogous.

Here the coefficients $A$ depend only on coefficients $k$ in (3), (5), (6) and (8) and powers $\alpha$, $\beta$, $\gamma$ and $\delta$ depend on parameters $\nu$ and $m$ in (3) and (8).

For example, with $\nu = 1/6$ and $m = 2/3$ we get

$$\omega = A_\omega Q^{\nu/6} D^{-1/12} s^{-5/18} g^{-5/12} \tag{19}$$

The branches in deltas are not always stable in the above mentioned sens; some of them are silting, while others become more active and scour. But, apparently, in both cases they tend to a stable condition.

Erosion or accretion regulate automatically the relation between branch sizes and their hydraulic regime. In practice, equal composition of bottom sediments in the different branches of the delta, the similar type of channel process, the same physical-geographical conditions make the application of such relations to deltas easier.

Relations (18) and (19) are difficult to use in practice and since $D$ and $s$ generally differ
little in the branches of the same delta it is possible to apply simplified relations as

\[
\begin{align*}
\omega &= A'_\omega Q^{a_\omega} \\
B &= A'_B Q^{a_B} \\
h &= A'_h Q^{a_h} \\
v &= A'_v Q^{a_v} \\
J &= A'_J Q^{a_J}
\end{align*}
\]

which can easily be obtained by graphical or analytical treatment of observations in different branches with bankfull (or with mean-maximum) discharges. Here it is necessary to keep conditions:

\[A'_\omega \cdot A'_B \cdot A'_h \cdot A'_v = 1; \quad \alpha_\omega + \alpha_v = \alpha_B + \alpha_h + \alpha_v = 1; \quad A'_J = \frac{A'_o^2 n^2}{A'_h^{2y+1}}; \quad \alpha_J = 2\alpha_v - (2y+1)\alpha_h.
\]

For the Volga and Danube deltas (fig. 4) with water discharges in branches, corresponding to mean maximum flood, discharges at the head of delta, the following values of \(A'_o\) and \(\alpha\) in (20) were obtained (table 2):

**Table 2.**

<table>
<thead>
<tr>
<th>Deltas</th>
<th>(\bar{Q}_{\text{max}}) m³/s</th>
<th>(A'_o)</th>
<th>(A'_B)</th>
<th>(A'_h)</th>
<th>(A'_v)</th>
<th>(A'_J)</th>
<th>(-10^{-5})</th>
<th>(\alpha_\omega)</th>
<th>(\alpha_B)</th>
<th>(\alpha_h)</th>
<th>(\alpha_v)</th>
<th>(\alpha_J)</th>
<th>(m = \frac{\alpha_h}{\alpha_B})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volga</td>
<td>24 800</td>
<td>3.979</td>
<td>6.873</td>
<td>0.579</td>
<td>0.251</td>
<td>5.22</td>
<td>0.832</td>
<td>0.516</td>
<td>0.316</td>
<td>0.168</td>
<td>-0.085</td>
<td>0.612</td>
<td></td>
</tr>
<tr>
<td>Danube</td>
<td>10 140</td>
<td>3.605</td>
<td>6.080</td>
<td>0.593</td>
<td>0.277</td>
<td>8.14</td>
<td>0.834</td>
<td>0.487</td>
<td>0.347</td>
<td>0.166</td>
<td>-0.131</td>
<td>0.712</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.**

<table>
<thead>
<tr>
<th>Deltas</th>
<th>(k_1)</th>
<th>(k_2)</th>
<th>(k_3)</th>
<th>(k_4)</th>
<th>(k_5)</th>
<th>10^{-5}</th>
<th>(s) kg/m³</th>
<th>(D) mm</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volga</td>
<td>4.00</td>
<td>7.0</td>
<td>0.57</td>
<td>0.25</td>
<td>0.25</td>
<td>5.3</td>
<td>0.1-0.2</td>
<td>0.15-0.2</td>
<td>0.020</td>
</tr>
<tr>
<td>Danube</td>
<td>3.60</td>
<td>5.9</td>
<td>0.61</td>
<td>0.28</td>
<td>0.28</td>
<td>8.0</td>
<td>0.6</td>
<td>0.10-0.15</td>
<td>0.023</td>
</tr>
<tr>
<td>Kura</td>
<td>2.40</td>
<td>4.9</td>
<td>0.49</td>
<td>0.42</td>
<td>0.42</td>
<td>—</td>
<td>1-3</td>
<td>0.10-0.25</td>
<td>—</td>
</tr>
<tr>
<td>Amu-Darya</td>
<td>1.65</td>
<td>4.6</td>
<td>0.36</td>
<td>0.60</td>
<td>0.60</td>
<td>31.7</td>
<td>5-6</td>
<td>0.05-0.25</td>
<td>0.015</td>
</tr>
<tr>
<td>Terek</td>
<td>1.95</td>
<td>4.2</td>
<td>0.46</td>
<td>0.52</td>
<td>0.52</td>
<td>40.0</td>
<td>7-10</td>
<td>0.2-0.5</td>
<td>0.023</td>
</tr>
</tbody>
</table>

The very high correlation coefficients (20) claim attention. For the Danube delta they are 0.93-0.99. Also, for the Danube delta the relations

\[
s = 0.595 Q^{0.002} \quad \text{and} \quad n = 0.023 Q^{0.003}
\]

were obtained. This confirmed the lack of relationship between sediment concentration \(s\), roughness coefficient \(n\) and water discharge \(Q\) and allowed the use of simplified relations (20) instead of (19).
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Calculations of relations (20) for the Danube delta branches were made for discharges corresponding not only to mean maximum discharge at the head of delta but to mean annual discharge and mean minimum discharge at the head of the delta (fig. 5). In the first case the correlation coefficients obtained were much higher than in the other cases, confirming that the best relation between hydrologic-morphometric characteristics of the channel obtains for maximum water discharges (close to bankful discharges), that is, with maximal flow activity.

**Figure 4.** The relations between hydrologic-morphometric characteristics of the Danube delta branches and branch discharge, corresponding to mean maximum flood discharge at the head of the delta. The arrow indicates examples of calculation with $Q = 600$ m$^3$/s. The branches: 1. active (exposed to erosion); 2. silting; 3. stable

**Figure 5.** The relations between cross-section area of the Danube delta branches and water discharge I, II, III — relations as (15) for the cross-sections Danube at Orlovka (I), branch Old-Stambulsky (II) and branch Vostochny (III); IV, V, VI — relations as (20), with branch water discharges corresponding to mean maximum (IV), mean (V) and mean minimum (VI) annual discharges of the Danube at the head of the delta
Close values of the power in relations (20) for the Volga and Danube (table 2) permitted another simplification and gave relations:

\[
\begin{align*}
\omega &= k_1 Q^{5/6} \\
B &= k_2 Q^{1/2} \\
h &= k_3 Q^{1/3} \\
v &= k_4 Q^{1/6} \\
J &= k_5 Q^{-1/9}
\end{align*}
\] (21)

that correspond to theoretical relations (19).

For different deltas the values of coefficients \( k \) in relations (21) were obtained: (See table 3).

The regular dependence of coefficient \( k \) on sediment concentration \( s \) claims attention: as \( s \) increases, \( K_1, K_2 \) and \( k_3 \) decreases and \( k_4, k_5 \) increase, in accord with theoretical conclusions (equations (19)).

Relations (21) can be applied to the deltas, for which hydrometric data are not available. In this case the deltas listed in table 3 are used as analogues. For this purpose it is necessary to know approximate values of \( D \) and \( s \) in the delta being considered.

Relations (18)-(21) obtained for the delta by treatment of observations or derived from the delta analogue may be used:

1. for approximate calculation of hydrologic and morphometric characteristics with known bankfull discharge;
2. for approximate calculation of water discharge distribution between branches of known morphometric characteristics with bankfull discharge, e.g. from formula

\[
\frac{Q_1}{Q_2} = \left( \frac{B_1}{B_2} \right)^{1/s_B}
\] (22)

3. for determination of stability of the branch and to determine the tendency of its development. If actual channel sizes are greater but velocity and slope are less than those from the calculation for a steady channel with a certain bankfull discharge, this can indicate a tendency to silt of the branch. The reverse relation indicates erosion tendency of the branch;
4. for forecasting of delta branch development with artificial variations of river runoff value or its distribution between the branches.

In this case the relations (20)-(21) become prognostic.

REFERENCES

2. MIKHAILOV, V.N. (1965): The channel processes in rivers mouths, Questions of hydrology, Ser. 3, Issue of Moscow University, Moscow.
DISCUSSION

Two other USSR papers were also presented by Mr. MIKHAILOV (paper of S.S. BAYDIN and of N.A. SKRIPTUNOV).

1. **Question de M. SEMINESCU MIHAI**:

   On doit remercier Monsieur MIKHAILOV pour ses très intéressants exposés qui ont soulevé les problèmes pertinents pour l'étude des deltas.

   Par rapport aux études faites dans l'Union Soviétique sur l'évolution des divers deltas et à la possibilité de faire des prévisions sur l'évolution d'un delta, je soulève la question si on a étudié les phénomènes pendulaires entre les bras d'un delta, c'est-à-dire si on a constaté, pour de longues périodes, bien entendu, qu'un des bras du delta a eu un développement important et après un certain temps cette évolution progressive a cessé en faveur d'un autre bras qui a commencé à se développer jusqu'à un certain moment quand le cycle recommence par le développement du premier bras.

   Peut-on faire des prévisions pour des problèmes autres que les problèmes naturels, c'est-à-dire pour des aménagements de deltas, aménagements qui peuvent modifier les prévisions?

**Réponse de M. MIKHAILOV (en russe)**:

On ne peut étudier l'évolution d'un bras pris isolément. Il faut considérer le delta dans son ensemble. Ainsi, si l'on envisage un ensemble constitué par deux bras, l'évolution de l'un influence le développement de l'évolution de l'autre. Il y a une relation entre le développement des deux bras. Pour le cas d'un estuaire à une seule embouchure, on a pu développer une théorie. Pour plusieurs bras, en général, l'un d'eux a un développement plus rapide, à l'exception cependant du cas où il y a une répartition symétrique entre les deux bras. La raison doit en être cherchée dans diverses influences et notamment dans la granulométrie des sédiments.

II. **Question par M. E. LATES**:

   Quel est l'ordre de grandeur des différences (en pourcentage) obtenues entre les résultats des calculs d'après la méthode morphométrique et les résultats des observations directes en nature (à l'exemple des deltas d'Amou-Darya, de la Volga et du Danube)?

**Réponse de M. MIKHAILOV (en russe)**:

Les écarts entre les résultats des mesures et ceux de la méthode morphométrique sont assez élevés. Ils sont de l'ordre de 17% en moyenne.

   Mais on a aussi fait des essais en laboratoire et là, les différences sont plus considérables.

III. **Questions of Mr. van der MADE**:

   Many rivers carrying large amounts of sediments have three reaches:
   (a) a braiding reach;
   (b) a meandering reach;
   (c) a stable reach.

   1. Is this succession also the rule in the rivers mentioned in the paper?
   2. Can the theory predict the behaviour of a certain part of the river?

**Réponse de M. MIKHAILOV (en russe)**:

1. Cet ordre de succession n'est pas absolu, mais c'est celui qui se présente pour les rivières avec delta très développé et aussi pour les rivières à section très encaissée présentant de grandes variations d'amplitude de niveau.
2. La théorie n’est pas encore assez définitivement établie pour pouvoir prédire le comportement d’une certaine partie de la rivière. Parmi les trois formes, celle avec méandres a été beaucoup plus étudiée. Cette étude a débuté, il y a peu de temps, et la question est à peu près résolue pour les rivières à méandres. Des caractéristiques ont été établies pour les rivières du premier type indiqué.

IV. Mr. Coleman observes that wind can produce water level changes but it also can modify the reparation of the discharges between the different branches of the delta.

V. Mr. P. Santea constate qu’il est bien difficile d’exposer et de comprendre la théorie présentée par M. Mikhailov dans le temps trop limité réservé à la présentation d’une communication et à sa discussion. Il demande si M. Mikhailov ne pourrait pas préparer une étude plus étendue que M. Tison accepterait sans doute de publier dans son bulletin (M. Tison apprécie cette proposition).

VI. Commentaires de M. Popp :
J’ai entendu avec intérêt les communications que vient de présenter M. Mikhailov et tout particulièrement celle de M. Baydin. Son schéma en quatre phases concernant les rivières qui se jettent dans la Caspienne et le lac d’Aral peut d’ailleurs se retrouver dans les phases subactuelles et actuelles de l’évolution du delta du Danube.

VII. Les président, M. Volker, se fait de nouveau l’interprète des auditeurs pour remercie M. Mikhailov.

Données sur la granulométrie de la couche superficielle de sédiments du complexe lagunaire Razelm-Sinoé

I. State, I. Decu

ABSTRACT: The lagoon complex Razelm-Sinoe by its origin and evolution is considered to belong to the Danube Delta, which has been subject to an intensive colmatage processus during the last geological period.

Data presented in the paper are meant as a contribution for a better understanding of the granulometry plane distribution of the deposits on the bottom of the main lake-basins of the complex (Razelm, Golovita, Sinoe).

Data obtained have resulted from 29 samples (using a special pipe) analysed in the laboratory. Deposits on the bottom of these lakes have both a mineral and biological origin and have been brought there in very different ways, the main part being conveyed from the Danube river through the connecting channels and canals (Dranov, Mustaca, Dunavâl, Fundea).

Only through Dranov and Dunavâ canals penetrate yearly into the Razelm lake approximately 308.000 tons (192.006 m³) of suspended load, which are depositing gradually as they move away from the mouth.

Data obtained have been used to draw up five cross profiles showing the percentage distribution of some characteristic diameters ranging between 10 mm and 0.005 and also a map, showing the plane distribution of the median diameter (d50).