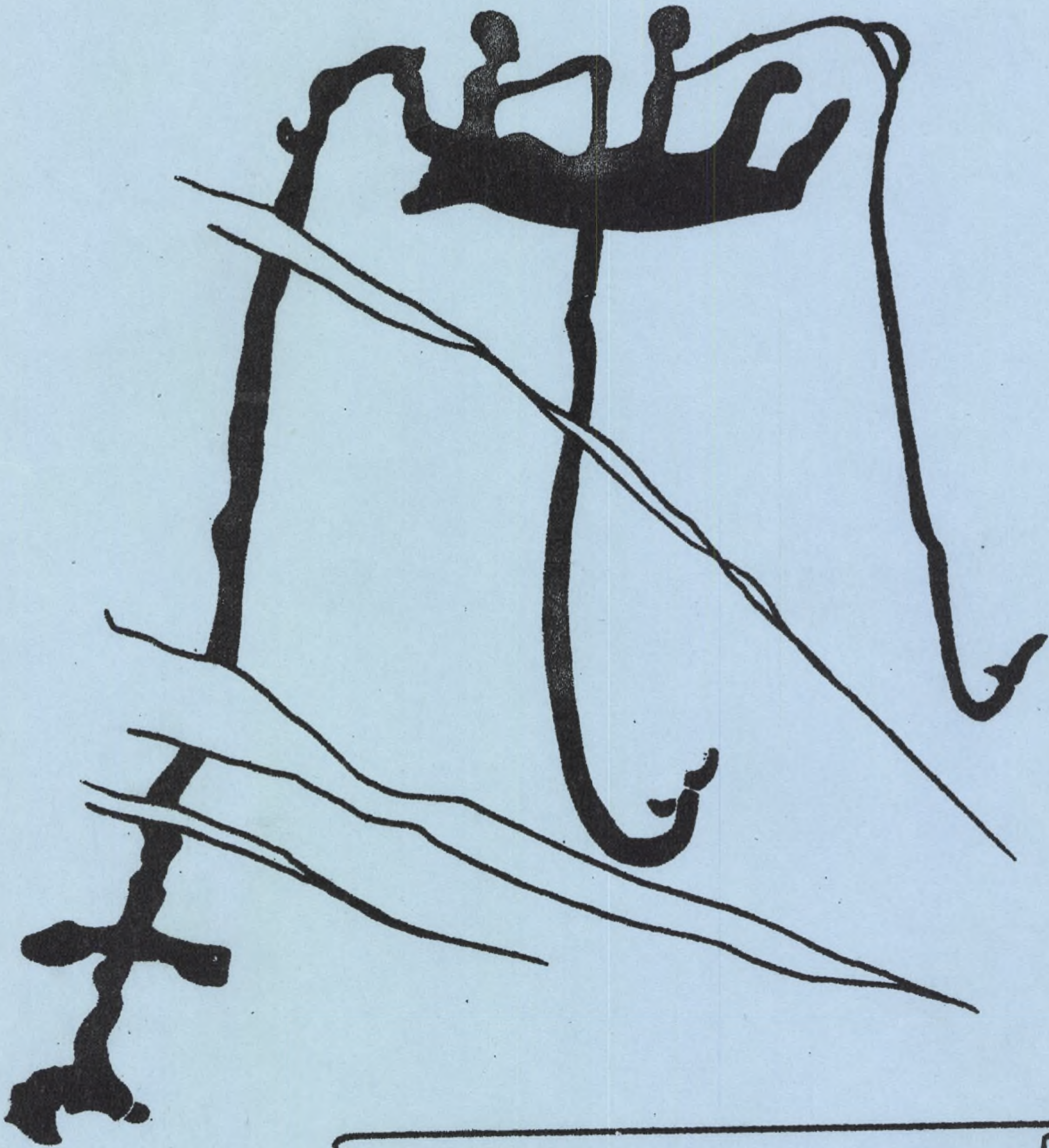
Ödsmål, Kville sn, Bohuslän

Hällristning Fiskare från bronsåldern

Rock carving Bronze age fishermen



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Determination of the Wind Stress Coefficient by Water Level Computations II.

by Artur Svansson

January 1968

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In an earlier paper (Svansson 1966) the present author published numerical computations of water levels and currents in the Gulf of Bothnia, treated as a canal. The equations used there as well as in the present work are reproduced in Fig. 1 , where τ_W means the wind stress and τ_B the bottom stress.

Computations similar to those presented in Svansson (1966) have been carried out this time systematically in the following manner. For the first five days of the period in October 1958 the mean square deviation (MSD) between computed and measured levels has been determined for various combinations of the bottom friction constant (one of the constants β , R, ρ and R') and the wind stress constant (K_2 in $\tau_W = K_2 W^2$). A minimum value of MSD is supposed to indicate the wind stress coefficient searched for.

Results.

Fig. 2 presents the results with the bottom friction expressed as $\tau_B = \beta u H$. We see that in section 15 the pair $\beta = 7.5 \cdot 10^{-5}$ s^{-1} and $K_2 = 2.0 \cdot 10^{-6}$ gives the best results. For the sections 6 and 23, however, higher values of K_2 are needed to give a minimum of MSD.

In Fig. 3 τ_B has been expressed $\tau_B = \rho u/H$. The best pair $\rho = 0.04$ m^2/s and $K_2 = 2 \cdot 10^{-6}$ gives a value of 2.75 cm for the MSD in section 15, which is lower than in any other combination.

In Fig. 4 ($\tau_B = R u$) the combination $R = 2 \cdot 10^{-3}$ m/s and $K_2 = 2.0 \cdot 10^{-6}$ is the best for section 15.

In all the computations referred to above it is clear that it is not possible to get the absolute minimum of MSD by the same K_2 for all three sections. To investigate if this discrepancy could be omitted the sectioning was scrutinized and it was found that some improvements could be made in the northern part of the area. Dashed lines in Fig:s 7 and 8 apply to these changes.

Fig. 5 shows the computation with the new parameters (τ_B = R u). Actually there is improvement in such a way that the minima of the sections 15 and 23 have come closer to each other. But on the other hand the absolute minimum of MSD for h23 is deteriorated in comparison with the results of Fig. 4.

Finally τ_B was put $R'u|u|$ as introduced by Hansen (1956), see Fig. 6. Also here the revised sections were used. The best results are achieved by $R' = 15 \cdot 10^{-3}$ a value approximately five times higher than that one used by Hansen (1956).

Conclusion:

The aim of this work to determine the wind stress coefficient K_2 must unfortunately be left uncompleted as different values are achieved at the three different sections. Possibly the value found for section 6 , approximately $3.5 \cdot 10^{-6}$, comes closest to the true value as the influence of the bottom friction is smallest at this relatively deep part (See Fig. 7).

The plans are now to test Platzman's (1963) prediction equations , where the bottom friction is no longer a function of the mean velocity only, but also of the level gradient and the wind stress. Simultaneously the transversal wind stress component so far neglected will be taken into consideration.

References:

Hansen, W., 1956: Theorie zur Errechnung des Wasserstandes und der Strömungen in Randmeeren nebst Anwendungen. Tellus Vol. 8, pp. 287-300.

Platzman, G.W., 1963: The dynamical prediction of wind tides on Lake Erie. Meteorological Monographs Vol. 4, 26 , pp. 1-44.

Svansson, C.A., 1966: Determination of the wind stress coefficient by water level computations. Medd. Havsfiskelab. No. 8.

$$\begin{cases} \dfrac{\partial u}{\partial t} = -g\dfrac{\partial h}{\partial x} - \dfrac{\partial P_a}{\partial x} + \dfrac{\tau_{wx}}{H} - \dfrac{\tau_B}{H} + g\dfrac{\partial \bar{h}}{\partial x}\,; \\[2ex] b\dfrac{\partial h}{\partial t} + \dfrac{\partial}{\partial x}(Au) = 0\,; \end{cases}$$

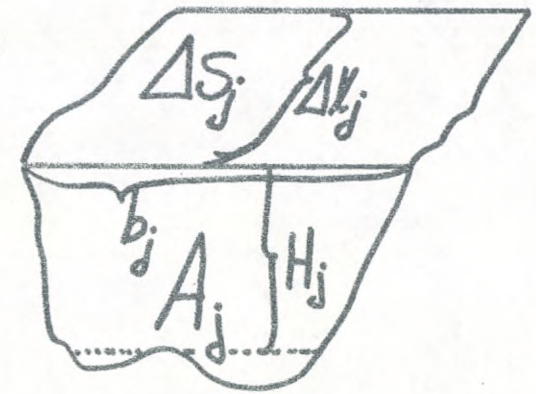


Fig. 1.

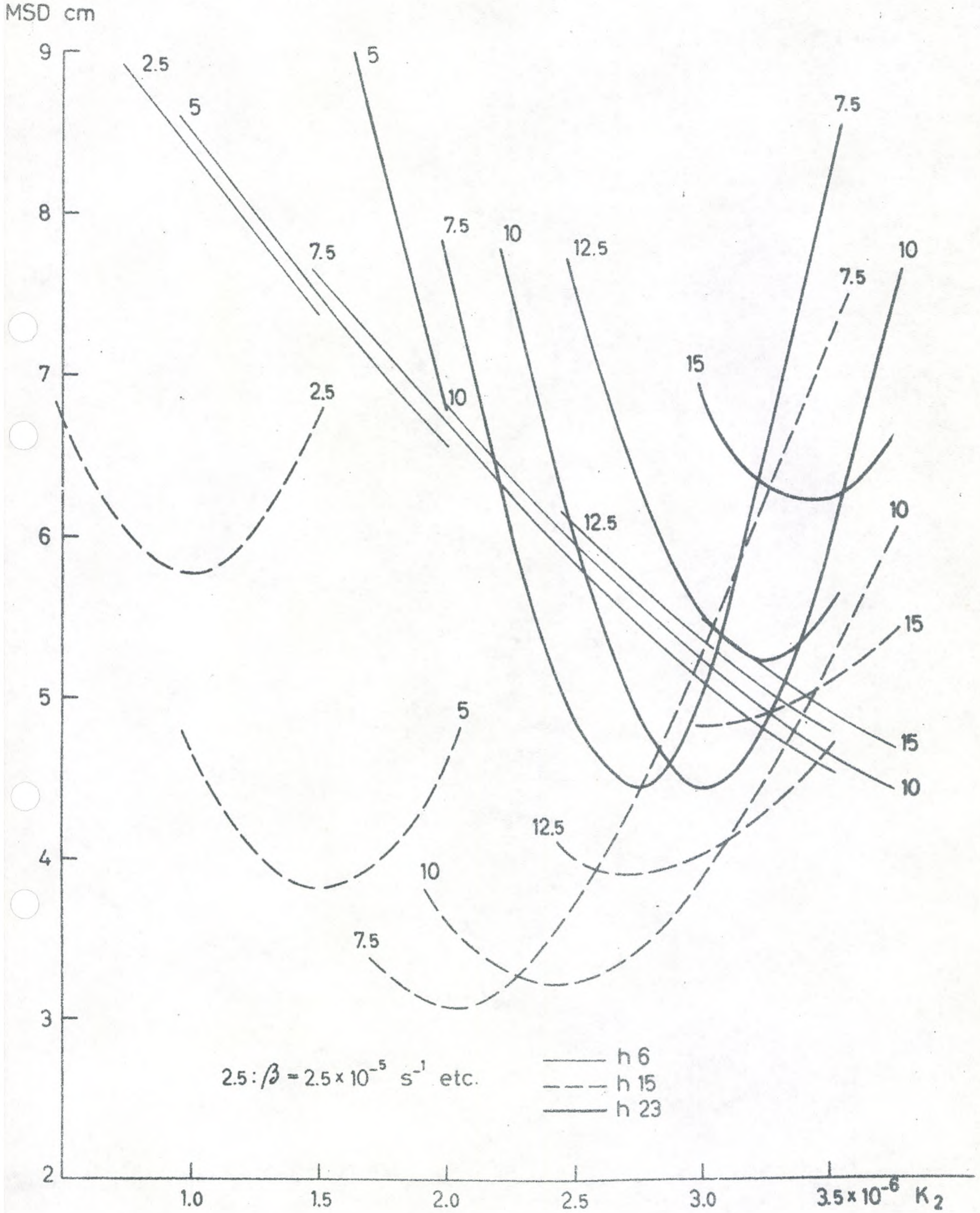
$$\frac{\tau_B}{H} = \beta u = \frac{R}{H}u = \frac{\varrho}{H^2}u - \frac{R'}{H}u\cdot|u|$$

$$u_j^{n+1} = \alpha u_j^n + \frac{1-\alpha}{2}\left(u_{j+1}^n + u_{j-1}^n\right) + \Delta t\left[-\frac{g}{\Delta x_{j-1}+\Delta x_j}\left(h_{j+1}^n - h_{j-1}^n - \left(\bar{h}_{j+1}^{n+1} - \bar{h}_{j-1}^{n+1}\right)\right) - \frac{\Delta_x P_{aj}^{n+1}}{10\,a} + \frac{\tau_{wxj}^{n+1}}{H_j} - \frac{\tilde{\tau}_{Bj}^{n+1}}{H_j}\right];$$

$$h_j^{n+1} = \alpha h_j^n + \frac{1-\alpha}{2}\left(h_{j+1}^n + h_{j-1}^n\right) - \frac{A_{j+1}u_{j+1}^{n+1} - A_{j-1}u_{j-1}^{n+1}}{\Delta s_{j-1} + \Delta s_j}\cdot\Delta t\,;$$

Notations:

U	=	Transport of water	m^3/s
g	=	Acceleration of gravity	m/s^2
A	=	Cross section area	m^2
b	=	Width of section	m
Δs	=	Area between sections	m^2
Δx_j	=	$\frac{2\Delta s_j}{b_j+b_{j+1}}$	m
H	=	Bottom depth = A/b	m
h	=	Variation of water level	m
$g\frac{\partial \bar{h}}{\partial x}$	=	Tide generating acceleration	m/s^2
q	=	Density	t/m^3
p	=	Pressure	t/m and s^2
p_a'	=	Atmospheric pressure	– " –
p_a'	=	p_a'/q	m^2/s^2
τ'	=	Turbulent stress component	t/m and s^2
τ	=	τ'/q	m^2/s^2
W	=	Surface wind velocity	m/s
n	=	Index of timestep	
j	=	Index of section	
α	=	Smoothing coefficient (usually = 0.75)	



MSD cm
9
8
7
6
5
4
3
2
1.0
1.5
2.0
2.5
3.0
3.5 x 10^-6 K2
2.5
5
7.5
10
12.5
15
2.5 : β = 2.5 x 10^-5 s^-1 etc.
h 6
h 15
h 23

Fig. 2.

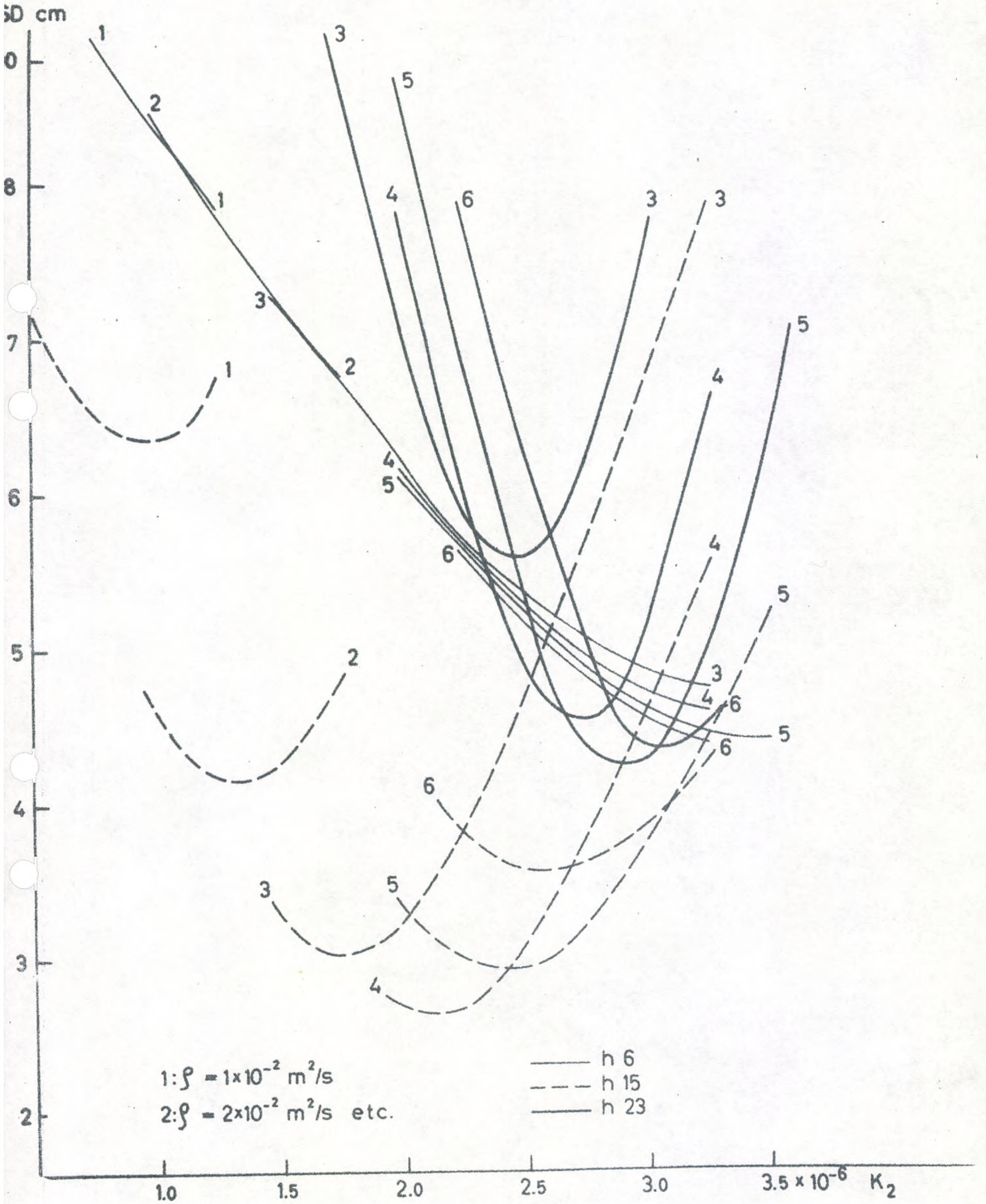

SD cm
K2
1.0
1.5
2.0
2.5
3.0
3.5 × 10^-6
h 6
h 15
h 23
1: ρ = 1×10^-2 m^2/s
2: ρ = 2×10^-2 m^2/s etc.

Fig. 3.

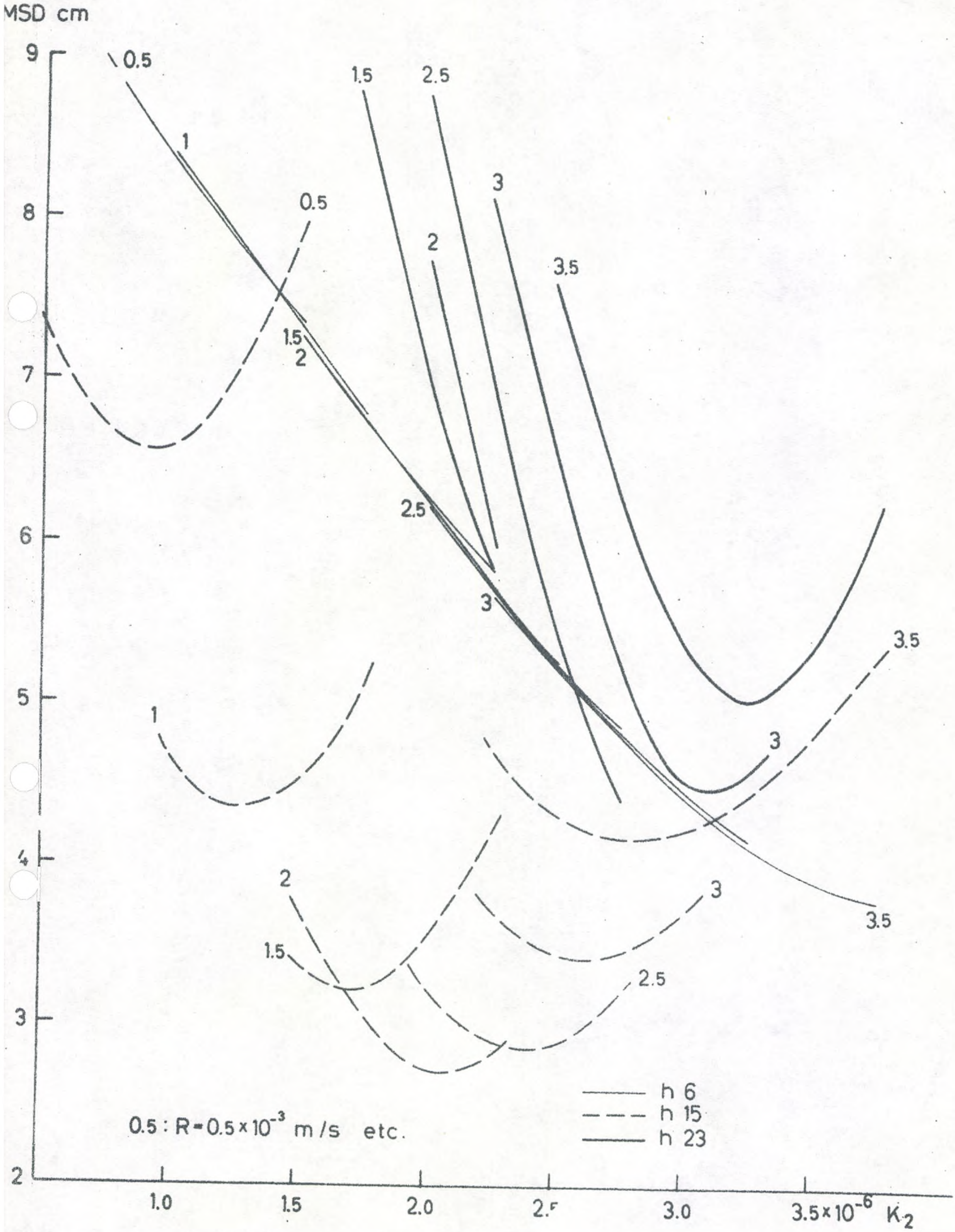

MSD cm
9
8
7
6
5
4
3
2
1.0
1.5
2.0
2.5
3.0
3.5×10⁻⁶ K2
0.5
1
1.5
2
2.5
3
3.5
0.5 : R = 0.5×10⁻³ m/s etc.
h 6
h 15
h 23

Fig. 4.

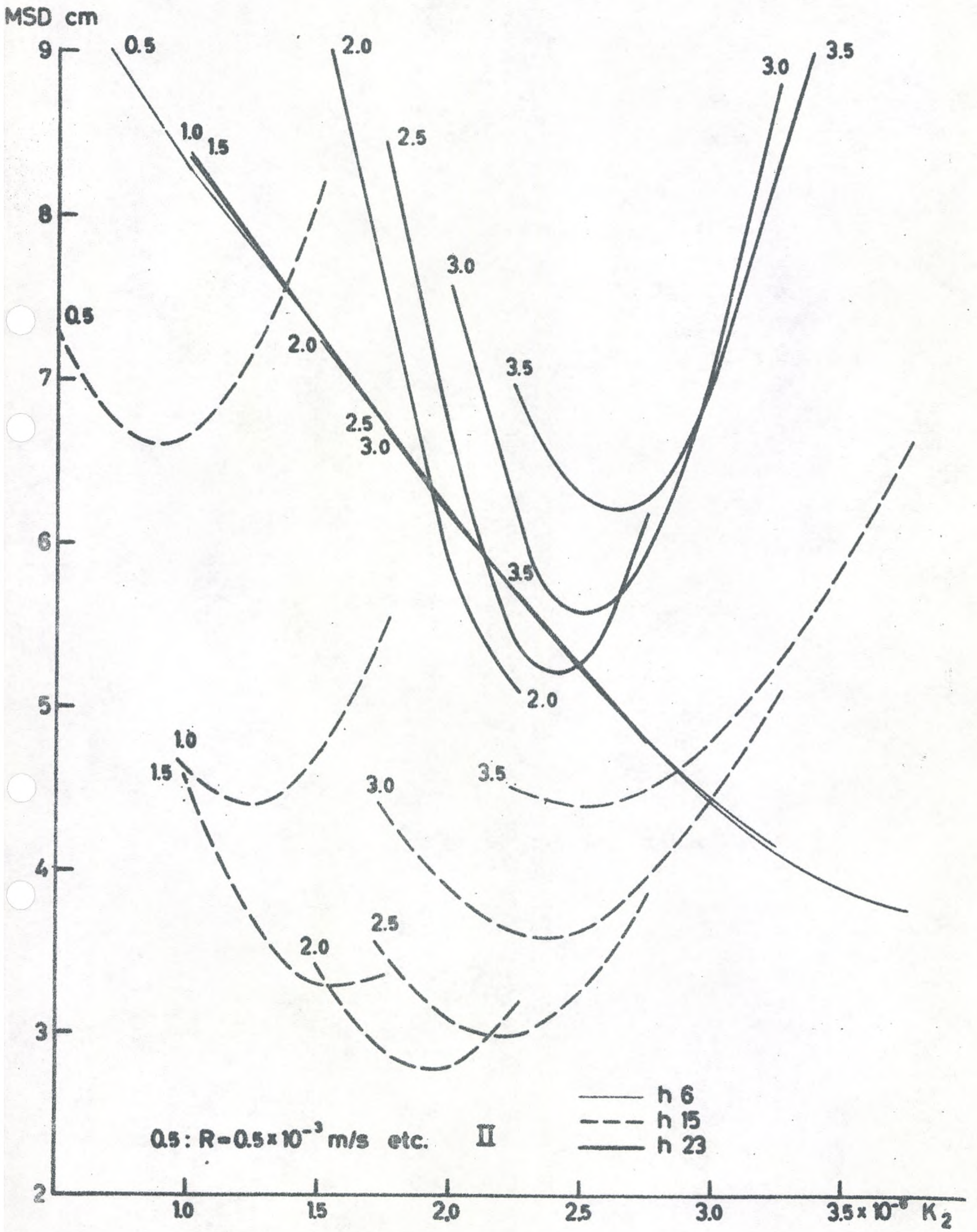
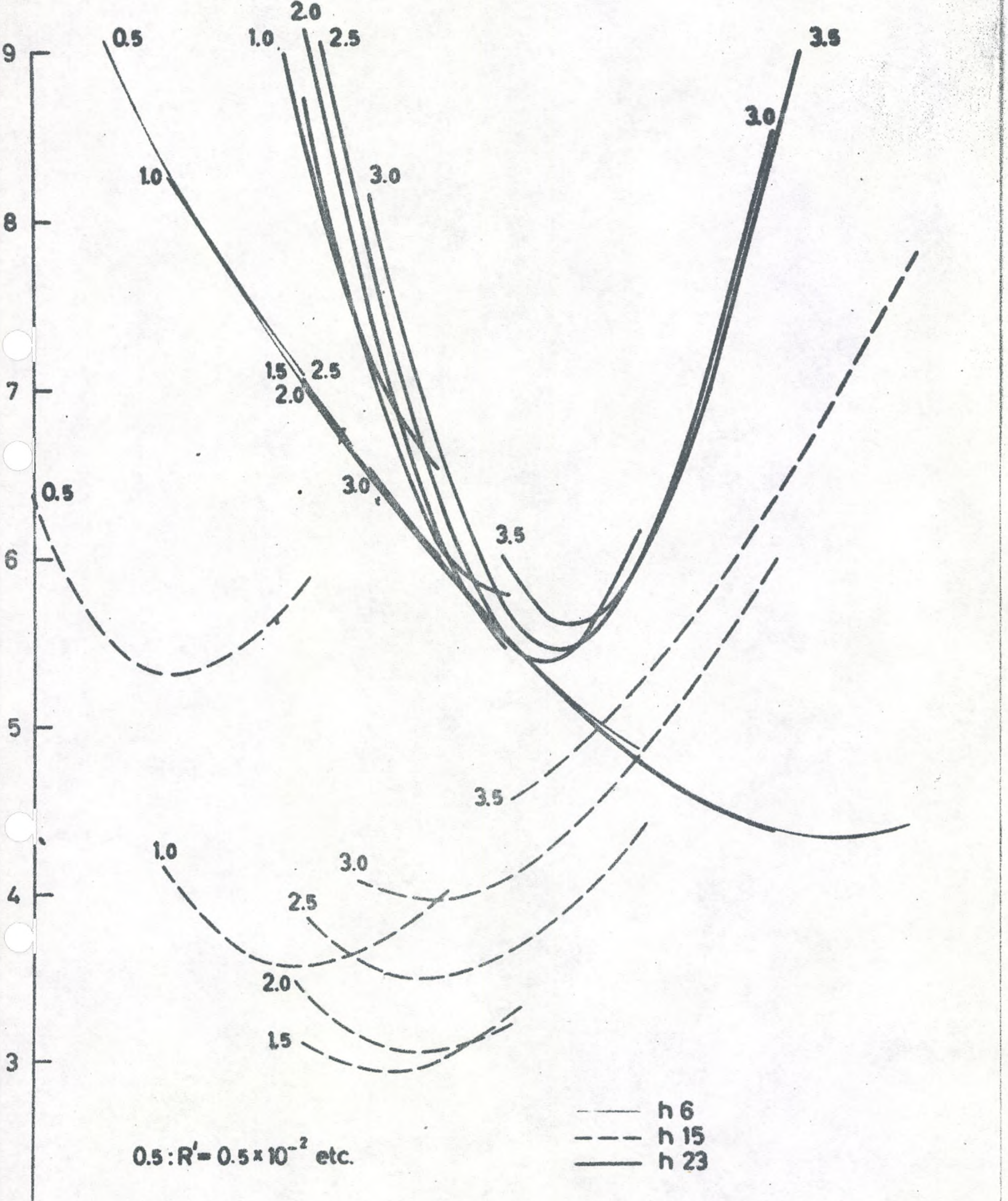

MSD cm
9
8
7
6
5
4
3
2
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1.0
1.5
2.0
2.5
3.0
3.5 x 10⁻⁶ K2
h 6
h 15
h 23
0.5 : R=0.5 x 10⁻³ m/s etc.
II

Fig. 5.



9
8
7
6
5
4
3
2
1.0
1.5
2.0
2.5
3.0
3.5 × 10⁻⁶ K₂
0.5
1.0
1.5
2.0
2.5
3.0
3.5
h 6
h 15
h 23
0.5 : R' = 0.5 × 10⁻² etc.

Fig. 6.

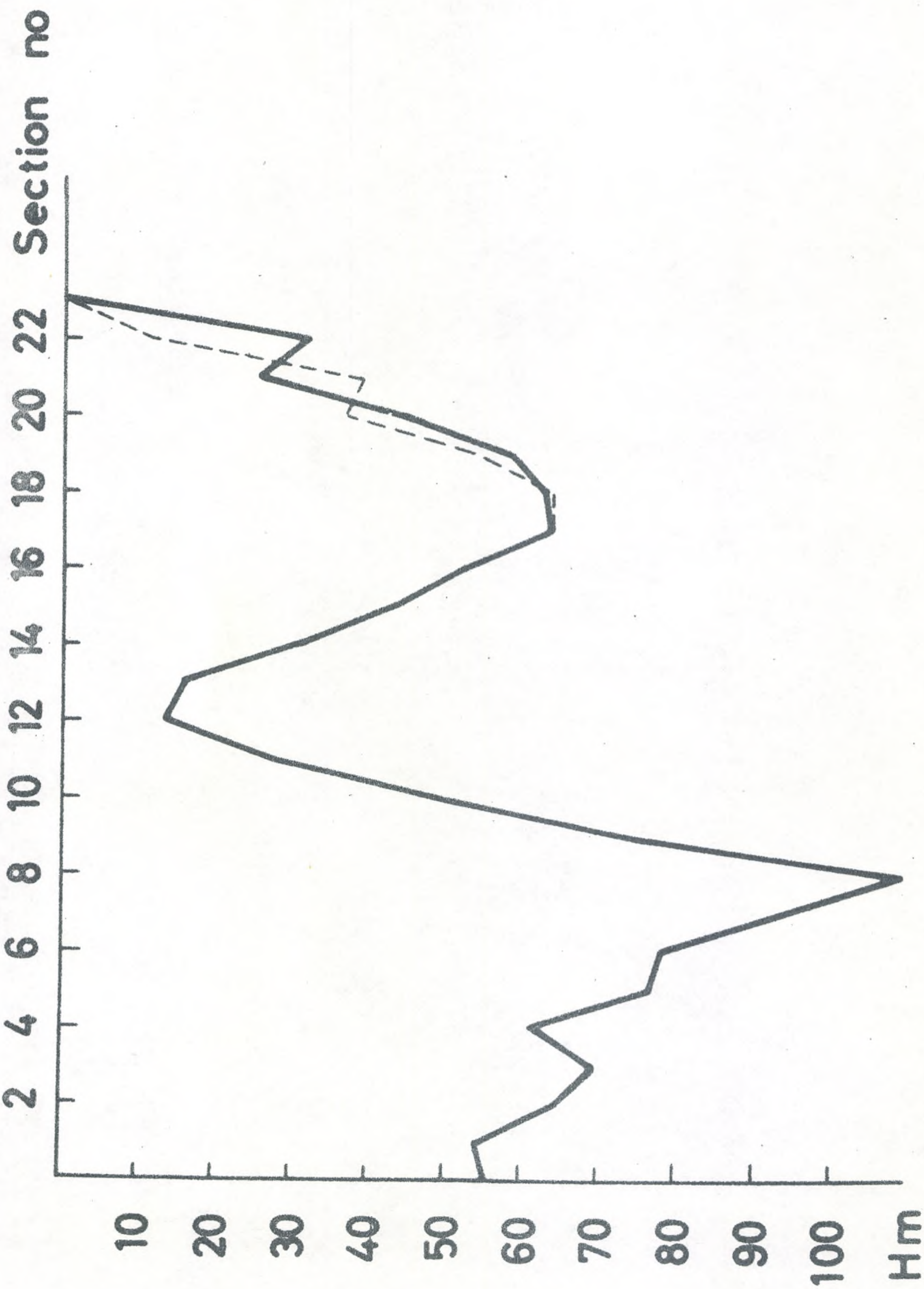

Section no
2
4
6
8
10
12
14
16
18
20
22
10
20
30
40
50
60
70
80
90
100
Hm

Fig. 7.

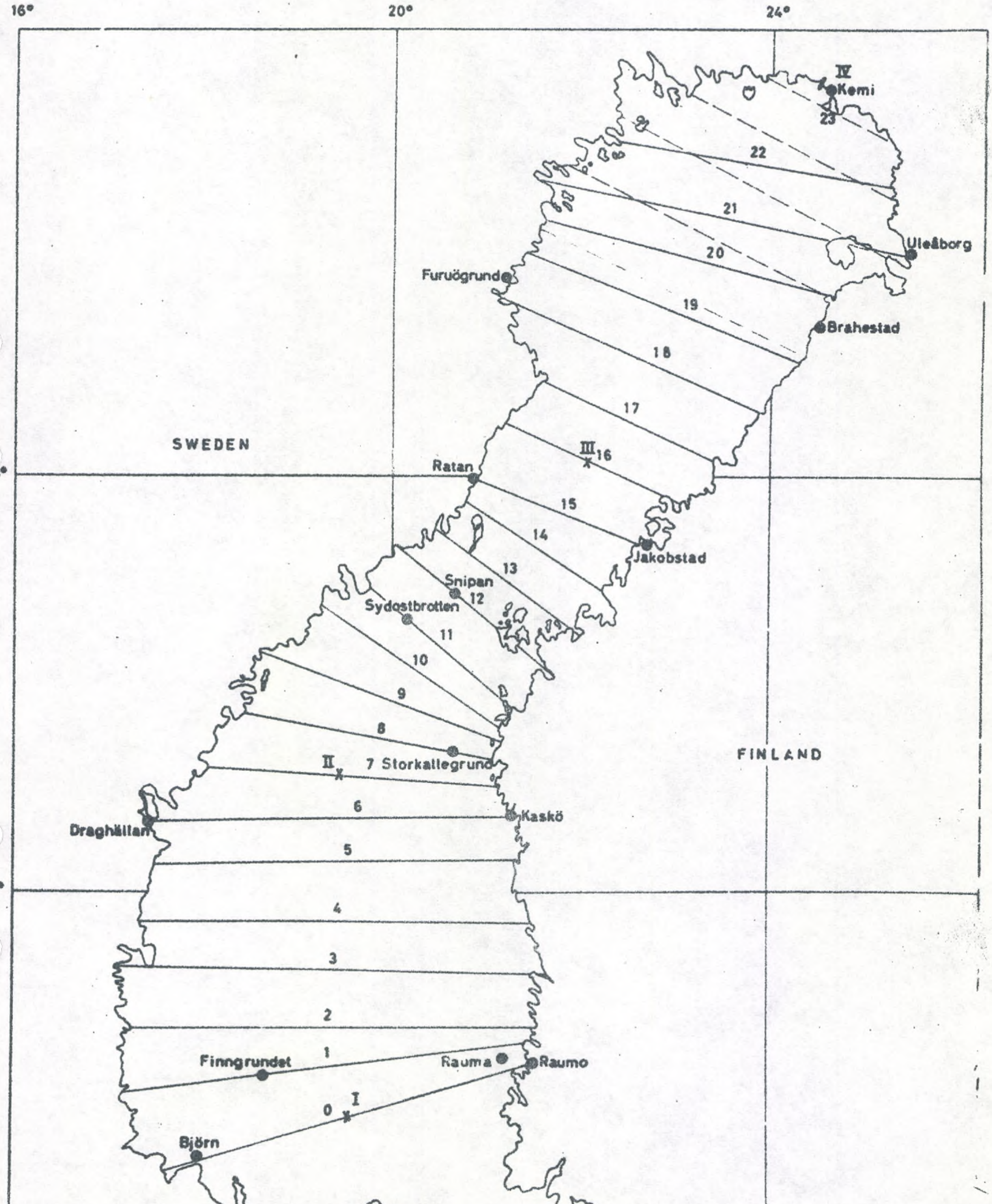

16°
20°
24°
62°
SWEDEN
FINLAND
IV
Kemi
23
22
21
Uleåborg
20
Furuögrund
19
Brahestad
18
17
III
16
Ratan
15
14
Jakobstad
13
Snipan
12
Sydostbrotten
11
10
9
8
II
7 Storkallegrund
6
Kaskö
Draghällan
5
4
3
2
1
Finngrundet
Rauma
Raumo
I
0
Björn

Fig. 8.