SHAFT DRILLING ACTIVITY FOR THE WATER PROTECTION OF BAUXITE MINES IN NYIRÁD

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SUMMARY

The author acquiants with some experiences of shaft drilling activity which has been developed at the Bauxite Prospecting Company since 1963.

Drilled shafts can be considered as specifying elements of the active water protection system of the bauxite mines in Nyirád. They are located on faults in order of good water producing. Difficulties in drilling may be raised by complicated geological conditions e.g. step like changes in direction may lead to the sticking of the drilling tool and the jamming of the casing. The author shows packed hole drilling technology which has been developed for the decreasing of inclination.

He acquiants with roller bits which have been used and points out some results achieved in the course of drilling in dolomite.

He deals with some disturbances in mud cieculating, due to the loss of mud.

INTRODUCTION

Bauxite occurs in lense shaped bodies in the area of Nyirád. The significant part of mineable bauxite is located under the original level of the main karst water system. The mining of bauxite is made possible by active water protection. It is ensured by the system of drilled shafts from which water is lifted with the help of high capacity submergible pumps.

The company has been dealing with shaft drilling since 1963. Three experimental shafts have been sunk for the determination of suitability of technology. Having finished the experiments successfully, shaft drilling in full operation began from 1966.

Up till now 33 dewatering shafts have been drilled. Under the influence of approximately 18000 m^3/h quantity of water lifted simultaneously from producing wells, the level of karst water in this area sank nearly 100 ms.

LOCATION OF DRILLED SHAFTS

Dewatering drilled shafts satisfy the requirements best if their water producing capacity reaches or approaches the continuous operation capacity of submergible pumps which can be built in to a given depth. Therefore it is very important to choose the location of the shaft properly. Considering some mining points of view and effective dewatering the shafts are located on faults among bauxite lenses /Figure 1./.

In the area of Nyirád the level of the main karst water system should be sunk to a depth of approximately 170 ms beneath the surface. Considering the local depression as well, the fault should be drilled at a depth ranging from 200 to 250 ms in the karsted, fissured dolomite.

Shaft drilling locations are chosen in advance according to the analysis of the data obtained in the course of bauxite prospecting drillings. In order to decide the suitability of the location a small diameter technical hole is bored. It makes clear the permeability of the prospected area, the suitability of shaft drilling technology and the location of faults or fault zones.

SHAFT CONSTRUCTION

While planning shaft constructions two main points of view should be taken into consideration. On the one hand the sizes, the number and the location depth of submergible pumps to be built in, and the expected geological, hydrogeological conditions of holes together with the physical properties of rocks /drillability, stability, permeability etc./ on the other.

The construction of shafts planned according to the above in the area can be characterized by the following. In the interest of rig protection the loose strata near the surface are ceased off by a surface hole constructed in a traditional way. Its depth is 20 ms. In the case of unfavourable hydrogeological and drilling conditions of the hanging-wall formations /e.g. conglomerate/ the length of the surface hole may extend to 60-80 ms.

The number of drilling stages is 2-4 depending on conditions. The largest diameter used in drilling is 2,95 ms the smallest one is 1,35 m. The water-bearing dolomite is usually drilled with a 2,00 m diameter bit and it is cased with a 1,40 m diameter steel casing equipped partly with filter /in which three submergible pumps can be placed/. Sometimes a 1,35 m diameter bit and a 0,80 m diameter casing are used /for one pump/. The depth of shafts is 220-300 ms.

In Figure 2. a typical shaft construction with a short surface hole and the drilled strata can be seen.

DRILLING RIG

Shafts are drilled with a Wirth-made /GFR/ drilling rig type L-10. It has a diesel engine with a capacity of 125 kW. The 16,9 meter high drilling mast can be loaded with 1000 kN. The opening of the rotary table is 2110 mm. In the case of using a larger diameter drilling tool the running trip can be carried out with the help of special landing construction. The drilling tools have flanged joint and they are equipped with two compressed-air pipes for airlift outside the tubing.

MUD CIRCULATING

The capacity of airlift used for mud circulating is 600-1000 m^3/ h in the case of filled shaft which results a flow velocity of 2,4-3,8 m/s in the drill pipe. The cleaning of the bottom hole is made effective by this and there is no regrinding of cuttings. The beginning period of shaft drilling is characterized by the above mentioned condition. With the progress of the dewatering programme - under the influence of the quality of water lifted from the drilled shafts - the level of water sank 96 ms. Therefore while drilling permeable zones the level of mud in the shafts has sunk lately so much that the effectiveness of mud circulating has decreased, it has become periodical and even ceased in some cases.

During plant experiments methods for the ensuring of suitable mud circulating have been developed at our company.

In the upper part of the shaft reaching dolomite considered for water producing the mud circulating substance is bentonite mud with a density of 1,1 x 10 kg/m^3. Losses here, besides the ensuring of mud circulating should be ceased in the interest of stability of the shaft wall. The prompt ceasing of mud loss has great importance even in the case of its small quantity because during drilling water permeable zones may open repeatedly and the total value of losses may exceed the supplying possibilities. It may be ceased later only by means of cementing the whole stage after having used a large quantity of mud forming material. Smaller mud losses can be ceased by using packing substances /peat, sawdust, clay/ and larger ones by supplying a short cement plug.

In the water-bearing dolomite stage mud circulating is carried out by water, packing substances or cementing should not be supplied. In the case of disturbances in mud circulating due to tho loss of water, mud circulating capacity is increased with the changing of the operational parametres of the airlift.

BIT LOAD AND ROTARY SPEED

The value of loading and rotary speed is determined by the drillability of rocks. It is necessary to change these values during drilling depending on the demand for torque and tool behaviour.

Maximum two third of the mass of collar string may be used for bit loading [1,2] similarly to normal rotary drilling. It is necessary to reserve a certain part of the capacity of the rig in order to cease jammings due to probable rock falls and inclining. In practice the value of loading is between 50-300 kN. In the case of drilling dolomite it is often necessary to use decreased loading in order to get mono-axial holes.

The rotation speed of the rotary table can be changed between 0-30 1/min. In these extreme values the rotary speed of the bit should be determined in such a way that the outside cutters should not exceed their allowed maximum revolution number and the quiet working of the tool should be ensured as well.

In Figure 3. the revolution number of one- and two-support cutters used at the company can be read as a function of rotary speed of the bit. The range of rotary speed of the bit used is the following /see striated areas in figure/:

2,95 m diameter bit	5-10 1/min
2,50 m diameter bit	8-13 1/min
2,00 m diameter bit	10-15 1/min

At hole adjustment the rotary speed of the bit is higher than the above values.

DRILLING TOOLS, DRILLABILITY OF ROCKS

The largest part of drilled rocks belong to the medium hard category from the point of view of drillability, therefore toothed cutters are used on cone bottom bits. One support cutters used at an early stage of shaft boring were gradually changed for two support ones which have a lot of advantages. The latter are characterized by larger operational safety, endurance and loadability. The surface in contact with the cutter teeth and the rock is smaller, therefore the specific load is bigger.

Most bored rocks can be well drilled with cutters. In the hanging-wall certain gravel and clay strata may raise difficulties. At drilling gravel good results have been obtained by using cutting edges in the place of cutters.

In clay experiments of drilling in two passes have been justified. A pilot hole has been drilled with a 1,35 m diameter bit equipped with cutting edges and then it has been reamed to 2,95 m diameter by a bit equipped with cutters. Altogether penetration rate has been doubled.

From the point of view of drillabilty dolomite has a determining importance. Drilling in dolomite starts with a 2 m diameter bit at a depth ranging from 80 to 130 ms beneath the surface and it is continued up to the ultime depth of shaft i.e. to 220-300 ms. Therefore 160 ms on average fall on dolomite. The length of hole section affecting the dolomite is considerable since it represents more than half of the over-all drilling length. Under drilling technical aspect its importance is even more accentuated.

Dolomite has a variable development, it is characterized by the frequent succession of hard and loose sections, it is crumbled, fissured and cavernous near the faults. Besides the significant variability of the characteristics of the rock it is necessary to take into consideration the changing of drilling conditions as well. From the loose section of dolomite and the fault zone, rock falls often occur which cause jamming of the tool. Cuttings regriding can be resulted by the sunken water level due to the weakening of mud circulating which brings about the decrease of penetration rate. Consequently, in dolomite several factors of drillability /rock structure, load, rotary speed, mud circulating/ may change significantly.

The character of the rock can be determined by the specimen rock obtained. The cuttings of hard dolomite are close grained. Mud circulating lifts 2-10 cm cuttings from fissured, crumbled dolomite and 20-30 cm cuttings from loose and breccia ones.

The drillability of bored dolomite can be well characterized by the rate of penetration for a unit load. In Figure 4. the summarized data of dolomite sections drilled with a 2,00 m diameter bit can be seen: the specific drilling rate in loose dolomite /even without extreme values / is six times higher than that of hard dolomite.

Similar results are given by dolomite drilling performance curves drawn for 2,00 m diameter according to relations between load and penetration rate /Figure 5./.

DECREASING OF SHAFT INCLINATION

During drilling fault zones and dolomite of irregular formation another problem arises besides the above mentioned. Succession of loose and hard strata within the same large diameter borehole is particularly hazardous as the possibility for drilled shafts to be deviated is more marked.

The allowable extent of borehole inclination is limited by the technology of drilling on the other hand, and by operating conditions on the other. For the work of drilling it is necessary to make possible the moving of the drilling tool without jamming, the running-in of the rigid casing string, the running in of the gravel pipes to the annulus and the producing of a uniform filter bed.

Drilled shafts have a much less inclination than that of boreholes drilled with conventional rotary techniques, since it is possible to concentrate rather heavy weights quite near the bit and the collar string has no deflection. "Dog legs" i.e. sudden changes in direction within a short section are hazardous, while holes with uniform inclination i.e. mono-axial holes are suitable for the purpose.

When drilling through a faulted zone in dolomite particularly hazardous "bends" may be produced within the cross section of drilling, since in such cases both virgin, hard dolomite and detrital ones are present. Similar case occured at drilling shaft No 4. /Figure 6./. In loose sections the borehole is widened out, as a consequence of which bit has no support sideways at such points and - following the least resistance - it slides down from the hard surface. In one of the shafts a 55 cm long inclination has occured at a length of 1,5 m within a section of 20°. This phenomenon is frequently accompanied by a substantial change in the direction of inclination, thus creating even heavier conditions in the borehole.

Initially, drilling tools were assambled from strings of collar mounted above the bit. In the initial plans it was foreseen to ensure the verticality of hole direction partly by holding some sections of collar in hung state, partly by the so-called pendulum effect. Having drilled some shafts it became evident that this method was not suitable for dolomite since the holes were not prevented from being inclined to such an extent that run-in casings became jammed.

With gathering more data on the characteristics of the inclinations produced in dolomites the method of stabilizing suitable to prevent hazardous inclinations could be improved [3].The stabilizer has two purposes: its long lateral cylinders serve to keep the uni-axial direction, while the cutters below them are to straighten the wall of the borehole and cut down "dog legs".

The optimal arrangment of stabilizers was conducted by field tests in the course of plant experiments. Favourable results were obtained by using the so-called triple stabilized type drilling tool. In agreement with the experiences of drilling small diameter rotary holes this "packed" hole method [4] leads to such a uniform hole inclination by which the casing programme is not hindered. Inclination data of shaft No 19 drilled with "packed hole" technology can be seen in Figure 7.

In addition to proper stabilizing while choosing drilling parametres it is necessary to take into consideration the following: decreasing the bit load and increasing the weight hung up; hourly change in the direction of rotation; borehole adjustment in the case where the quality of rock is altered; reducing the drilling rate in faulted zones.

Initially, difficulties were encountered in five shafts on account of hole inclination. With the application of the "packed hole" method, as well as the careful observation of the above mentioned instructions, the extent of hole inclinations could be kept within the range of values and shafts, as planned, have been completed.

FINAL REMARKS

A suitable shaft drilling technology has been developed and adapted successfully for the difficult conditions in the area which has been justified by the results achieved. Altogether 39 shafts have been drilled /3 experimental shafts, 3 air shafts and 33 dewatering ones/. The total length drilled with large diameter exceeds 6800 ms.

Within the active water protection system shaft drilling activity is continued for the further decreasing of water level. New shafts are partly located on the skirts of the area, meanwhile the level of the main karst water system continues decreasing. Consequently, the changing of geological and hydrogeological conditions of bores should be taken into consideration. The shaft drilling technology which has proved good will be suitable for drilling under new conditions as well with minor modifications.

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LEGEND

Fig.1: Location of drilled shafts
A : drilled shaft
V : fault
n_1 : the karst water level in 1963
n_2 : the karst water level in 1981
1 : dawk
2 : gravel
3 : limestone
4 : sandstone
5 : clay
6 : dolomite
7 : bauxite

Fig.2: Construction of drilled shaft
1 : dawk
2 : marl
3 : limestone
4 : sandstone
5 : clay
6 : dolomite
7 : cement plug
8 : filter casing
9 : filter gravel

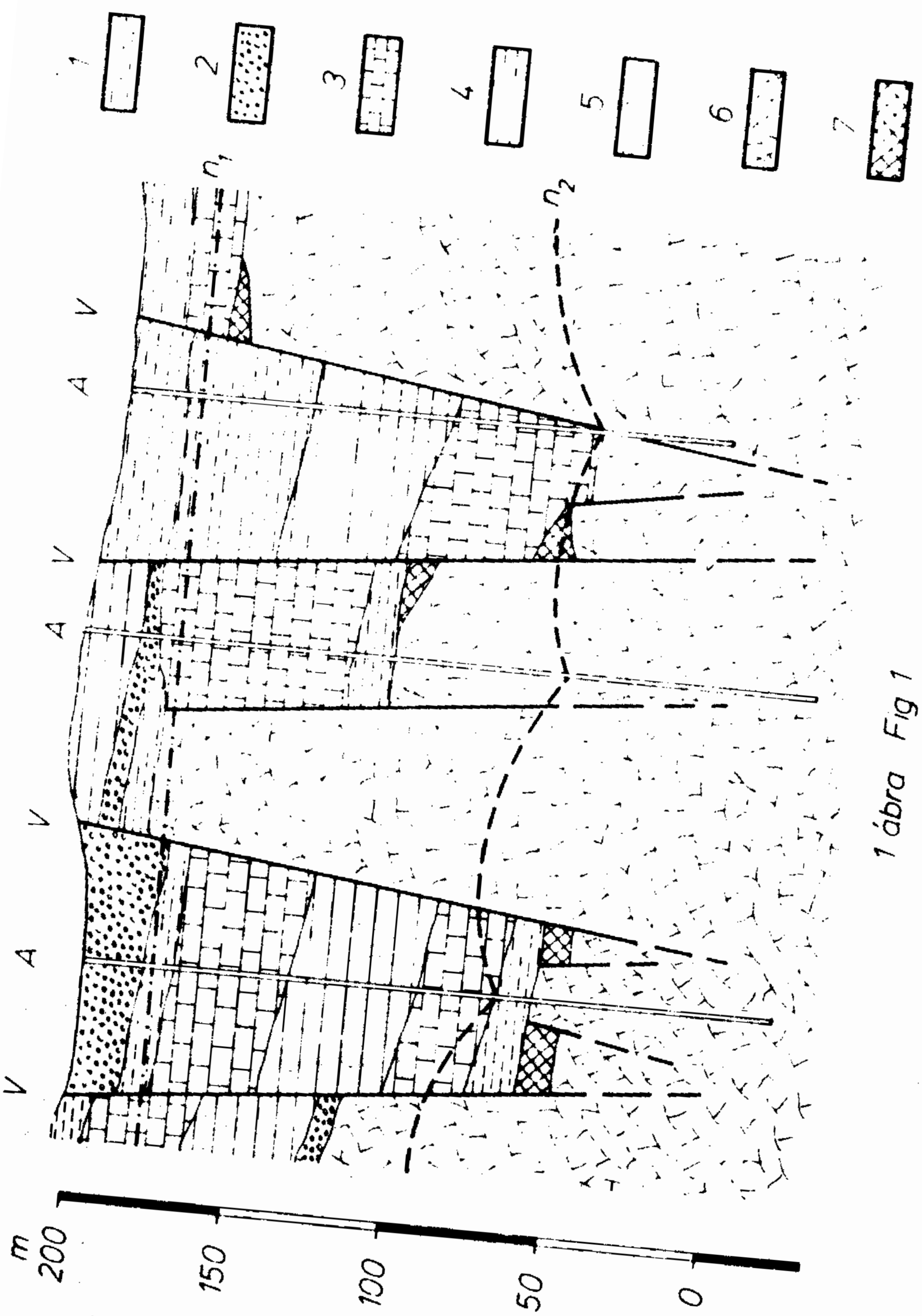
Fig.3: Rotary speed and revolution number of cutters
n : rotary speed, 1/min
n_1 : revolution per minute of one support cutters
n_2 : revolution per minute of two support cutters

Fig.4: Specific drilling rate in dolomite
v_{ff}: specific drilling rate, 10^{-3} kN /mm/kN/
l : drilled length, m

Fig.5: Dolomite drilling performance curves
F_f : specific bit load, 10^2 kN/m_3/kN/cm/
V_{fn}: specific drilling rate, 10^{-3} m/min^{-1}
1 : hard dolomite and limestone
2 : fissured dolomite
3 : fissured dolomite, marl
4 : friable-loose dolomite, sandy clay

Fig.6: Shaft inclination in fault zone
a : top view
b : section
c : dog-leg
v : fault
d : line of dip

Fig.7: Inclination of shaft No. 19.
1 : drilling rate, 10^{-5} km/h /cm/h/
2 : bit load, kN
3 : loss of water, m^3/h
4 : hole diameter, m
5 : inclination, m



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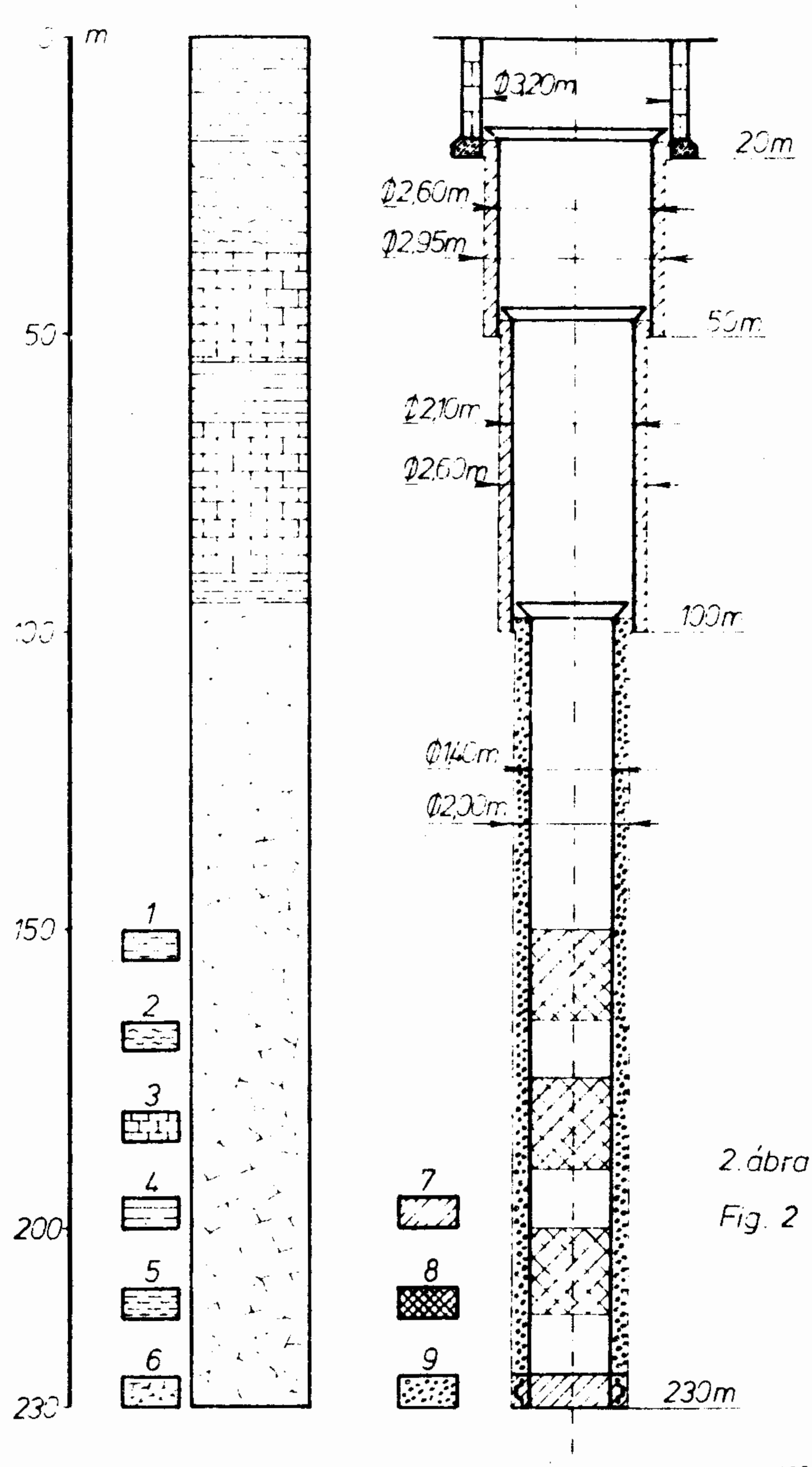
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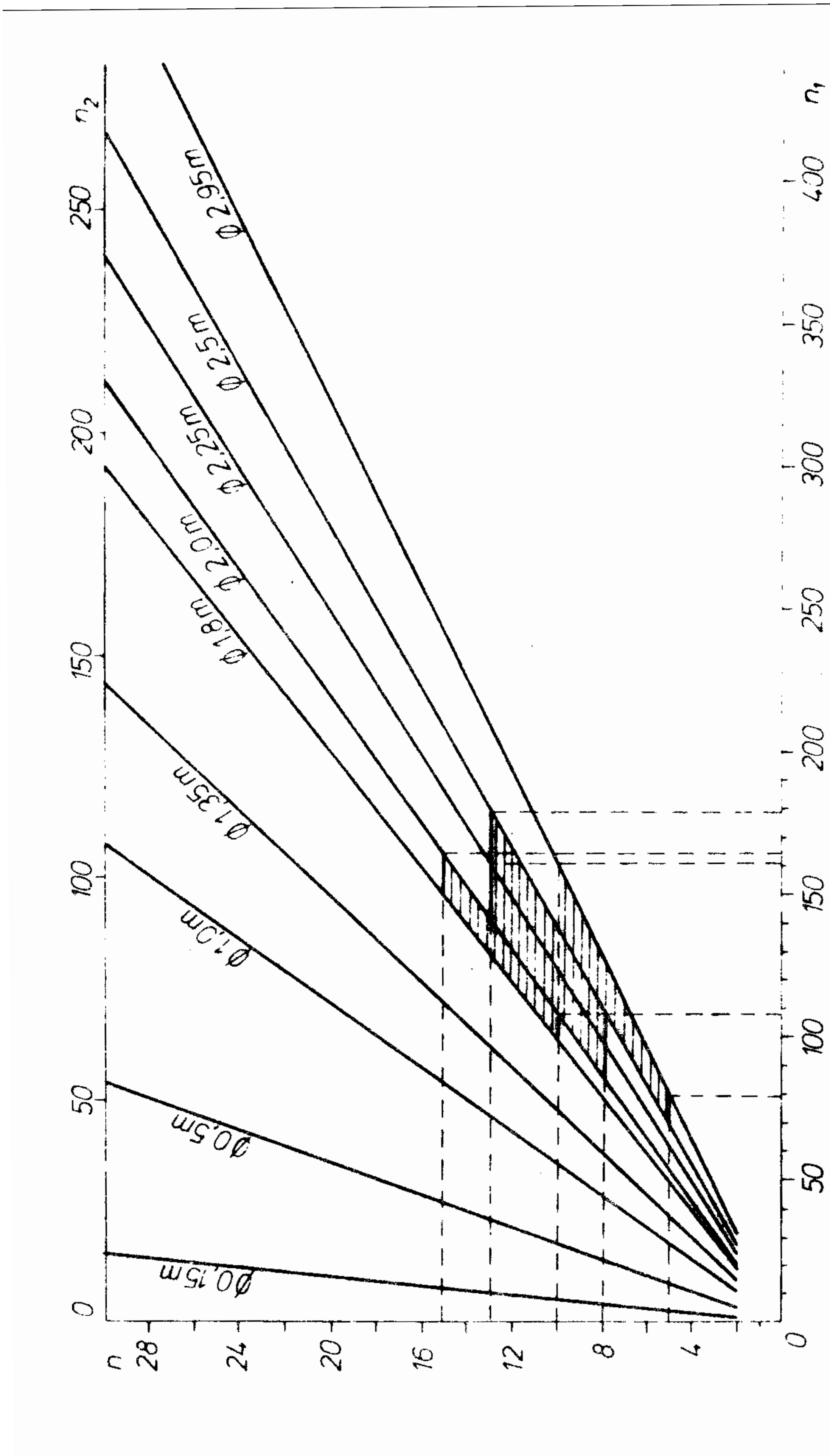
Fig. 2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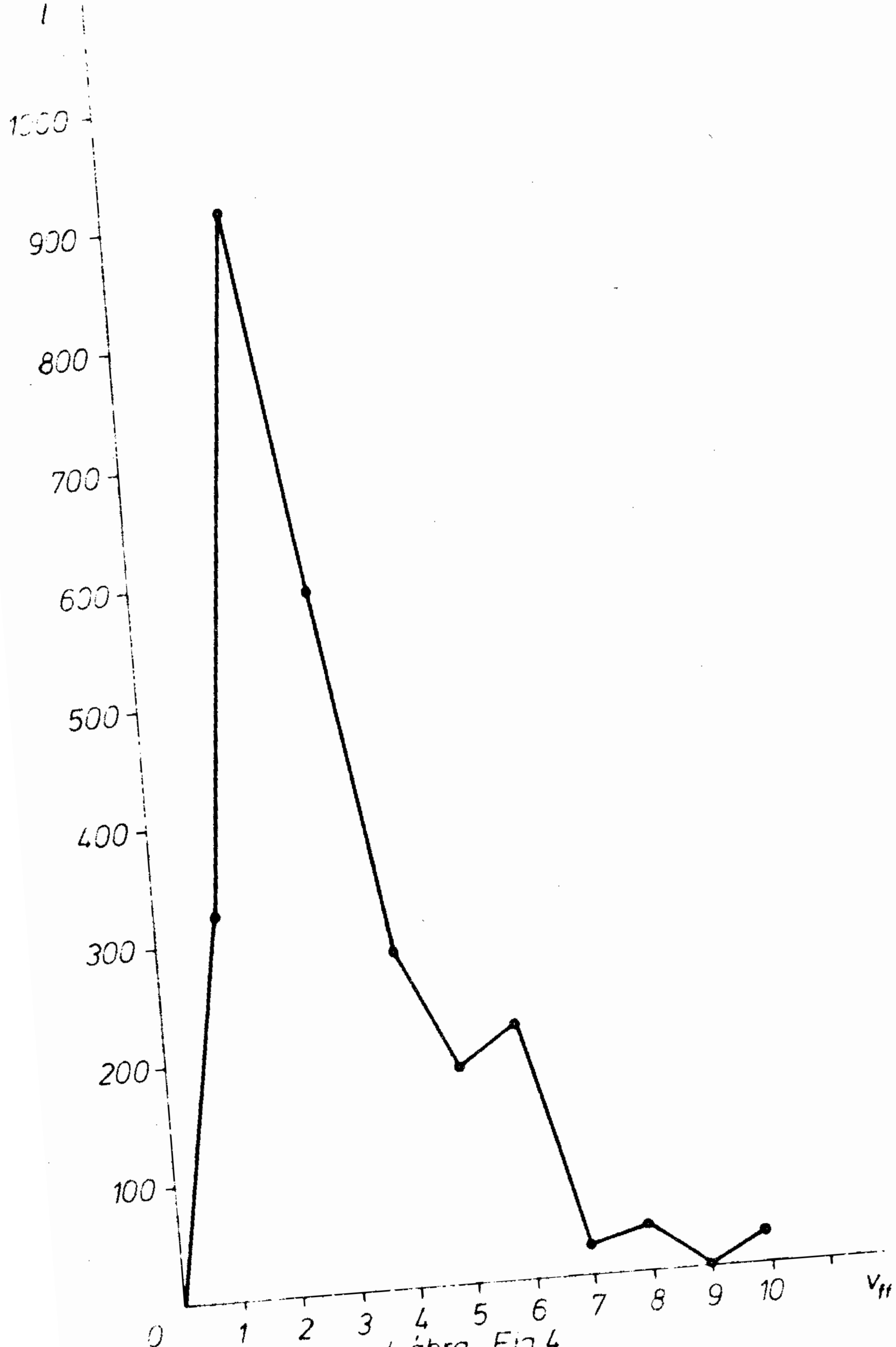

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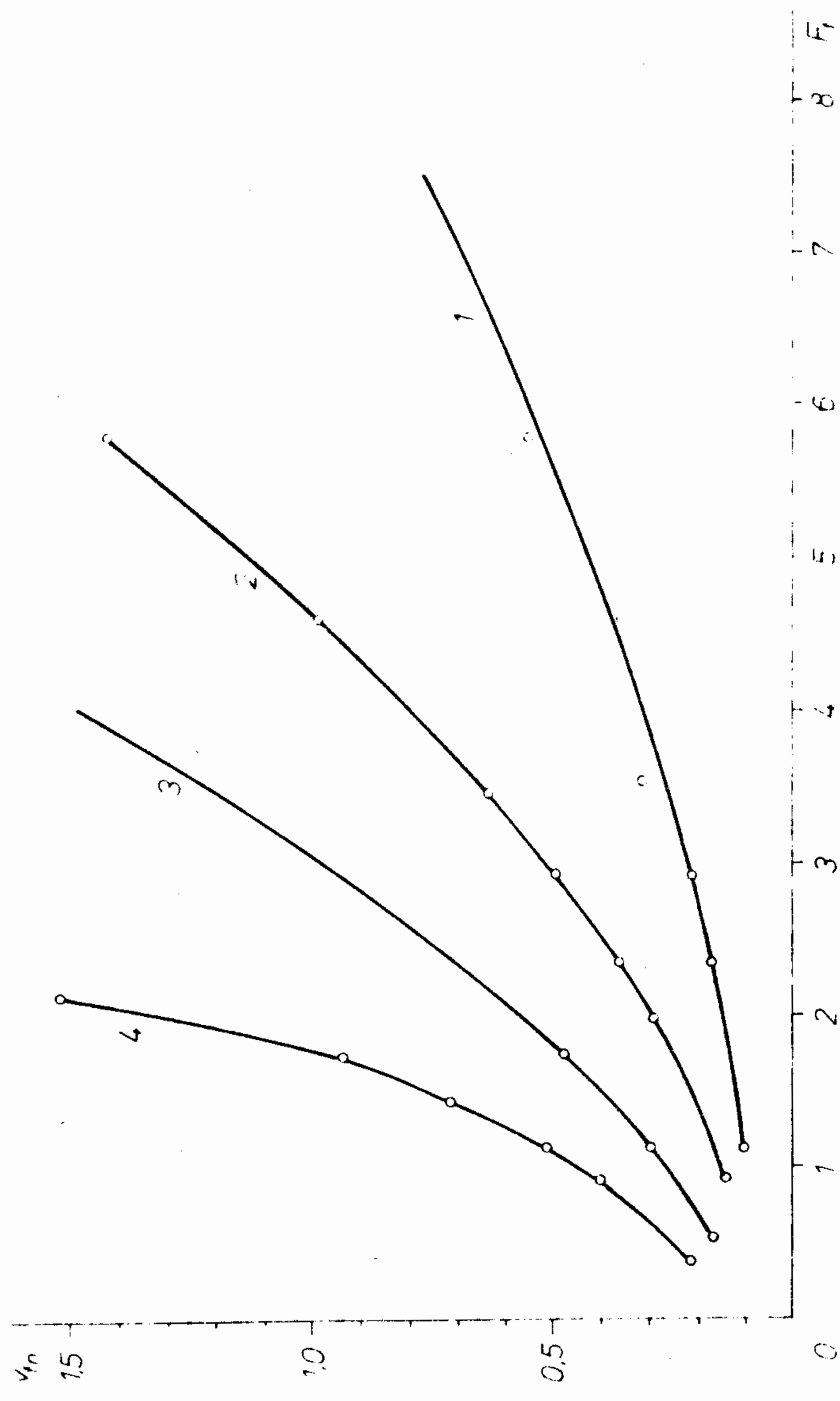

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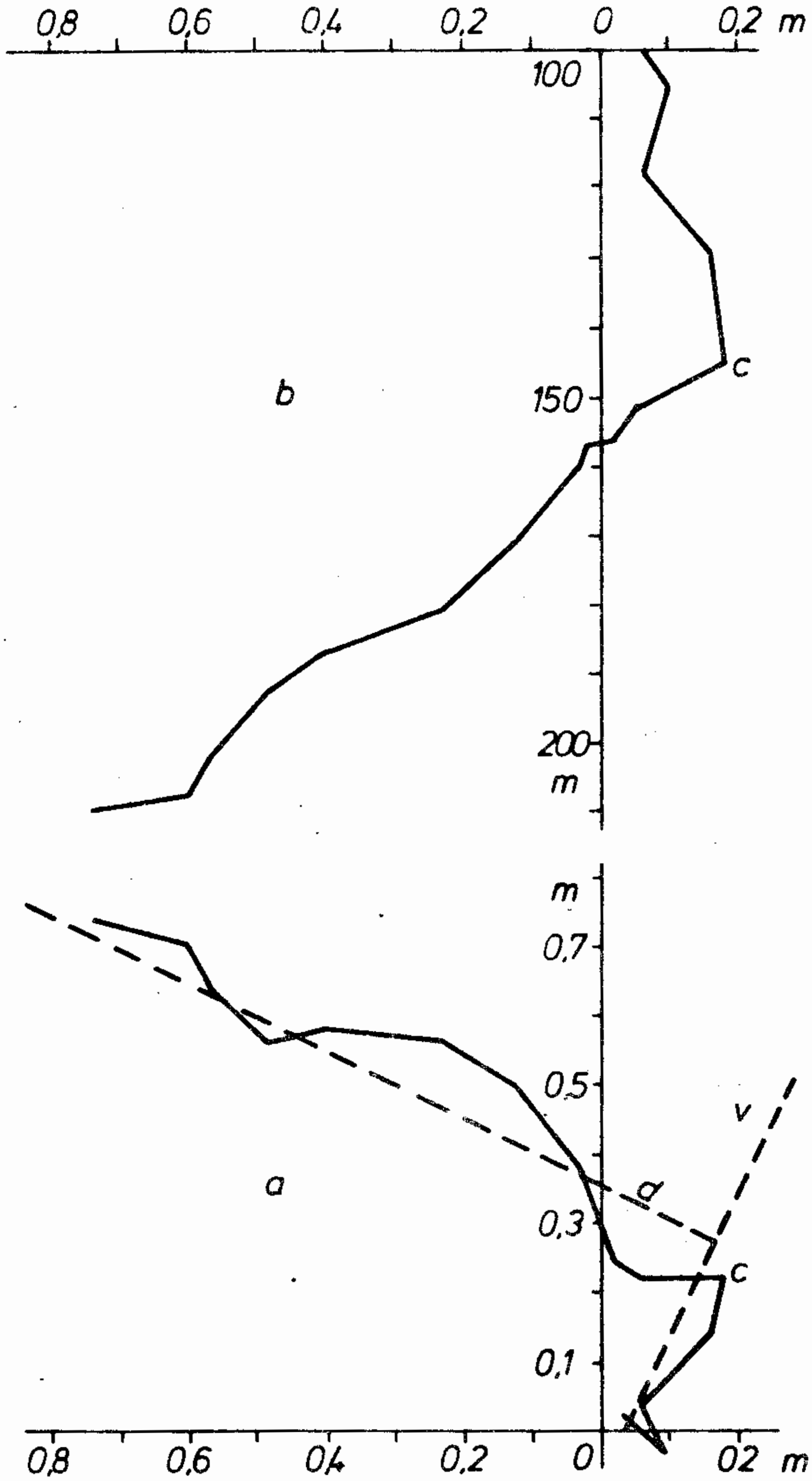

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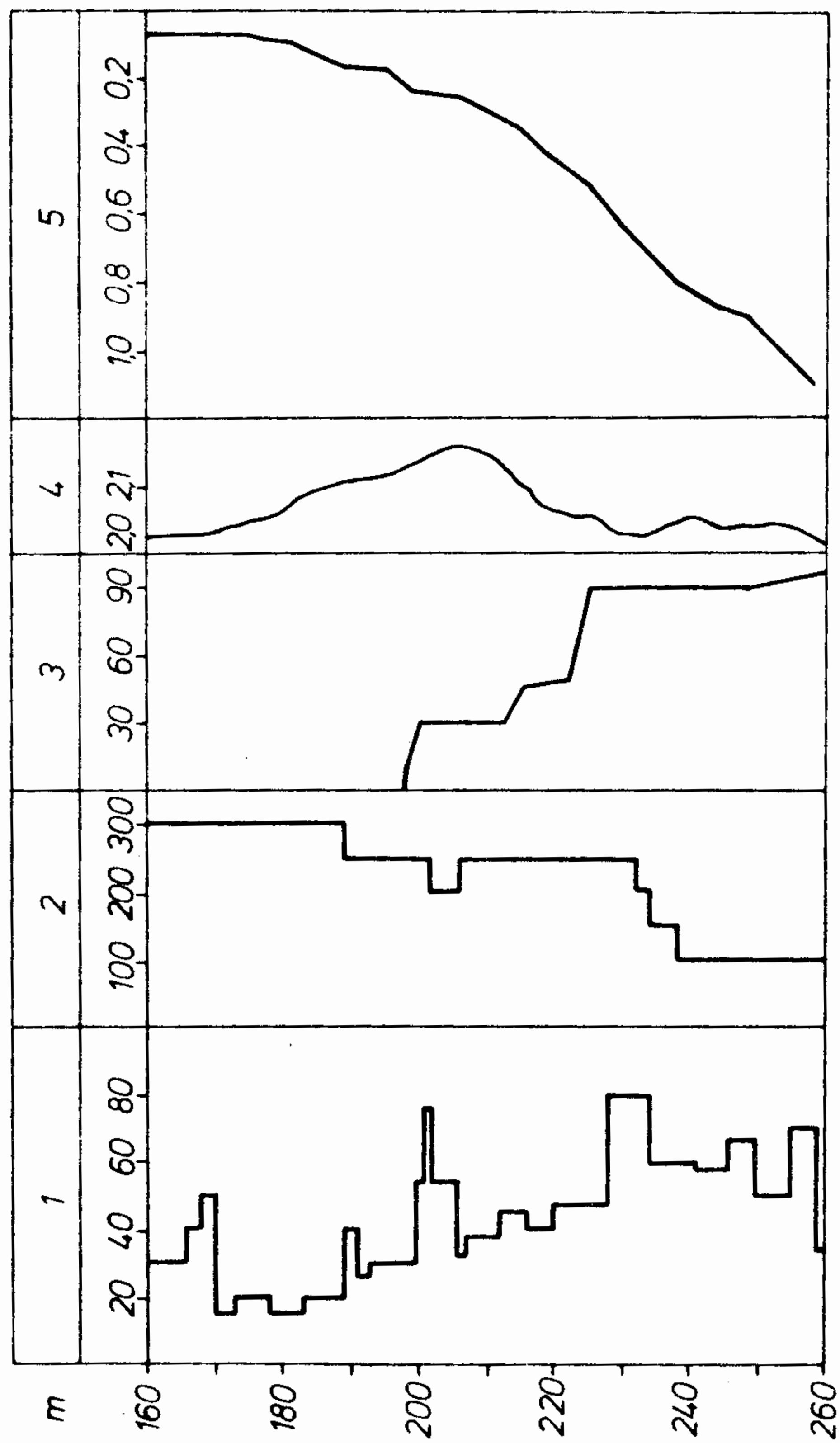
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