HYDROGEOLOGICAL CONDITIONS OF LIGNITE BASINS IN POLAND AND THEIR CHANGES CAUSED BY DEWATERING OF OPEN PITS

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ABSTRACT

This paper is an informative one. Its objective is to acquaint the participants of symposium "Hydrogeology of Lignite Basins" held in Poland with hydrogeological conditions of lignite basins in the host country. Besides, it provides with some data how drawdown of groundwater table changes the water conditions in the open pits surroundings.

INTRODUCTION

Lignite is one of two main source for electric energy production in Poland. Its output on a greater scale began on the turn of 1950. In the seventies, the lignite output was in range of 35-40 millions ton per year, now it amounts to about 65 millions ton/year. It is anticipated that lignite production will reach 75-80 millions ton per year in the nineties. All lignite is mined from open pits. The lignite basins are Tertiary (mostly Miocene) Age and occur in the central, Western and South-Western part of the country. Lignite has the heat value about 2000 kcal/kg (8500 kJ), moisture about 50 %, ash contents 6-12 % and sulphur contents 0.2-1.0 %. The total lignite reserves are estimated to be about 14 billions ton. The floor depth of seams below the terrain surface (corresponding to the depth of open pits) varies from 40 to 200 m for the current operations and will reach 260 m in future. The thickness of lignite occuring in 1 to 3 seams is from 5 to 60 m, and overburden thickness is from 30 to 160 m in operate open pits (up to 240 m in future). The overburden constitutes Tertiary and Quaternary formations consisting of silt and clays (30 % - 75 %) and sands (70 % - 25 % respectively). In overburden there are also a small amounts of muds, peats, gyttjas and other formations. All lignite basins are in flat or slighthly hilly terrains.
The lignite seams are flat or dip slightly up to ten degrees, they are sometimes cut by faults. In two basins only lignite seams are strongly faulted by glacier and have inclination from 30° up to vertical one. All deposits are below the

natural groundwater table that occur most frequently right under the terrain surface (form 1 down to 5 m). The groundwater table should be always lowered before mining operations begining and should be kept below the floor of the pit during the whole exploitation period. The mine life exceeds 35 years. however, for the particular open pits ranges from 15 to 50 years. Annual precipitation in the regions of lignite basins varies from 500-700 mm/year, the climate is moderate (the average annual temperature is about +8^{o}C, but minimum and maximum are from -30^{o}C up to 30^{o}C). The information given above do not concern directly hydrogeology, howevèr, they provide the better background in which hydrogeological conditions are considered.

ADAMÓW LIGNITE BASIN (Fig. 1)

There are four lignite fields in this basin. The lignite occurs here in one flat seam 5 to 9 m thick under the overburden of 35-50 m consisting of clays and silts (55 %) and sands and gravels (45 %). The hydrogeological conditions are characterized by four (4) aquifers, two (2) are over and two (2) below the lignite seam. The first aquifer of free water table is in the sands and gravels right below the terrain surface. They have mostly thickness up to 10 m but sometimes it reaches 40 m in erosive washouts (old burried river valleys). The permeability of those sands is from 5 m/day to 50 m/day, the greatest values are characteristic for burried valleys filled with gravels and coarse sands. The average permeability for those sands is 27 m/d. The original groundwater table was 1-5 m below the terrain surface and it was inclined toward the Warta River and its tributary rivers draining the area (toward N, NE, N). The second aquifer occurs in sandy lenses within in clays and contents static water under pressure 1 to 3Ba. The thickness and spreading of particular lenses is rather small. The lignite seam is practically impermeable. The third aquifer is in fine Tertiary sands underlaying the lignite seam. Thickness of this aquifer is from 2 m to 30 m. Aquifer is wide spread contrary to small size of the aquifers over the lignite seam. In these sands, the hydrostatic head is from 1 to 5Ba and permeability from 1.5 - 4 m/day. The fourth aquifer is in fissured cretaceous marls underlaying intermediately the above Tertiary sands. The aquifer is wide spread. The groundwater table is under pressure (similar to the above sands) and permeability from 2 to 45 m/day. All aquifers have hydraulic connections especially intensive in deep burried valleys. The dewatering of the first of open pits began in 1958 and there 20-40 m^3/min. of water was pumped. In 1974 and 1976 the dewatering of subsequent open pits started. The amount of water pumped in these pits varied from 40-80 m^3/min. when groundwater drawdown was 25-40 m. Water is drained by deep wells with submersible pumps. The total volume of water pumped in three pits amounts to 130 m^3/min.

The cone of depression arose around the open pits in the Quaternary superficial aquifer and in under lignite aquifer (common for sands and marls). In the aquifer just under surface, the cone of depression is very irregular and dependent on thickness and geological structure. It varies from 1 to 5 km from the open pit boundary. The greatest radius of the cone of depression can be observed along the aforesaid Quaternary burried valleys. The cone of depression in the Tertiary aquifer has more regular shape and it ranges from 4 km to 7 km from the edge of particular pit. It depends on course of erosive valleys washed-out in the roof of Cretaceous marls. The common cone of depression of three open pits is about 20 km long (in direction NW-SE) and 4 to 7 km wide. Development of cone of depression is manifested in disappearance of water in municipal wells so it was necessary to make 8 now deeper water wells and water-pipe network at the cost of the mining company. The cone of depression development did not cause any visible changes in the soil moisture and has no influence on plant crops and state of forest.

KONIN LIGNITE BASIN (Fig. 2)

In the Konin lignite basin, there are several lignite deposits which are mined in four (4) open pits the fifth one has already been finished. Lignite occurs generally in one flat seam 7-10 m thick (except for one pit where two (2) seams 25 m thick in average occur). The overburden 45 m to 75 m thick consists of clays and silts in 80 % and sands in only 20 %. Here, there are four (4) aquifers. The first one occurs in the Quaternary sands right under the terrain surface. Its thickness varies from 0 m to 20 m, it has free water table, and permeability from 1 to 50 m/day (on average about 10 m/day). The second aquifer occurs in closed lenses of sands within the overburden clays. It contains static water under pressure 1 to 5 Ba (depending on the depth). The thickness of lenses varies from 1 to 10 m their spreading is very limited and their permeability is 2 to 10 m/day. The third aquifer occurs in the Tertiary sands underlaying the lignite seam. It is very widely spread and it constitutes from fire sands 20 to 70 m thick, that contain ground water under the pressure of 4-7 Ba. The permeability of these sands is 3-4 m/day. The original groundwater table was inclined from NN toward SS. The fourth aquifer occurs in the fissured Cretaceous marls also wide spread. Groundwater of this aquifer has the common water table with Tertiary one due to direct hydraulic contacts. The permeability of marls depends on fissures and is from 1 to 30 m/day, on average 3 m/day. This aquifer is recharged mainly by the Warta River flowing in distance of several kilometres. A very significant element of hydrogeology of this region is presence of big lakes mainly groove and postglacial ones. They recharge the Tertiary under lignite aquifer and increase significantly the groundwater inflow to the mine. The drainage of the first open pit in this region was started at the beginning of 1950-ies, then the subsequent open pits dewatering started at the end of 1950, at the beginning and

in mid 1960 and at the end of seventies. The water inflow to the particular open pits varied from 30 to 120 m^3/minute, on average about 45-70 m^3/min. The greatest values were observed when distance from open pit to a lake decreased (down to about 300 m). At present about 220 m^3/min. of water is pumped in the whole lignite basin. Four (4) depression centres have developed in the particular open pits, where groundwater drawdowns are about 60 m. On the boundary of the pits, however, it amounts to 30 m, in rough. Dewatering effected development of cone of depressions in aquifers of under coal sands and marls as well as in sands right under surface. The main cone of depression develops in wide spread aquifer of Tertiary sands and Cretaceous marls. It range is irregular. On south and East it reached only the lakes being 500 to 1000 m from the open pits to West and North, where there is neither recharging nor limiting water inflow, structures the cone of depression developed to the distance of about 8 km. This value is very concordant with the forecast performed by simple analitical methods at the beginning of sixties. In irregular Quaternary aquifer right under terrain surface, the cone of depression depends on occurance and thickness of sands. So its range does not exceed 600 m however, in one case i.e. where there is a burried valley filled with coarse sand it is 1800 m.
The cone of depression has resulted in disapperance of water in shallow wells at farms but has not caused any drying of soil and had no effect on the crops and state of forest surrounding the mines. Some deep water intakes and water-pipe networks were built in this region to compensate the people for this effect.

TURÓW LIGNITE BASIN (Fig. 3)

Turów Lignite Basin has a shape of real basin (tectonic depression) of an area of about 100 km^2. The bed constitutes impermeable paleozoic rocks filled with the Tertiary formation having thickness from 50 m on the boundary to 300 m in the middle. Two lignite seams occur here, having total thickness about 40 m. The overburden and interseam sterile is 160 m thick on average. They consist of clays in 50-80 % and sands in 20-50 % respectively depending on the basin region. Sands occur in form of closed lenses from 1 to 30 m thick and extend from several hundreds meters up to 3 kilometres. They contain static groundwater under pressure of 2-20 Ba depending on depth. At the West side along the pit slopes, the Nysa River flows. Its valley 5-20 m deep is filled with gravel and is cut by the open pit slopes.
Mining operations and water drainage in this pit has been continued for above 40 years progressing deeper and deeper from basin border down to its centre. Dewatering is effected underground galleries driven in lignite seam and with gravitational full filters and overflow filters as well as with pumping wells. Inflow from the Nysa River burried valley is cut by cut -off well. The water inflow increases when the open pit is deepened and mining operations advance toward south, (when more sand lenses occur), increases from 20 m^3/min.

(in the seventies), up-to 40 m^3/min. at present. The closed-type aquifers (lenses) in this basin resulted, that there is no cone of depression around the open pit though its depth is about 150 m.

BEŁCHATÓW LIGNITE BASIN

It is the greatest lignite basin in Poland. Here, there are very complicated hydrogeological conditions. The depth of lowered groundwater level table amounts to 300 m, the average radius of cone of depression is 12 km, The Bełchatów lignite basin will be discussed in the separate paper, so it is not presented here in details.

ŁUŻYCE LIGNITE BASIN

In this lignite bearing region, there are several lignite fields, which have various geological structure and different hydrogeological conditions. The construction of new surface mines in this region is anticipated in the latter part of nineties. The more extended deposits are here built by 1-2 flat lignite seams 8.5 to 11 m thick under overburden of 65-80 m. The overburden mainly consists of sandy formations from Quaternary or Tertiary period with number of clays intercalations. The sands thickness in overburden varies from 20 to 60 m. Permeability for Tertiary sands in 2 m/day and for Quaternary sands up-to 50 m/day. The lignite seam is cut by erosive washouts (burried valleys) filled with sands and gravels having thickness up-to 80 m and permeability 70 m/day. In the close vicinity of these lignite basins (200 m, a river flows. Its postglacial valley is filled with gravels and has hydraulic connections with overburden aquifers and also with burried valleys as well as with lignite underlaying Tertiary aquifer. Those Tertiary sands contain groundwater under pressure of 8-9 Ba. Their thickness is in the range of 80 m and they have widle regional spreading. The calculated volume of groundwater inflow for groundwater table drawdown of about 90 m for both Quaternary and Tertiary aquifers is 200 m^3/min. If a cutt-off sealed wall will be constructed to the depth of 70 m from the river side this inflow will be reduced down to 110 m^3/min. The average cone of depression has been calculated on about 10 km. In this areas, it is anticipated loss of water in shallow wells. Additionally it is anticipated that in areas where the first groundwater table is originally shallower (than 5 m) the conditions of forest growth will be worse due to subsoil drying. In places where water level is shallower than 1 to 2 m the crops especially from meadows can decrease. In the vicinity of above discussed flat lignite fields other deposits having glacitectonic disturbances occur. Lignite seam is here folded (100 m deep synclines and shallow anticlines 10 m). Width of those structures an average is 300 m and they run in W-E direction. Synclines are filled with sands and clays (fifty-fifty), however in the areas of erosive washouts (burried valleys) thickness of sands increases up to 100 m. The permeability for Quaternary sands varies here from 6 to 15 m/day and for Tertiary ones 1 to 2 m/day. These fold structures are underlaid by Tertiary sands of permeability 2-3 m/day. The common groundwater table for all these aquifers that have hydraulic connection is right under the terrain surface. For the planned mining operation down to 90 m a mathematical model has been built. It takes into account also presence of lake from the west and gradual advance of open pit face toward this lake from the East (from 5 km to 800 m distance). The calculations made by the method of finite elements allow inflow from the overburden to be determined at the variable rate from 5 to 10 m^3/minute and for under-lignite Tertiary aquifer from 15 m^3/minute at the beginning up to 70 m^3/min. for the fully-developed dewatering system (pumping wells). With regard to very complex (folded) geological structure the changes of hydrogeological conditions in the surrounding of open pit will be very differentiated in the first (upper) aquifer. The cone of depression will develop mostly as a result of geological structure, but the influence of hydraulic parameters will be very small. The cone of depression will develop only in the direction, of folds axis. In transverse direction, it will exceed the mining boundary only couple hundred meters. It will spread to the lates along the axis of syncline, and stop on them the west and East (in distance of 5 km). The cone of depression will spread quite different in Tertiary (deeper) aquifer. It can spread here more freely in all directions depending to the permeability on distance of about 5 km. The lowering of groundwater table in Quaternary (upper) aquifer can result in water run-off from streams and shallow lakes (on the East and West) and local drying of soil. The similar lowering of groundwater table in the Tertiary (deeper) aquifer can have influence on water run-off from the deep (50 m) postglacial lake 3 km toward SW from the planned open pit.

SUMMARY AND CONCLUSIONS

1. All lignite basins in Poland are situated below groundwater table, the depth of required drawdown of groundwater table that enables open pit mining operations is from 40 to 200 m.

2. Aquifers in lignite basins mostly are:

   - in the upper part of overburden - Quaternary permeable formations (sands and gravels) 10 to 150 thick with permeability from 15 to 70 m/day, free groundwater table and various and often complex space structures (burried postglacial valleys, accumulation of boulder clays etc.); those aquifers are recharged by precipitation, rivers and lakes;

   - in the lower part of overburden - Tertiary (fine sands occuring in form of closed lenses that have small spreacing and small non-rechargable static water reserves being under the pressure from several to dozen Ba;

- under lignite seams Tertiary aquifer from fine sands having thickness 10-100 m, permeability 2-4/day, hydrostatic head 5-20 Ba and have wide spreading (hundred kms);
- Mesozoic aquifer in form of fissured marls and limestones (sometimes karstified), seldom sandstones; permeability of this fissure aquifer i.e. very variable (average from 2-50 m/day) hydrostatic head stabilises just under terrain surface due to hydraulic connections with upper aquifers; this aquifer is also wide-spread like the above Tertiary one.

3. A very essential and frequent element of hydrogeological conditions are lakes and rivers close to the lignite basins. They are constant recharge contours which have sometimes strong influence on groundwater inflow to the mines and spreading of the depression cone.

4. Water inflow to operating and designed lignite open pits in Poland is from 30 to 400 m^3/min. when groundwater drawdown in the dewatering centre is from 40 to 200 m respectively.

5. The majority of open pits are drained by wells with submersible pumps. The number of such wells is from 50 to 600 for one open pit and their individual out-put is from 0.1 to 6.0 m^3/min.

6. Advance of draw-down in the drained open pits follows with speed from 20-30 m/year in the first period of dewatering to 5-10 m/year later on which causes respective lowering of original groundwater table around.

7. The cone of depression in the adjacent areas spreads depending on geological structure, presence of unper meable structures limiting ground water flow as well as constant recharge structures (rivers). The cone of depression in the shallow Quaternary formation is rather small, and irregular due to differentiated geological structures. The cone of depression in deeper Tertiary and Mesozoic wide-spread aquifers develops in much more regular way. In practice cone of depression spreads from 1 to 20 km, around the open pits however, in more cases is from 7 to 10 km.

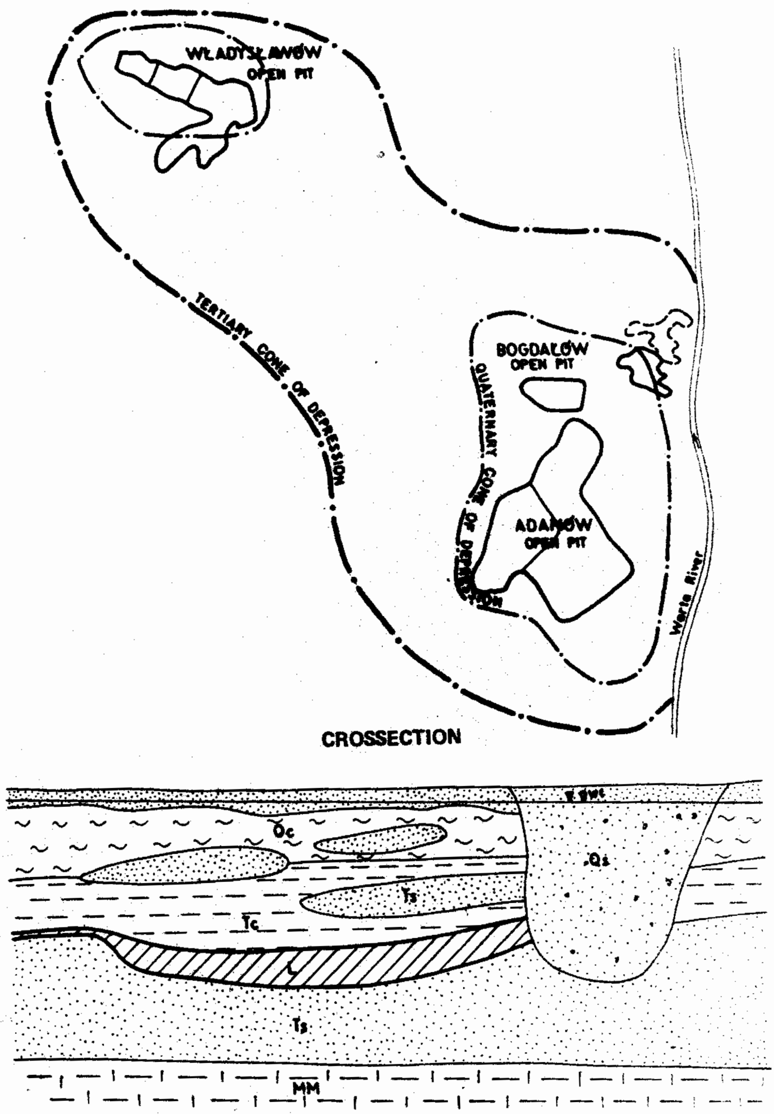
8. Within cone of depression the following phenomena can be observed:
   - water run-off from streams and lakes, which results in the flow decrease, sometimes in case of small streams and lakes even total drying of occurs,
   - decrease of natural springs and efficiency of wells that takes water for consumption; sometimes even drying of wells is observed,
   - decrease of soil moisture on the areas, where original groundwater table was less than 2 m below the terrain surface and where there is no isulating clay layer in the subsoil,

- decrease of crops from the meadows located in the land depressions,
- worsening of vegetation conditions for forests, when they grow on sandy soil without clay subsoil and where original groundwater table was less than 5 m below the terrain surface.

It has not been found so far, any visible decrease of agricultural crops within the cones of depression, because plants use to utilize directly precipitation water in higher rate that it was forcasted before.

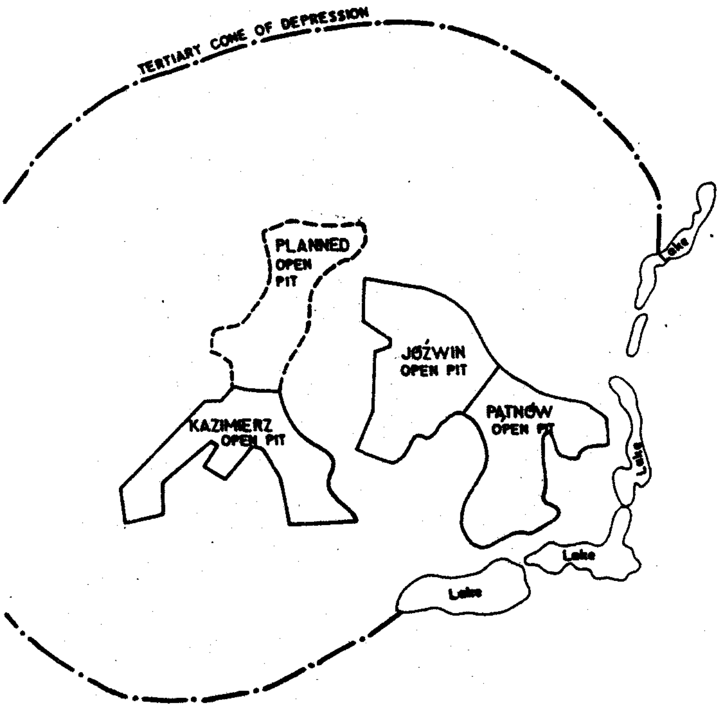
At present, the study and research is done on the changes of physical and chemical properties of groundwater on the areas where cone of depression can comprise a salt diapir (Bełchatów Lignite Basin). Moreover a research on distant and deep groundwater circulation in the vicinity of operations with deep drawdown of groundwater table below 150 m) has been started. This research has been stimulated by the occurance of thermal water in the deep pumping wells taking groundwater from pre-Kenozoic aquifers.

Fig. 1. ADAMÓW LIGNITE BASIN



MM — Mesozoic Marls; Ts — Tertiary Sands; L — Lignite; Tc — Tertiary Clays; Qc — Quaternary Clays; Qs — Quaternary Sands

Fig. 2. KONIN LIGNITE BASIN



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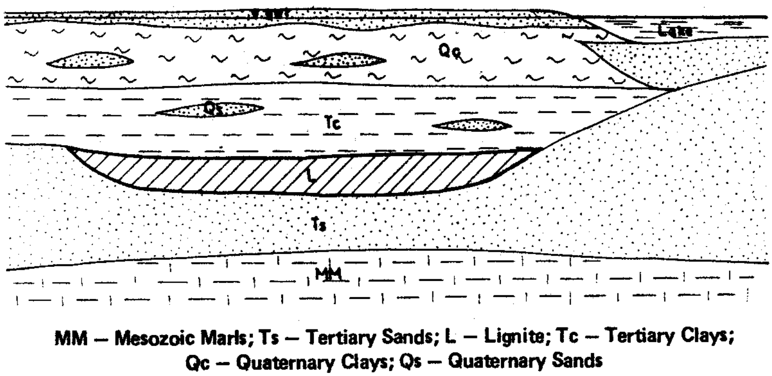

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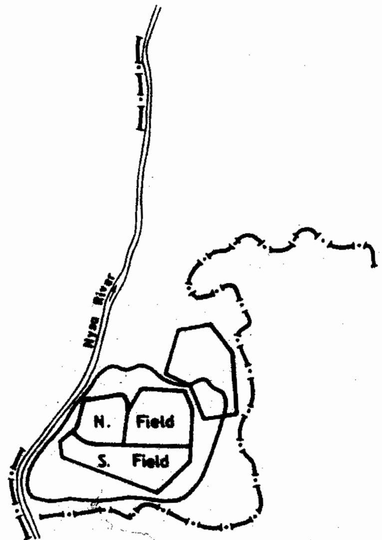
Fig. 3. TURÓW LIGNITE BASIN



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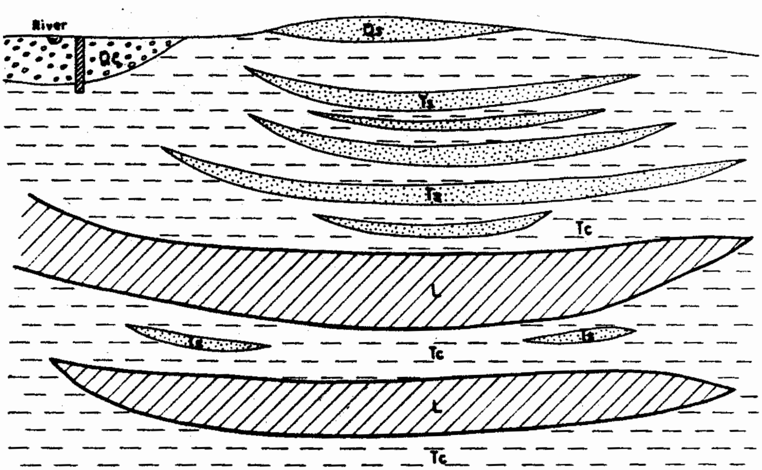

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