Mine Water in the Ruhr Area (Federal Republic of Germany)

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ABSTRACT

This paper describes the geological, hydrogeological and hydrochemical conditions in the Ruhr area, all fundamental factors influencing the quantity and quality of mine water. Possible means of raising water in the Ruhr area are described. The southern area is unusual in that it is not mined nowadays. Drainage in this area is managed by Ruhrkohle AG's Central Drainage Division.

INTRODUCTION

Water is the basis of life for plants, animals and humans. It is an indispensable factor in the production of food and many technical commodities; but alongside these life-giving uses, water can also take on destructive forms such as floods. Consequently, man's most ancient large scale engineering achievements include constructions that protect against water as well as those utilizing it.

This applies to the coal mining industry also, where water can not only be a disturbance, it can even become a source of real danger. As a result, miners have been dealing with the problem of controlling water since time immemorial. Alongside pure mining equipment, constructions engineered for drainage and water control rank among the great technical feats of the industry.

COAL MINING

In Germany, coal is currently mined in the following areas (Fig. 1):

- Ibbenbueren
- Ruhr area
- Aachen
- Saar area

The coal concerned is from the Carboniferous Period and is partly covered by an overburden.

GEOLOGY OF THE RUHR AREA

In the Ruhr area, the Upper Carboniferous strata come to the surface in the south and are situated under a cretaceous overburden in the north (Figs. 2 and 3). The Carboniferous strata comprise alternate layers of sandstone and claystone with interspersed coal seams; they are given the following local names from top to bottom:

- Dorstener Schichten
- Horster Schichten
- Essener Schichten
- Bochumer Schichten
- Wittener Schichten
- Sprockhoeveler Schichten

The whole series in which coal seams are found - the so-called "Produktives Karbon" - has a thickness of 3000 m. It only contains 150 coal seams, which together build up a thickness of no more than 70 m. This means that only around 2.9 % of the 3000 m thick series is build up of coal seams. The ratio of coal seam to total thickness increases as we move upwards from the basal "Sprockhoeveler Schichten" to the "Wittener Schichten" and reaches a maximum of 3 - 4 % workable seam in the "Bochumer Schichten" from Sonnenschein Seam upwards. In the younger strata of Upper Carboniferous it drops again.

The Upper Cretaceous strata lie discordantly on top of the Upper Carboniferous strata and begin with the Cenomanian series. The lower layer of this series consists of a transgression conglomerate of claystone shingle, slaty claystone and Carboniferous sandstone. On top of that lies the "Essener Gruensand" (a glauconitic sandstone), which acts as an aquiclude in the central Ruhr area. However, "Essener Gruensand" only is an aquiclude if it consists of developed clay properties coupled with large thickness. The clay portion gives the rock the characteristic of an aquiclude and a plasticity. On top of the "Essener Gruensand" lie brittle limestones and marlstones, both of which can be aquiferous. On top of the Cenomanian strata lie the fissured marlstone and argillaceous limestone strata of the Turonian Age. This series includes two glauconitic sandstone horizons: "Bochumer Gruensand" and "Soester Gruensand". The solid Turonian strata are fissured and aquiferous.

The strata of "Emscher Mergel" above (Coniacian to Lower Middle Santonian) have a special status with respect to their thickness, rock composition and hydrogeological characteristics; they reach a thickness of 400 m in the central Ruhr area. The Cenomanian and Turonian strata vary in their structure, but the "Emscher Mergel" consist of a continual series of clayey and sandy marlstones with a high lime content. The upper 1 to 2 metres of "Emscher Mergel" are weathered to a clayey silt / silty clay and are aquiclude. Under this layer, the clayey marlstone is fissured and aquiferous up to a depth of 30 m; these fissures become less towards the base, finally disappearing altogether to leave an aquiclude. The "Emscher Mergel" therefore forms a seal between the lower Cenomanian and Turonian groundwater zone and the upper Santonian and Quaternary groundwater zone.

The upper strata of the Upper Cretaceous layers (upper Santonian and Campanian) are several hundred metres thick. In the central and western Ruhr area these deposits have developed a sandy/marly texture. In the form of "Recklinghaeuser Sandmergel", the strata comprise alternating layers of clayey/marly fine sand and hard calcareous sandstone beds. In contrast, the form of "Halterner Sande" consists of generally loose quartz sandstone, some beds being reinforced with chalk or pebbles. The "Recklinghaeuser Sandmergel" and "Halterner Sande" are good aquifers.

The Pleistocene strata cover the deposits of the overlying cretaceous. Because of the way they were formed, the rock structure of these strata varies enormously; they are mainly Nordic Pleistocene deposits, i.e. ones they were laid down underneath or at the edge of glaciers. The grain structure covers a wide spectrum ranging from boulder clay to loess (of fine sands and silts) and loess clay to coarse-sandy terrace gravel.

The Holocene deposits consist of sediments from rivers and streams, most of which are clayey, fine sand silts with deposits of peat and humus.

The layering and composition of strata in the Ruhr area are shown in Figure 2. The Carboniferous strata series has been pushed into a system of anticlines and synclines by a folding movement from the south. As well as the anticlines and synclines, there are large transverse faults in the region which are subject to vertical movements. These transverse faults run more or less at right angles to the anticlines and synclines, and have resulted in the formation of step faults, graben- and horst- structures. The Upper Cretaceous strata lie discordantly on top of the Carboniferous strata.

Layering within the individual strata is shown in Figure 2, which is a section taken from Figure 3.

MINE WATER INFLOW

The varying geological and hydrogeological layout of the Ruhr area give rise to three different water movement zones (Figure 2):

Type a: the southern Ruhr area which is not covered by any overburden; mine water inflow is governed by and dependent on precipitation and can reach 40 m^3/min.

Type b: the central Ruhr area with an overburden up to 400 m thick and mine water inflow between 0.5 m^3/min and 10 m^3/min.

Type c: the northern Ruhr area with an overburden of more than 400 m; here, inflowing mine water originates from tectonic faults. Inflow is around 1 m^3/min.

WATER CHEMISTRY

There are three general groups of groundwater types in the Ruhr area.

Near the surface we find hydrogencarbonate water with a total soluble content of under 1000 mg/l. This water is strongly influenced by precipitation.

In the southern area where no overlying impermeable rock is present we find sulphate water with a soluble mineral content of several thousand mg/l. This sulphate water is created by the oxidation of pyrite.

The Ruhr area's deep groundwater is chloride water. Soluble content is mostly well above 5000 mg/l and reaches extreme values of over 200 000 mg/l, the concentration increasing with depth. This water type contains sodium, magnesium, calcium and minor quantities of barium and strontium.

Thermal depth soles can be found near the big faults. These thermal soles are related to hydrothermal deposits (Figure 4).

HISTORY OF MINE DRAINAGE

Ever since man began mining he has had to cope with the problem of mine water too. Regardless of what is being mined, water from any source encroaching on pits has been one of the great annoyances to miners since time immemorial.

Before effective pumps were around, every mine was restricted in depth from the very outset simply by the groundwater level. There was no machinery available to help; the water was carried above ground in leather buckets by miners standing on railings above each other. Later, instead of doing it by hand, people started to haul the buckets up using windlasses or horse gins. Finally things became mechanised, but even then things could not progress to great depth.

It wasn't until the power of the water itself was harnessed that mining became possible at great depth. Figure 5 shows a waterwheel-driven windlass which was manually controllable via the water intake. Note the control stand, from which the operator had visual and verbal contact with those active at the mouth.

The next step towards mining at depth was when people began digging horizontal or slightly inclined adits into the hillside from the valley floor in order to drain away water through these adits. Probably earlier, but certainly no later than at this point, the fact that controlling mine water meant extensive safety measures and a huge expenditure caused people to start thinking "mining is not the job of <u>one</u> man alone". This in fact was written in the "*Schwazer Bergbuch*" as early as 1596. This idea of solidarity and groupwork - which is so important in the mining industry - is especially evident in the field of common drainage interests.

So-called "Wassergemeinschaften", a type of drainage cooperative, existed as early as the 11th and 12th centuries in the Oberharz region of Germany, and the drainage adits dug in all of central Europe's metal ore mining areas in the Middle Ages and early modern times paint a clear picture of the popularity of this idea.

Experience gathered by ore miners was passed down to the more recent coal miners, and it comes as no surprise that "Wassergemeinschaften" are evident in the Ruhr area. They were created under the claim for drainage adits in the second half of the 18th century in the form of drainage adit cooperatives ("Erbstollengemeinschaften").

The oldest and largest adit of this kind in Germany is the "Schlebuscher Erbstollen" and its continuation, the "Dreckbaenker Erbstollen". Both of them start in the Ruhr valley and provide the deepest possible natural drainage for the Herzkaemper Mulde mines at Sprockhoevel. Digging work began in 1765, and both adits combined form a passage about 12 kilometres long. The work of the miners who built them was of such quality that they still remain intact more than 200 years on.

Two more "Wassergemeinschaften" are known in the Witten-Bommern area: the "St. Johannes Erbstollen", completed in 1820, and the "Bommerbaenker Erbstollen" of 1798.

As mining began to extend below the depth of the valley floors, deep adits lost most of their importance as methods of drainage. Deeper mining was made possible by the introduction of the steam engine, which was used to power water raising mechanisms in mines. In 1808, Vollmond Colliery in Bochum became the first coal mine in the Ruhr area to employ this type of steam-driven drainage machine. In the period following, each colliery installed its own drainage equipment suited to the volume of mine water accumulating there, and raised the water alone together with the water accumulating due to mining activities.

Despite this, people continued to consider the possibility of a common solution to the mine water problem which would extend beyond the limits of one single mining company. This became acutely relevant in the difficult 1880s, when a commission headed by the "Association Promoting Mining Interests" attempted to find a way to provide common drainage for all Ruhr area pits. The commission suggested collecting water from all Ruhr collieries at the deepest valley floor site and raising it from that point. Alas, the fragmented division of property obviously prevented this solution from ever being implemented.

The first of the pit closures in the Ruhr area in the 1920s brought the problem of shared water danger sharply back to the forefront of Ruhr coal miner's minds. But even spectacular water bursts and intervention by the mining authorities did not succeed in making the common solution popular.

FOUNDING OF PUMPING COOPERATIVES

It was not until 1942, when the Praesident open-cast mine at Bochum was destroyed together with its drainage system and rising water threatened several bordering collieries, that another "Wassergemeinschaft" was formed. It was called "Pumpgemeinschaft Praesident" (Praesident Pumping Cooperative), and included collieries owned by the former mining companies Hannover-Hannibal, Constantin, Rheinstahl, Lothringen and Bochumer Bergbau AG.

The first German coal mining crisis after the War struck in 1957/58. As collieries closed down, the problem of drainage for the remaining ones suddenly became acute, and finally in 1964 the well-known "Pumpgemeinschaft Ruhr" (Ruhr Pumping Cooperative) was formed, combining all of the Ruhr area's 37 mining companies.

The "Pumpgemeinschaft Ruhr" was founded as an association under German civil law with effect on 1st January 1964 "with the intention of doing all to avert negative effects on the drainage of member coal mines caused by a coal mine closure after 1st January 1959, and to spread remaining effects among the member companies". All of the 37 mining companies active in the Ruhr area at that time became members.

The Pumping Cooperative stopped invoicing its customers in 1969 when this problem area was newly resolved by the so-called "Erblastenvertrag" (Inheritance Contract), which is part of the set of agreements which reorganised Ruhr mining in July 1969. The agreements were between the Federal Republic of Germany, the parent companies and Ruhrkohle AG. From that point on, the Federal Government and the Land of Nordrhein-Westfalen financed (among other things) the majority of excess expenses for any additional drainage work by Ruhrkohle required as a result of colliery closure.

CENTRAL DRAINAGE DIVISION

When Ruhrkohle AG was founded in 1969, all 25 drainage installations which at the time were needed to protect mines still operating, and that were amalgamated in the "Pumpgemeinschaft Ruhr", were consequentially handed over to Ruhrkohle AG. This marked the birth of the Central Drainage Division.

The Division is an operating unit within Ruhrkohle AG which deals singularly with the raising and removal of mine water from inactive areas. It was created with the intention of forming a common unit to undertake drainage work in the inactive areas of the 7 plant management companies existing at the time in Ruhrkohle AG.

The Division's job is a common one covering the whole Ruhr mining industry: to protect the working mines from unwanted water ingress and bursting originating from inactive areas, therefore securing the continued operation of the active pits.

The Division's job can be broken down as follows:

- planning and management of central drainage installations in inactive areas;
- advising the plant management companies and mines when implementing drainage measures in inactive areas;
- calculating the overall cost of external water drainage work in accordance with the Inheritance Contract, and drawing up the associated general plans and finance schemes.

There has been a total of <u>87 closures</u> if we include the closure in 1983 of Erin Colliery, which belonged to the "Eschweiler Bergwerksverein" and whose water is drained via the inactive areas Lothringen, Mont Cenis and Friedrich der Grosse into the Carolinenglueck central drainage plant at Bochum. The mine water from these inactive mines is collected together at <u>28 locations</u>, raised, and drained into the rivers Ruhr, Emscher and Lippe.

The large number of closures made it necessary to combine drainage activities in inactive areas. The efforts that have been made to raise inactive mine water in a location as central as possible can be clearly seen in Figure 6. Areas with central drainage plants, whose management is in the responsibility of the Central Drainage Division, are shown in the diagram as horizontally shaded regions. Inactive areas, in which drainage water is passed through and raised via active collieries, are vertically shaded.

Up to 1960, only two mines (Prinz Regent/Dannenbaum and Praesident) were closed, and 2 collection locations were set up, whereas by 1965 there had been 21 closures with 12 collection locations. One year after Ruhrkohle AG was founded - i.e. 1970 - closures had been carried out needing 21 collection locations. In the sequence of diagrams, the continuous expansion of horizontally and vertically shaded areas clearly illustrates the decline of coal mining in the Ruhr area. This tendency continued through to 1984, with closures totalling 79, including Erin, and 30 collection locations. At that point the central drainage plants did not yet include the well-known plants Gneisenau, Zollverein and Minister Stein.

This is no longer the case if we look at the diagram of today's arrangement, with the 87 closures and 28 collection locations mentioned earlier (Figure 6). However, this diagram already needs modifying to include the Radbod, Minister Achenbach and Osterfeld mines, and a few other subregions now amalgamated.

The 11 collection locations run by the Central Drainage Division each occupy one drainage area, called "Wasserprovinz", and these areas alone cover a total of 51 closed collieries. They extend about 60 km across the Ruhr area, from the Concordia plant in the west to Gneisenau in the east, i.e. from Oberhausen to Dortmund.

The Carolinenglueck central drainage plant is the largest drainage area, about 110 km², and is headquarters of the Division. Mine water from a total of 12 closed pits is raised there and pumped away from a depth of 915 m below mean sea level.

The 12 pits concerned are:

- Praesident
- Centrum-Morgensonne
- Carolinenglueck
- Constantin
- Koenigsgrube
- Hannover-Hannibal
- Shamrock
- Graf Schwerin
- Lothringen
- Friedrich der Grosse
- Mont Cenis
- Erin

If we combine the inactive areas drained by the Division's 11 plants we obtain a total underground drainage area over 700 km² in area - larger than Lake Geneva.

The central drainage plants are operated using a two-shaft system, and efforts are always made to tailor the closed pit to suit the needs of the drainage system and keep the remaining pit works as small as possible.

Despite these measures, today's area of supervision, which includes 21 air shafts, still requires a 40 km long underground network including more than 75 km of pipeline and 200 km of electricity cable. The machine sets needed for pumping (approximately 90) have an installed load of around 90 MW. Alongside the conventional horizontal rotary pump systems there are 14 modern submersible motor pumps with delivery heads of up to 1000 m and a throughput of 9 m³/min when in use. These submersible motor pumps can be up to 12 metres long and 23 tonnes in weight; they were specially developed with the help of the Central Drainage Division.

In addition to actually running the plants, the tasks of planning and implementing external water drainage are considerable too, mainly due to the complexity of the problems involved and the care required to make the correct decisions. At the forefront of every closure is the consideration of a host of criteria with regard to the future site at which mine water will be raised from the areas being closed. Only when all these criteria have been investigated a decision can be made, the main priority being of course to protect the surrounding mines.

There are two possible solutions: passing through the water to an active colliery or an existing central drainage plant, or build a new independent drainage plant in the area being closed.

In both cases, nearby mining activities and existing passages mean that the existing "crossing points" adjoining the neighbouring mines are to be tested to see if water will always remain unhindered in passing. This can be difficult if - as is often the case - these points are no longer accessible. The mining authorities are required to keep a constant check on the drainage of water.

An increase in the water level is always a considerable advantage to drainage work because it lowers the pump delivery heights and therefore long-term raising costs, and it creates a settling and sedimentation zone for the mine water. On the other hand, the level must not rise above the deepest safe crossing point, because this closes the commonly available option of pumping the water at a higher level to another location. As well as the crossing points, the local geological conditions must naturally also be tested for connections via tectonic fault systems.

As all drainage measures in inactive areas are in general intended for the long term, the long-term mining plans in neighbouring mines must also be given consideration. Even if all underground conditions are met and expected water quantities catered for, the situation regarding above-ground water handling can equally be a deciding factor in planning.

Alongside these continual adaptation activities, existing external water drainage systems must constantly be checked to make sure they are still necessary. The objects of this part of planning are, in order of possibility, centralization of drainage plants, step-by-step raising up of the dewatering - level, and finally closure of complete drainage plants.

In this context, the theoretical evaluation and practical testing of crossing points with regard to their ability to conduct water is very important. In this case actual quality of a crossover point can only be determined in a build-up test.

The necessary conditions for this are:

- safeguarding of controllable measures while guaranteeing absolute safety for the active areas;

- exclusion of the large proportion of consequential damage caused by water rising near the surface;

- constant control of the maximum mine water quantity present at any time.

The safeguarding of controllable measures means taking reversible steps until safe water transfer is proven or until the possibility of unpredictable consequential damage is excluded. In the worst case that means being able to return to the original state in the drainage area where water is building up.

At the same time, the neighbouring drainage area into which the built-up water is to be directed must be furnished with enough pumps to manage the additional water. Planning for this problem requires the involvement of the mining authorities from the very outset in order to obtain a risk assessment from the point of view of an authorizing body.

This type of build-up test was performed on the central drainage plant "Friedlicher Nachbar" in order to examine the possible ways of switching pumping over from the "Robert Mueser" drainage plant should this ever prove necessary.

Further tests are planned, although the procedure in this type of operation requires such a high degree of care that only a long-term testing program can be considered. The final objective is to significantly reduce mine water drainage activities.

Conveyed quantities

So how much water is actually there to be drained?

In Germany between 1960 and 1990, an average of about 190 million m³ of mine water were raised each year. The Ruhr area accounted for the majority of this with a share of 66 %.

If, for the sake of example, we look at the Ruhr area's figures over a longer period of time we can see that the quantity of water raised over the past 60 years has remained almost constant. In the 1920s, when only 40 million tonnes of coal were mined, the same amount of water was pumped as in the seventies, when about 70 million tonnes were mined. We can therefore come to the important conclusion that <u>no</u> direct relationship exists between the amount mined and the quantity of mine water raised.

Figure 7 shows the quantities of water raised in the Ruhr area between 1982 and 1992. The fluctuations, some of which are considerable, are mainly a result of variations in precipitation.

With regard to the origin and drainage of mine water, Ruhrkohle AG (RAG) 1990 gave the following figures for 1990: a total of 117 million m³ were raised by RAG. This quantity consisted of 43 million m³ collected in and raised by active collieries, and 74 million m³ raised from inactive areas. Of the latter, the Central Drainage Division pumped 65 million m³, i.e. 87%. The remaining 9 million m³ were transferred to and raised by active collieries.

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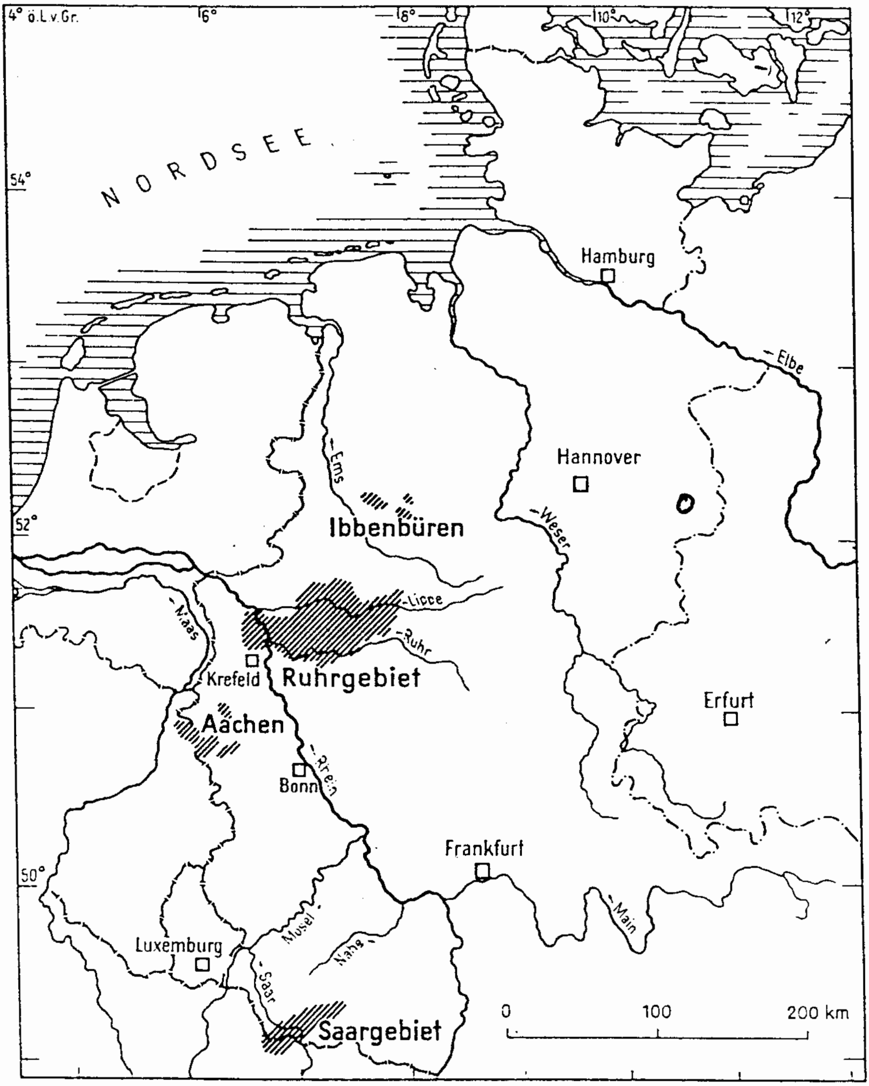

Figure 1: Coal deposits in Germany

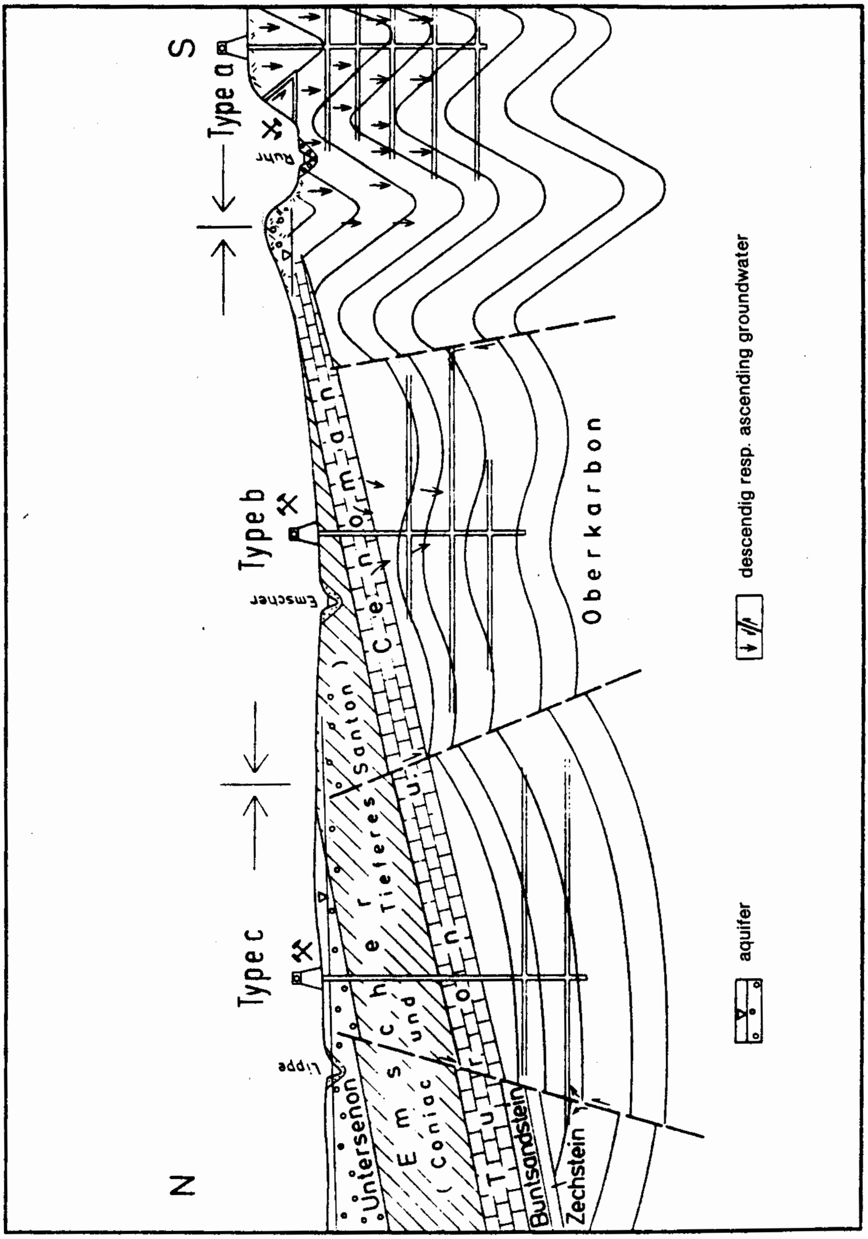

Figure 2: Schematic cross section through the Ruhr area (Schmidt 1986)

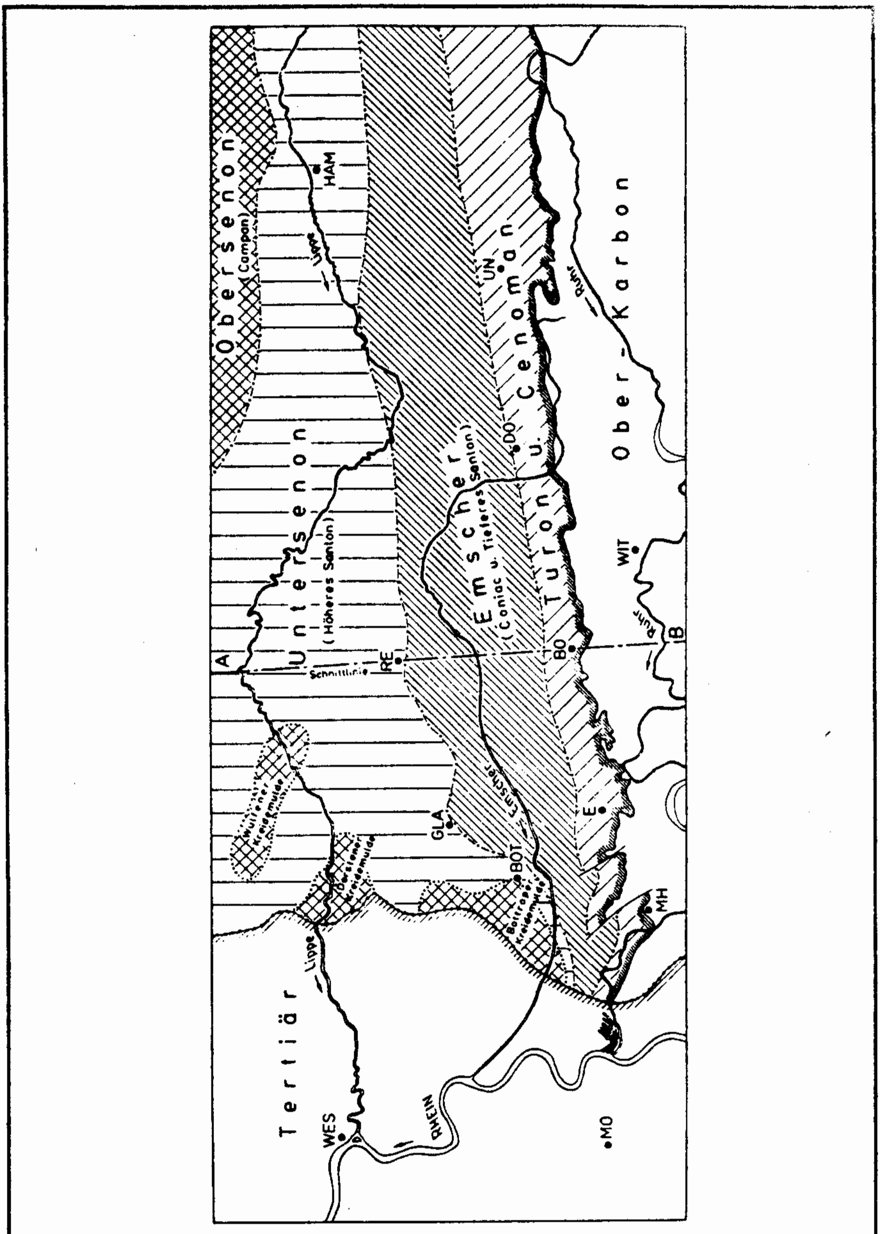

Figure 3: Distribution of strata in the Ruhr area (Schmidt 1986)

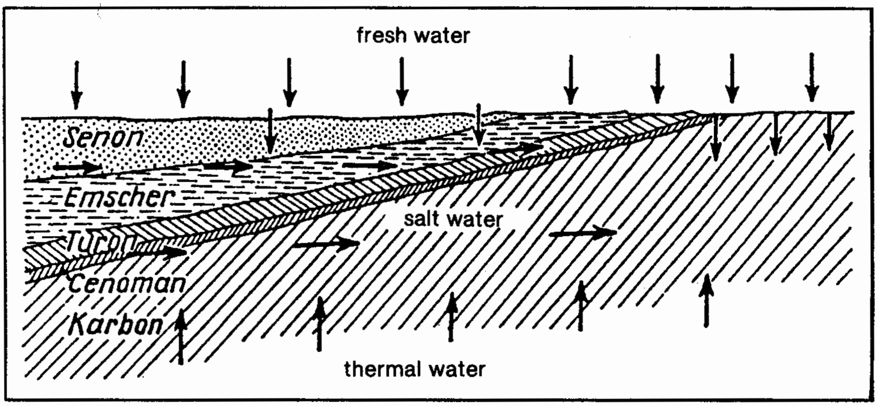

Figure 4:Chemistry of groundwater types in the Ruhr area

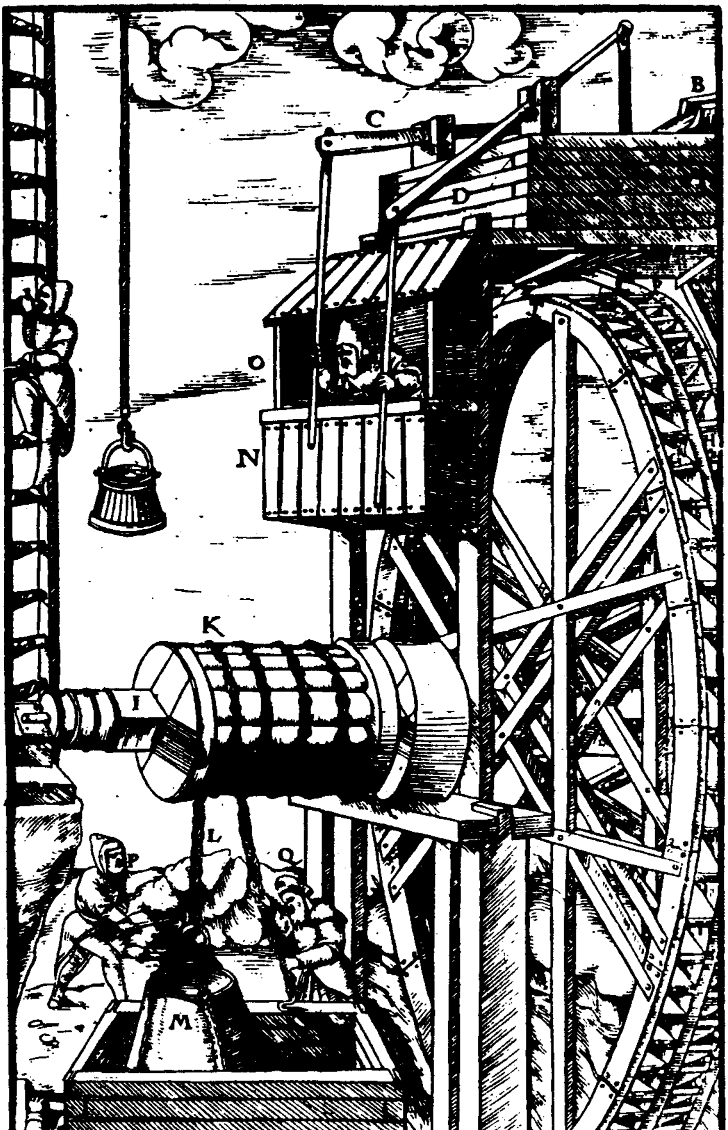

Figure 5: Waterwheel - driven windlass with manual control (Agricola 1557)

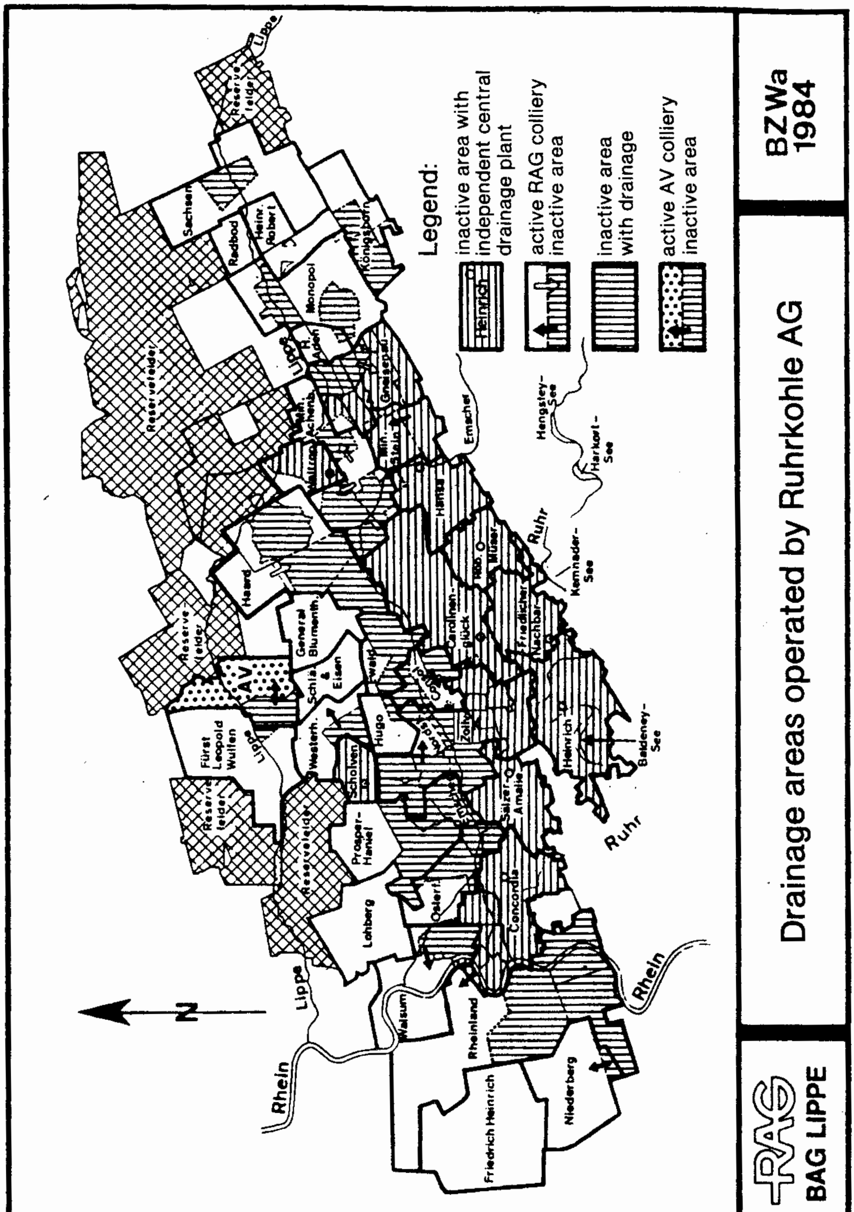

Figure 6: Drainage areas operated by Ruhrkohle AG (RAG)

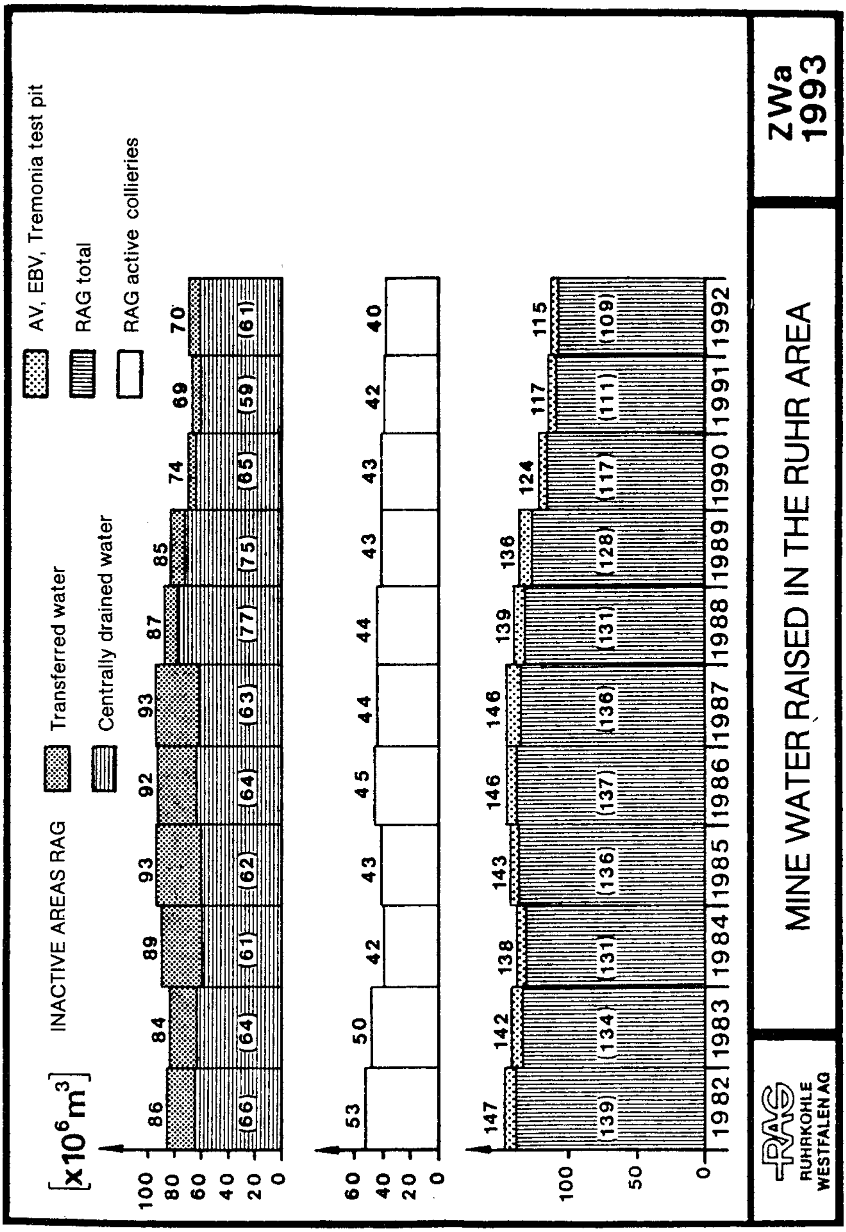

Figure 7: Mine water raised in the Ruhr area