# MINE WATER IN DUTCH COAL MINES IN THE POST-MINING STAGE

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## ABSTRACT

Mine water occurs and flows mainly in sandstone beds, intercalated in the impermeable shaly bulk of the coal bearing strata. The zonal distribution of water quality in the Carboniferous rocks in South-Limburg is controlled by meteoric waters descending via the overburden of Tertiary and Cretaceous age which consists of clayey sand and chalk, and by ascending waters introducing volatiles as well as chloride contents up to sea water quality and even higher.

Coal mining in South-Limburg was not considered economic anymore in 1965 and in subsequent years the coal mines were closed one by one. Although the Dutch coal mines dit not have to deal with a great influx of water as compared to many mines abroad, it was essential to protect operations in the mines not yet closed against water from the adjacent mines where all activities, including pumping, were to be stopped. For this purpose concrete dams were built in mine tunnels connecting different mine water basins. When part of an adjacent German coal field was shut down, it became necessary to keep the waterlevel in the southern mines under control by means of pumping.

The last coal mine in South-Limburg was to be closed in 1974 and it was considered necessary to keep an eye on the rise of the mine water level, not only to be able to predict possible environmental consequences of a rising level but also to timely establish possible contaminating effects of the rising mine water on the overlying rocks, which might endanger the production of drinking water. For this purpose 3 observation wells were installed in mine shafts where waterlevels could be measured, representative for various basins made up of groups of interconnected mines. Additionally, 4 new observation wells were drilled on locations where a concentrated influx of descending waters had been observed during mining activities. These wells do not quite reach the Carboniferous rocks but allow measurement of waterlevels and salinity in the overlying strata by means of filters and fixed salinometers on selected stratigraphic depths as well as sampling of water from these depths for chemical analyses.

## INTRODUCTION

Coal mining in the very southern part of The Netherlands started in the middle ages. The monks, implemented by pick and shovel, extracted the coal from Carboniferous strata which locally come to surface near the border with what is now the Federal Republic of Germany, but left no records of their dealing with minewater problems. By the end of the nineteenth century the industrial revolution had boosted the interest in coal production which resulted in an important increase of the number of concessions awarded and exploratory holes drilled in the south of Limburg. Coal production peaked in 1930 with more than 12 million tons. Just after W.W. II a revival of the production touched the level of 1930 but soon afterwards the growing economic interest in other energy sources choked the vitality of the coal mines. In 1965 coalmining in the southern part of Limburg was not considered economic anymore and the process of mine closures was put in motion. As the operating mines were artifically kept dry, the termination of all activities, pumping included, of mines shut down would cause an immediate threat for mines in which operations were planned to continue for a while, because of the many connections in the underground workings. The present paper briefly describes the measures taken to control the minewater during the process of mine closures as well as the environmental aspects of the rising water in the coal mines of South-Limburg.

## GEOLOGY

The Dutch coalfield, which continues into Belgium in the northwest and into the Federal Republic of Germany in the southeast, has an elongated shape and measures roughly 7 by 30 kilometer. It is situated on the northeastern edge of a structural high and separated from the Central Graben by a system of faults along which the Carboniferous surface sank to considerable depths (fig. 1).

The Upper-Carboniferous strata yielding the coal belong to the Westphalian A, B and the lower part of C. Important for the occurrence of mine water is the lithological alternation of shale and sandstone. The bulk of the coalbearing strata (at least 75%) consists of shale and sandy-shale whereas (quartzitic) sandstone occurs in minor intercalations. Coal and coaly layers may make up as much as 5% of the lithologic units. The Carboniferous beds do not normally dip more than 20° to the north and northeast. Only locally do dips of up to 90° occur (for instance in anticlines). The Westphalian sequence is intersected by two systems of faults; older southwest - northeast oriented upthrow faults and younger normal faults running northwest - southeast.

In the southeastern part of the mined area Carboniferous strata are found as high as 150 metres above sea level underneath a layer of overburden which may locally be less than 10 metres thick. Towards the northwest the Carboniferous surface dives progressively deeper until roughly 300 metres below sea level near the Belgian border where we find overburden thicknesses of nearly 400 metres.

The lithology of the overburden is important for the chemical composition of the mine water in the upper zone of the Carboniferous strata. According to the position with respect to the major northwest - southeast running faults, the rocks directly overlying the coal bearing Carboniferous may consist of Triassic sandstones (in the northern part), Upper Cretaceous glauconitic sands and clayey sands (southwest of the Heerlerheide fault), Upper Cretaceous chalks (in the central zone, northeast of the Heerlerheide fault) or Oligocene sands and clays (southeastern part, northeast of the Heerlerheide fault).

## DISTRIBUTION AND CHEMISTRY OF OCCURRING MINE WATERS

It is beyond the scope of this paper to elaborate on the mode of occurrence and the variation in chemical composition of the mine water encountered in Dutch coal mines. The most important information on the mine waters will be briefly dealt with, however, in order to subsequently make the protecting measures conceivable.
Since the early fifties, the investigation of both quantitative and qualitative aspects of the mine water in Limburg has principally been the work of Dr. W.F.M. Kimpe, who, as then Head of the Geologisch Bureau (a division of the Geological Survey of The Netherlands) was in charge of the geological and hydrogeological guidance of the mining activities. Mine water study was primarily aimed at ensuring a safe and uninterrupted extraction of coal. Mine water cards were made for all water occurrences, ranging from small incidental seepages to major breakthroughs which might last for years. Water quantity in litres per minute, temperature in $^{o}C$ and chemical composition were registered on these cards for all occurrences which were numbered and accurately expressed in coördinates and depth.

As compared with coal mines abroad the Dutch mines may not be very rich in water, yet the total yield given by Kimpe [1] averaged at 25 million $m^3$ per year at a coal production of 12 million tons. For the 12 individual coal mines in South-Limburg, the supply of mine water varies from 0,4 to 6,5 $m^3$ for each ton of coal produced.
Mine water occurs and moves almost exclusively in sandstone beds in which a high macropermeability is provided by a network of interconnecting joints. The primary porosity of the sandstones has been greatly reduced by the process of diagenesis which resulted in a negligible pore-permeability or micropermeability. Although the secundary (macro)porosity, due to fracturing of the sandstone, amounts to 3 or 4% only, Berding [2] calculated from 2 cases of inrushing water experienced in mine workings from closed sandstone reservoirs that the effective macropermeability of the sandstone beds amounted to 19 and 36 darcys. As to the mode of occurrence of mine water, two types of reservoirs can be distinguished.

Closed reservoirs lack connections with areas of water supply and, once cut into by mining activities, will be fully drained within a short period of time. Open reservoirs on the other hand are connected with areas able to provide a long term water supply, which can be either water descending from the overlying strata or water ascending from greater depths. Major inrushes of mine water from sandstone layers occur almost exclusively on greater depths in the lithologic sequence, especially in the lower and middle part of the Westphalian A. The shales, forming the bulk of the mined strata, do not contain free water and can be considered impermeable. Faults can either function as hydrological barriers (i.e. the older upthrusts running northeast-southwest) or as water conductors (some of the younger northwest-southeast oriented normal faults). Water transport across the latter type of fault can only take place where permeable sandstone beds happen to be in contact on both sides of the fault, provided the fault is not sealed off by fault gouge.

The variation in chemical composition of mine waters in the Dutch mining district has been elaborately described by Kimpe [1] , [3] and [4]. After studying a great number of water analyses he arrived at a spatial zonal distribution of waters occurring in the mined Carboniferous strata and its overburden which is schematically presented in table 1. The different zones gradually pass into one another and the distribution of the zones is depending on the local possibilities of vertical and lateral water transport and on the lithology of the formations overlying the Carboniferous strata. In the southeastern part of the mining district, where Carboniferous strata come close to surface, an exceptional occurrence of calcium-sulfate water, rich in iron, was found in the upper zone of the mined rock. The composition of this water, on top of the normal calcium-bicarbonate water, can be attributed to urban influence. Conclusive occurrences of ascending waters introducing juvenile components were especially found along certain northwest-southeast oriented faults and on the flank of the Waubach anticline. The zonal distribution of the chemically differing mine waters is believed to have been produced by vertical exchange rather than by lateral exchange. The question as to whether or not dissolved salts have laterally influenced the salinity of some mine waters to a great extent, has not yet been solved. If not, the exceptionally high Cl' contents of up to 25.000 mg/L (roughly 700 milli-equivalents/L) might have to be explained by a concentration of original connate water, either in situ or during migration from elsewhere.

## UNDERGROUND PROTECTION DURING MINE CLOSURES

A good insight in the mode of occurrence of the mine water and the hydraulic properties of the coal bearing sequence was not only a prerequisite for an adequate planning of mine operations in South-Limburg but also appeared to be invaluable during the process of mine closures in the Dutch mining district and the adjacent coal field in the Federal Republic of Germany.

In 1965 the decision was taken to successively shut down the Dutch coal mines but before this process of closing the individual mines was put in motion, operations in the German mine Gouley-Laurweg, just across the border, were to be stopped. The great influx of water of this mine, about 12 $m^3$/minute, was expected to flow directly into the adjacent Dutch mines through the many existing underground connections and would subsequently threaten the mining operations more to the north. As the pumping capacity in the Dutch mines was by far not enough to keep pace with this substantially enlarged water inrush, an inventory was made for the individual mines of inflowing water quantities, installed pumps, levels of open connections between the mines, quality of the separations between the underground workings and the planned closing dates for the various mines (fig. 2 and 3). Based on this study and on the experience with the older southwest-northeast oriented Willem fault as a hydrological barrier, the decision was taken to seal off that section of the coalfield situated southeast of this fault from the remaining coal district where operations were sceduled to continue for a while. The planning and execution of this project has been described by Crasborn et al. in 1971 [5] . By sealing off the openings in the Willem fault, the northern mines were protected against the water inflow of 19 $m^3$/minute which was to be expected from the combined mines Gouley-Laurweg, Domaniale and Willem Sophia. From the waterbasin, thus formed, the mine water could easily be kept at a level of about 165 to 170 metres below mean sea level (which is 25 to 30 metres below the deepest remaining perforation of the Willem fault), the more so because the inrush of water would be greatly reduced by the higher hydrostatic pressure which could be expected to (partly) choke some of the underground sources.

The construction of the 12 dams, necessary to restore the hydraulic barrier of the Willem-fault, had to be carried out with great exactitude as revisions or repairs would not be possible once the waterlevel had risen. The dams, to be built of concrete, had to be able to withstand pressures of 70-190 tons/$m^2$, according to their depths of construction and had to have lengths of 7-15 metres due to the local geological conditions. To eliminate water flows bypassing the dams through permeable sandstone beds, special care was taken to base the final choice of the location of the dams mainly on the local geological and hydrogeological details. As for the dam construction it was essential to close the cracks and voids in the rock surrounding the dam, to ensure a close fit with the roof and to fill the shrinking cracks between the concrete and the rock around. For this purpose a pre-injection with "cement-milk" took place to make the rock impermeable and after the construction of the dam a high-pressure injection filled up the last voids and shrinking cracks.

The Dutch mines southeast of the Willem fault were thus brought together with the German mine Gouley-Laurweg into a water reservoir separated from the remaining coalfield of South-Limburg but with an overflow connection with the mine Wilhelmina at a level of about 140 metres below sea level. The water in this reservoir was originally to be kept at a level of 165 to 170 metres below sea level (310-315 metres below surface) by means of pumping, but due to the discovery of a possible connection (fractured wall between workings) between the Domaniale mine and the German mine Anna, which was to remain in operation, this level had to be reduced to about 220 metres below sea level. The water in this reservoir will be kept at this level until the last mine in the German part of the coalfield will cease operations.

## ENVIRONMENTAL ASPECTS

The remaining Dutch coalfield, northwest of the Willem fault, can also be subdivided into several waterreservoirs, separated by existing dams, faults and unexploited zones between workings. Only at certain well known levels are these reservoirs connected with adjacent basins (fig. 3).

The individual water basins are not all interconnected. Basin I, mine Maurits, was sealed off from the adjacent mine Emma by a dam constructed in the only existing connection, a tunnel traversing the Puth anticline. Also basins II (part of mine Hendrik northeast of the Feldbiss) and VIII (mine Julia) are isolated from the workings of the other mines and will experience an independant rise of the water table. All other reservoirs show mutual overflows at certain levels and the rise of the water table will sooner or later be interdependant.

In order to keep track of the rise of the mine water in the various mines, 4 observation wells were installed in mine shafts, in which levels could be measured representative for basins IV, VI, VII and VIII. As long as the water level in the individual basins lies below the level of overflow with adjacent basins, the rise of this level will take place with different rates, depending on depth and distribution of mine workings, total quantity of inrushing water and the level, yield and pressure of individual sources. Apart from some very high rates of water rise (up to 90 cm per day), recorded in the early fill-up stages of deeper parts of reservoirs with a relative small volume of mine workings, the mine water was found to rise at a rate of about 6-13 cm per day. As the water level in reservoirs rises higher, the rate of speed can be expected to drop due to the growing hydrostatic pressure, choking deeper water sources. Provided the overflows as shown in fig. 3 are functionning all right and pumping in basin III will be continued, the ultimate water level in basins V, VI and VII will settle at about 63 metres below sea level and water in basins IV and IVa will reach a level of approximately 135 metres below sea level. Unfortunately the rate of water rise in basins VI and VII cannot be checked on any more as the observation well in mine shaft Emma was cut off in 1974 by the construction of a concrete plug in the shaft and measurement of the water level in the shaft of mine ON I became impossible in 1978 after an apparent rupture of the well pipe. At present, only levels in basins IV and VIII are regularly measured and it is felt that this is not enough to ensure a healthy control of the rising water table in the district as a whole. After all, it is quite imaginable that rising mine water might one day cause environmental problems. This could be either in the shape of swampy areas in low valleys in the mining district, especially in sections thereof which might have experienced a substantial relative subsidence, or as source of pollution in overlying Cretaceous chalk, which is widely used in the region for extraction of drinking-water.

As far as the latter possibility is concerned, real protecting measures against this danger are not easy to take. It is of great importance, however, to timely ascertain a possible encroachment of saline and perhaps sulfate rich mine water in the chalk aquifer. For this purpose a guarding system of 4 observation wells was materialized which allowed both a regular measurement of water levels in various overburden formations and a control of the chemical composition of the groundwater by means of sampling and fixed salinometers. The situation of the most important pumping stations for drinking-water and the distribution of areas where substantial influxes of descending water were experienced in the coal mines were decisive for the choice of the location of these observation wells I, III and IV, while well II is situated in an area of direct contact between the Carboniferous strata and the chalk aquifer (fig. 4 and 5). From the hydrogeological point of view it was considered necessary to sink these wells just into the Carboniferous rocks. Only then could the level and composition of the water in these rocks be compared with those of the overlying, possibly endangered strata, by means of well separated filters. The mine authorities, however, arguing that this might create the very passages of the mine water of which we are apprehensive, declared to decline all responsibility for possible pollution in that case. It was then decided to stop the wells 10 metres above the top of the Carboniferous rock. Based on measurements and estimates of the rate of mine water rise in the various basins, it is expected that the water level will reach the Carboniferous-overburden interface at the observation wells I and III in 1982, at the wells II and IV by 1986. After that, the possible encroachment of this water towards the chalk aquifer will depend on the complicated hydrogeological conditions in the overburden.

## FINAL REMARKS

Underground coal mining in the southern province of the Netherlands has known a long tradition and had become of predominating regional significance early this century. However, this safe and sophisticated mining industry lost its viability all of a sudden due to a shift in the demand for energy in favor of oil and gas.
During and after the mining activities the mine waters were seriously looked at in the South-Limburg coalfield, but evenso we have not been able to completely escape from the inclination

to do away with all of the complicated mining industry and its consequences, once the final decision had beek taken to put an end to coal mining. After the experience in minewater management we aquired in the Dutch coalfield it must be stressed that a good system of possibilities for minewater observation is essential to control the water and to be able to timely indicate potential environmental threats.
The rising minewater in the underground workings do not only represent problems, however. It may also offers new perspectives. The upper zone of infiltrated water in the workings may become a valued reservoir for industrial water.
Presently, investigations are being made of the feasibility to use the minewater deep in the mines for energy extraction. Locally occurring sources of thermo-mineral water might one day open other possibilities, however problematic it may have been in the mining days.

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List of Figures

| | | |
|---|---|---|
| infiltration zone | I | *zone of Ca[Mg]-bicarbonate (and Ca[Mg]-sulfate) waters.* |
| zone of base exchange | II | *zone of Na-bicarbonate waters.* |
| upper contaminated zone | III | *zone of Na-chloride (and Na-chloride-bicarbonate) waters.* |
| lower contaminated zone | IV | *zone of Na-chloride and Ca/Mg-chloride waters without sulfate.* |
| zone of ascending waters | V | *zone of thermomineral waters with high concentrations of Na-chloride or Ca[Mg]-chloride with or without sulfates.* |

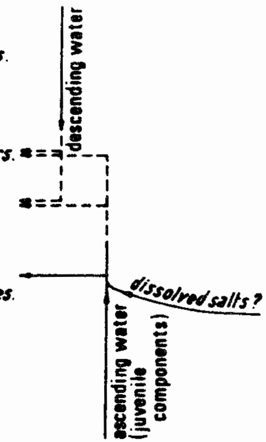


**Table 1 The zonal distribution of the types of minewater distinguished (after Kimpe 1963)**

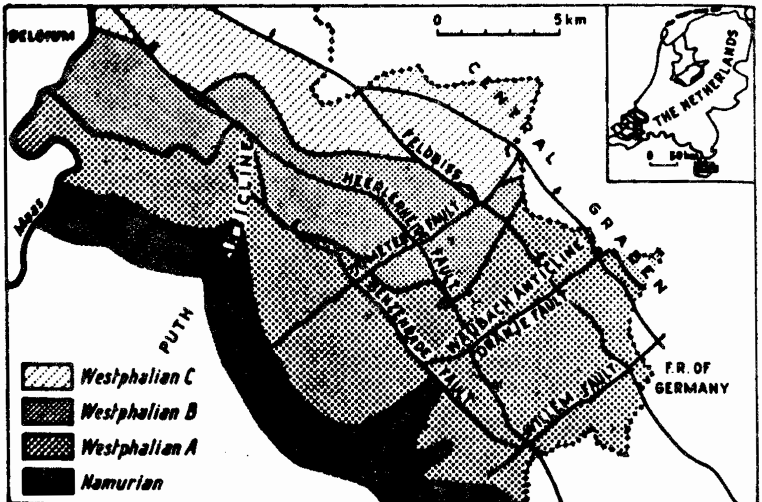


Fig.1 Main stratigraphic units (Carboniferous only) and structural elements in the coalfield of South-Limburg.

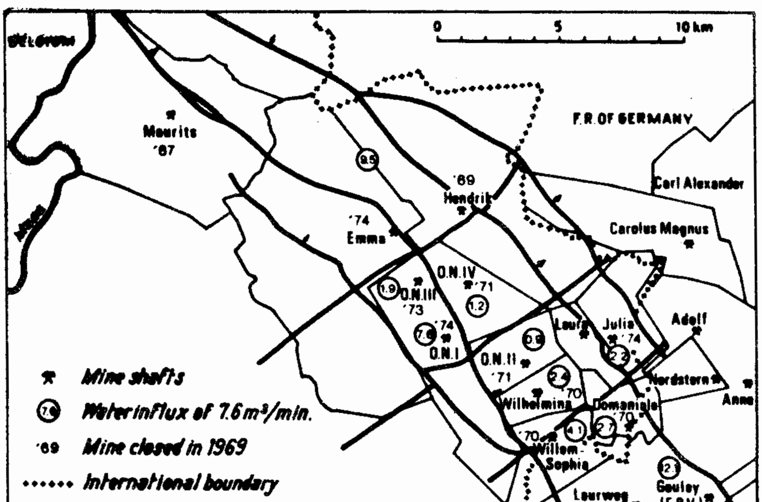


Fig.2 The various mineconcessions with waterinfluxes and closing dates (mainly after Crasborn et al. 1971).

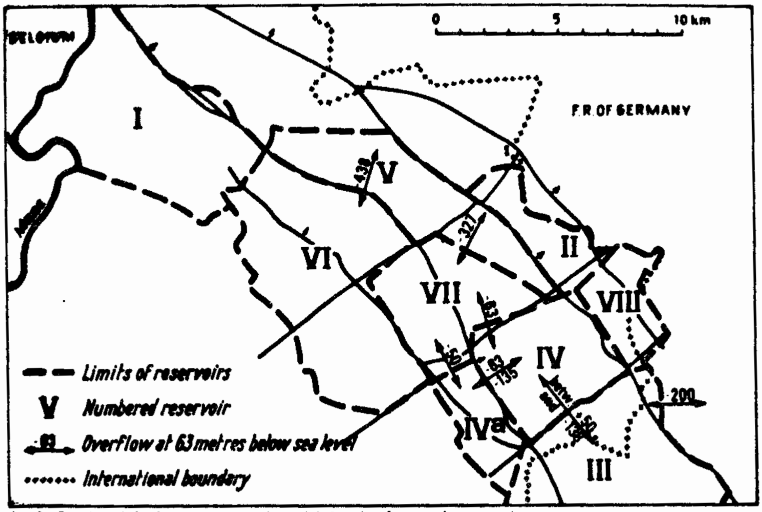


Fig 3 Distinguished water reservoirs with levels of mutual connections.

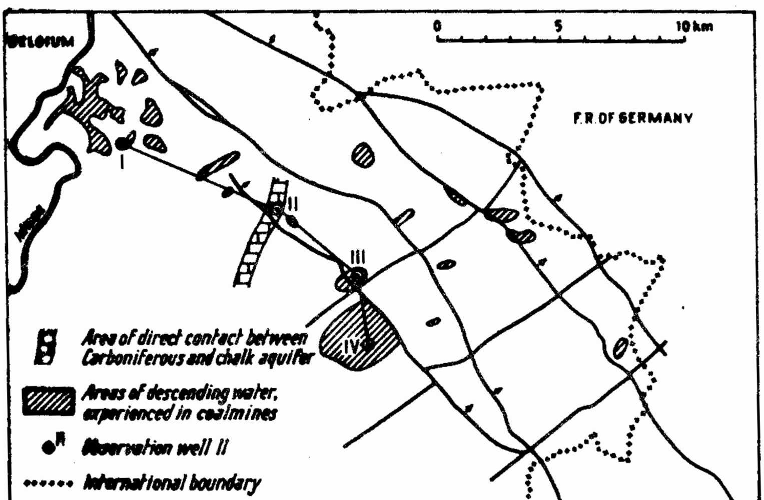


Fig. 4 Areas with important influxes of water from the overburden and location of the 4 observation wells.

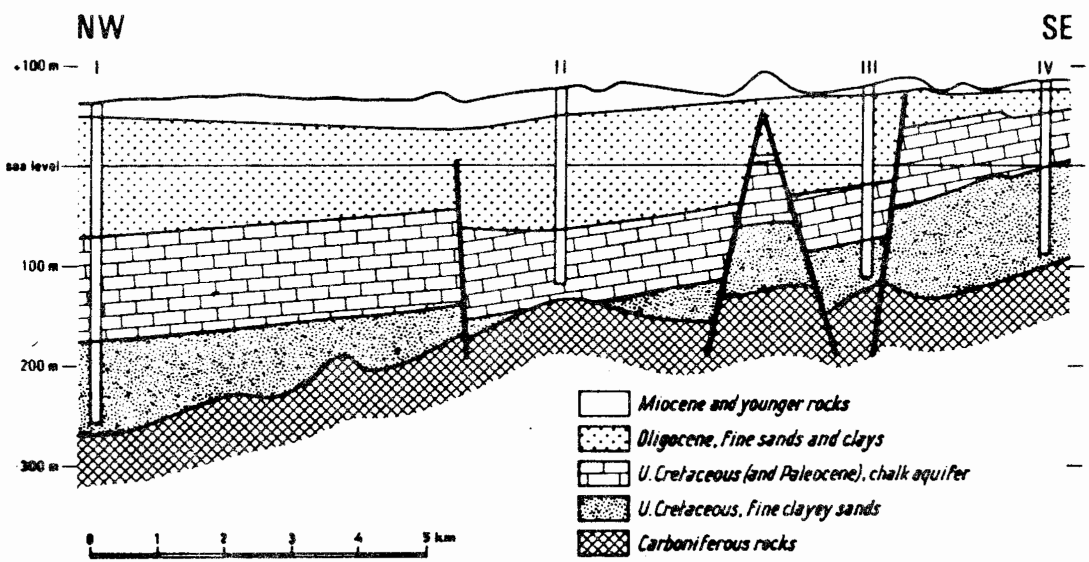


Fig 5 The position of the observation wells in the rocks overlying the Carboniferous strata