# Water control and mining grouting
# a South African historical perspective

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## ABSTRACT:

*The achievements of mining engineers in South Africa and elsewhere with respect to water control and mining grouting from the beginning of the previous century were quite extraordinary.*

*The contributions of these early pioneers have been greatly underestimated. Innovation and development in the mining industry was driven by the economic upswing of the coal and gold mining industries during the beginning of the 20th century and technical problems related to mining.*

*In South Africa the discovery and development of the Witwatersrand gold fields in 1886 and in particular the problems encountered in deep mines were the driving forces of the developments in deep mine grouting and water control.*

*Milestones in the South African mining industry relating to grouting and water control are:*

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|---|---|
| *1917* | *Introduction of mining grouting by A. Francois in South Africa.* |
| *1930* | *Improved drilling technology.* |
| *1950* | *Precementation of deep shafts.* |
| *1952* | *Comprehensive management systems for water control.* |
| *1956* | *The Water Act, No 54.* |
| *1960* | *Dewatering of regional compartments.* |
| *1991* | *The Minerals Act, No. 50* |

*Mining grouting is initiated primarily for water control, in some cases strength enhancement may also be required. Grouting using mainly environmentally acceptable cement slurries was introduced at a relatively early stage in the developments of the South African gold fields; without the cementation technique the enormous developments of the gold mining industry would probably not have been possible. The inherent environmentally friendly nature of grouting with cementitious and pozzolanic materials has contributed significantly to a relatively clean underground environment; more toxic materials such as AM 9 have been used but their use was abandoned rapidly at an early stage. In contrast the lowering of the water table by some mines and the resulting dewatering of large compartments had significant effects on the environment.*

*This paper endeavours to present a historical perspective of the developments and achievements of the early pioneers in the South African mining industry with respect to water control and mining grouting.*

## INTRODUCTION

A mine is an extensive drainage system. In addition mining action increases the transmissivity of a rock mass by causing deformations, opening of fissures etc. While South African mines typically have much lower water ingresses as some of the most watery mines e.g. in the Copper belt in Zambia, the large depths of the South African mines, result in high water pressures and hence create serious potential hazards, risking the flooding of mine workings, shafts etc with the potential loss of life.

The specific mining conditions in South Africa causing water hazards are:

a.) The large depth of the mine workings and the enormous extension of these workings

b.) The specific geology encountered in large areas of the gold fields. Particularly the dolomites overlying the West Rand and Far West Rand gold fields are large permeable water reservoirs.

Therefore, although South Africa is a low rainfall country, the specific underground conditions and geology make water a formidable “enemy” of the miner. An enemy which is ever present. Many techniques were developed over more than a century to control this “enemy”.

## A CENTURY OF WATER CONTROL

The richest gold field in the world was discovered in 1886 near Johannesburg, South Africa.

Mining was originally confined to a 70km belt along the reef outcrops of the Witwatersrand basin. Today gold is mined up to 4,000m below surface. ERPM in the East Rand passed the 3,000m mark 45 years ago and reached a world record of 3,428m below surface in 1959. At present investigations are underway to evaluate the exploitation of ultra-deep ore bodies down to 5,000m below surface.

However, the gold production of the South African gold mining industry has been declining steadily in recent years. In 1910 gold production was 234.25 tons. In 1970 South Africa produced 1000.4 tons of gold which was approximately 80% of the entire world production, during 2002 South Africa produced slightly less than 400 tons which was approximately 25% of the world production.

At the turn of the 20th century many water control techniques were already well established. First and foremost water control by pumping had reached a high sophistication. One of the first centrifugal pumps was invented by Denys Papins in 1689 and multistage centrifugal pumps, steam driven, were well developed by the mid 19th century.

For example, in opening the central and western areas of East Rand Proprietary Mines (ERPM) a large pumping system was installed with a total capacity of 200,000 gal/hour (910m³/hour) capable of pumping at a maximum effective head of 1000ft (305m). Control dams, dam walls were also constructed at selected spots (Bok, 1931).

Where pumping failed the freezing method was applied in many cases very successfully such as at the Easington Colliery and at the Londonderry Colliery at the beginning of the 20th century. (Jeppe, 1946)

The use of other water control measures such as water doors, control dams and brick and mortar plugs was also well established in the mining industry during the early years.

The Francois Cementation Process was patented in 1896 (Jeppe, 1946), brought to England in 1911 and first applied in South Africa in 1917.

However, South African mining engineers had other specific water problems resulting mainly as stated earlier from very high pressures at great depth.

Several milestones, which in some cases have revolutionised water control in the mining industry, can be identified during the past century.

The most important milestones in the South African Mining context relating to water control are:

1917 Introduction of Mining Grouting by A. Francois in South Africa.
1930 Improved drilling technology.
1950 Precementation of deep shafts.
1952 Comprehensive management systems for water control.
1956 The Water Act, No 54. (Amended by Act No 56 of 1961)
1960 Dewatering of Regional Compartments.
1991 The Minerals Act, No. 50

## 1917 INTRODUCTION OF MINING GROUTING BY A. FRANCOIS IN SOUTH AFRICA.

The contributions of South African mining engineers in the field of grouting in mining and construction has been greatly underestimated.Some of the first precementation works was executed by Portier in France in 1864, however, the South African mining cementation techniques are closely related to the name Albert Francois, a brilliant Belgian mining engineer.

Francois developed his cementation process in 1896 for the purpose of shaft sinking. However, Francois' most important contribution was the invention of a high pressure, steam driven, cementation pump (see Fig. 1) and the realization that cement at high pressures (up to 5,000 lb/sq inch, 350 kg/cm²) can be introduced into the minutest fissures in rock formations. The process was first brought to England in 1911 and was applied at the Hatfield Colliery in Yorkshire. Subsequently the Francois Cementation Process was applied with great success in many English collieries particularly in Yorkshire and the Midlands in the years following World War I.

Francois' first visit to South Africa was in 1916 at the invitation of Corner House and his involvement on the South African gold fields commenced in 1917. In 1914 Francois had offered his services to a Johannesburg mining house but it was only two years later when significant water inrushes occurred (4,500,000 gal/day, 852m³/hour) at ERPM that Francois was requested to assist. At ERPM 26th cross cut south, water was struck and in the 30 level west drive, water was encountered unexpectedly at high pressure (Krynauw, 1918). The Francois cementation process was immediately very successful.

By the end of 1918, the Francois cementation process was well established; the following projects had been completed successfully: Comet Deep (ERPM), 26th cross cut, 30th level West Angelo Deep 28th West Dam, 29th West Cross cut; Geduld Proprietary Mine Ltd: 2nd and 3rd level South, 4th level South Drive; Daggafontein Mine No 2 Shaft and No 4 Shaft, Brakpan Mines. In addition the Rand Water Board Pumping Station and the Mazoe Dam in Southern Rhodesia were successfully grouted and repaired with this process.

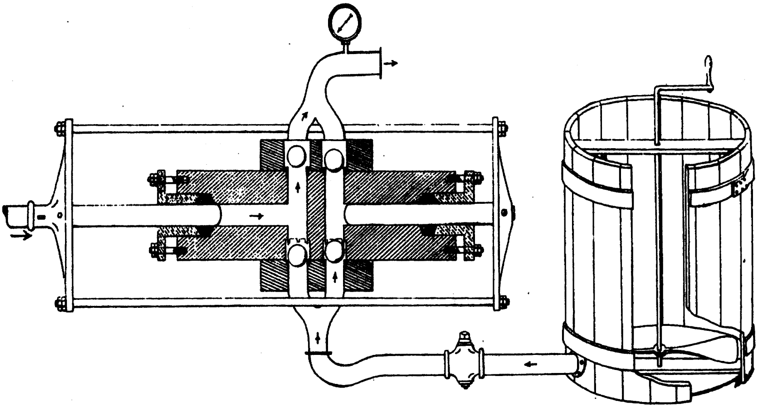

**FIG. I.—Diagrammatic Sketch of Water End of Cementation Pump and Mixing Tub.**

The Francois cementation process was described by Krynauw (1918), who worked closely with Albert Francois during 1917, as follows:

*"An essential condition in the introduction of cement into fissures and cracks is that the injection should be done under a considerable pressure, the object being, firstly, to overcome the contra pressure of water present in the fissure; secondly, for the purpose of forcing the cement as far as possible into the minute cracks, and, thirdly, for the purpose of squeezing out the superfluous water from the cavity which is being filled with cement pulp, and thus leave the cement in a condition most suitable for its rapid and efficient setting."*

After the discovery of the Witwatersrand gold fields, it was soon realized and verified that the gold bearing reefs continued below the water bearing dolomites. In 1910 the West Rand Estates Ltd located a shaft site commonly known as Pullinger near the centre of the Venterspost mining area. It was a circular shaft; sinking began in 1910, the shaft was lined with German Haniel and Lueg's cast iron tubbing and was abandoned in 1911 at a depth of 97ft (29.5m) as two of the most modern electric pumps at the time (combined capacity 818m$^3$/hour) could not cope with the inrushes of 208 000 gal/hour (946m$^3$/hour) and several mud rushes.

Subsequent applications which successfully established the Francois cementation process for shaft sinking in South Africa were the sinking of Daggafontein Mines (No. 2), West Springs No. 1 and two circular shafts at the Brakpan Mines.

However, a milestone was achieved by sinking Shafts No. 1 and No. 2 at the Venterspost Gold Mining Company. After the failure of the Pullinger shaft in 1911 it was decided in 1934 to use cementation for sinking the new shaft in the vicinity. Cementation work at Venterspost was divided into three phases (Allen and Crawhall, 1937/38):

*"The pretreatment of fissured dolomite free from decomposition.*

*The stabilisation of mud deposits occurring in the upper zones of the dolomite.*

*The correction of errors arising from insufficiently intensive ground preparation."*

The sinking of these two shafts was remarkable for several reasons:

For the first time it was shown that the cementation process was successful under the most hazardous conditions where previous attempts had failed such as sinking through water bearing dolomite.

In both shafts several water inrushes up to 3000m$^3$/hour were experienced AND for the first time a shaft was sunk through "Wad" (hydrated manganese oxide), which is low in density, highly compressible and, except for the absence of fibres, not unlike peat and often water logged.

Even today Wad, running dykes, sugary dolomite such as the PIORA syncline (Heinz, 2000) in combination with high water pressures must be the most difficult formations to mine or tunnel through. At Venterspost Shaft No. 2 the production through the worst horizons of the weathered dolomite up to a depth of 193m was 8.05m/month, below that depth productivity rose to 72m/month.

It is also interesting to note that during cementation drilling and injection the sinker took operative instructions from the cementation foreman (Allan & Crawhall, 1937).

Mining grouting techniques and equipment has continually improved over many decades. The development of air-driven, robust high-pressure cementation pumps has greatly facilitated the success of the Francois cementation techniques. Also, advances made in mixing technology have facilitated the improvement in mining grouting in the South African mining industry.

It is also of interest to note that already as far back as 1947 it was realized that finer cement grain sizes would achieve more extensive penetration with greater ease of pumping. It was concluded that ultra-fine cement would be warranted (Curtin, 1952). The possibility of “air-separated” and more finely ground cement was considered, but the need for special plant and the inadequacy of supplies prevented further progress.

In summary then it is clear that the cementation process as applied in the South African mining industry made a large contribution to the development of the industry.

## 1930 – IMPROVED DRILLING TECHNOLOGY

During earlier cementation projects at Daggafontein and West Springs long diamond drilling holes up to 200ft (61m) were drilled. The holes were drilled inclined, eighteen holes were drilled for a 45ft by 8ft shaft. At Vogelstruisbult GM for the first time percussion equipment was used to drill the cementation holes. The rate of diamond drilling was rather slow especially in cherty dolomite. The depth of the cover holes was 126ft, drilled at an average of 3ft/day (MacWilliam, 1935). As progress was too slow it was decided to drill percussion holes initially to a depth of 15ft; the shaft was then sunk 11ft. Rapidly these percussion holes were extended to 20ft and eventually 30ft. After cementation of the 30ft holes, the shaft was advanced 27ft. At Venterspost G.M this method was further improved to drill 40ft (12m) cementation cover holes to allow a 30ft (9m) advance.

Today most shafts are circular, sometimes the stretched circular shaft is used where a short flat usually less than 10% of the shaft diameter is introduced between two semicircles. Irrespective of whether a shaft has been pregrouted, the Mines and Works Act requires that holes are drilled and grouted ahead of the excavation to prevent blasting into uncontrollable quantities of water which could flood the shaft. Furthermore, it is desirable to have a dry shaft

to avoid an increase in relative humidity of the incoming mine ventilation system

to avoid degradation of the shaft steelwork and

to reduce ventilation and pumping power requirements over the life of the shaft.

Hence the importance of proper cover grouting procedures. (Heinz, 1997)

State-of-the-Art practice is to drill eight to twenty-four holes (depending on shaft diameter) up to 50m but typically 36m at 75° to 85° below the horizontal and so spaced and raked that the toe of each hole overlaps the collar of the succeeding hole on the pitch circle circumference. This results in a truncated cone of spiral boreholes at least one of which will intersect randomly orientated planar fissures drawn through the cone. These rounds are repeated every 30m so that the shaft is always at least 6m inside cover.

The improved drilling technology introduced at the beginning of the thirties in the past century resulted in a marked improvement of water control and shaft sinking productivity. After WWII further improvements in the diamond and percussion drilling technology were made. Small air driven simple and robust diamond drilling machines such as the Kempe rig became the work horse of the underground drilling industry. These machines are still in use today, fifty years after their introduction into the market.

## 1950 - PRECEMENTATION OF DEEP SHAFTS

Pregrouting or precementation of deep shafts prior to sinking has been applied in South Africa since the fifties, with considerable success. The earliest and most authoritative publications on this subject were by Newman (1956) and Muller & Spence (1960). Geological and geohydrological considerations are decisive parameters determining success or failure of a precementation, indeed its desirability, economically and otherwise.

Critical issues or parameters that require attention in pregrouting projects are (Heinz, 1988):

- a) The number of pregrouting holes drilled. The minimum should be 2 preferably 3 holes.
- b) The maximum sealing pressures applied and whether hydrofracturing should be allowed. Current practice in pregrouting of deep shafts in South Africa uses a sealing pressure at a certain depth equal to 2.5 times the in situ hydrostatic pressure at that depth. (Heinz, 2003)
- c) The economic benefits e.g. the reduction of overall shaft sinking time has been well established and should not be an issue any more. (Heinz, 2003)

The following information and data is required:

1. Comprehensive and exhaustive collection of geological and geohydrological information and data relevant to the project. In particular
   - a) Geological data, logs of all boreholes at the site and in the vicinity of the project
   - b) Aerial photographs and magnetic surveys to detect possible faults and dykes, infrared photography in dolomitic terrain.
   - c) Analysis of prominent joints and fissure patterns.
   - d) Compilation of information on water: water tables (perched), quality, direction and flow of water, in fact, a complete understanding of the water regime (surface and underground) is necessary.
2. Characteristics and values of the in situ stress fields.
   - a) Hydrofracturing data which will provide direction and value of stresses.
   - b) Determination of hydrofracturing stresses and possibly determining of similar values for existing fractures, weak joints etc.

Benefits of pregrouting of shafts can be summarised as follows:

1. It increases the safety of the sinking operation.
2. It minimizes the inflow of water and gas;
3. It minimizes the time lost due to additional grouting operations (cover grouting) during sinking and hence minimizes standing time of costly shaft sinking crews and equipment;
4. It provides improved rock strength for excavations in the immediate vicinity of the shaft area (grouted fissures have been found up to 60m from the pregrouted shaft);
5. It provides detailed information of the geology of the proposed shaft site and possibly information on ore grades in the shaft vicinity;
6. It reduces the number of intermediate underground grout stations during shaft sinking operations.
7. It allows the mine to start mining earlier in some cases several months, which should result in earlier positive cash flow from mining operations.

8. Ideally pregrouting is done outside the shaft perimeter with no interference between the sinking teams and the pregrouting teams or contractor.
9. Shaft sinking is an expensive operation, hence time allowed for supporting activities such as grouting during sinking operations though critical, are often curtailed to the detriment of the final result. Pregrouting minimizes this possibility.

Pregrouting can be done before sinking commences or during sinking. If done during shaft sinking the pregrouting holes should lead the sinking operation by several hundred metres. During the past fifty years pregrouting of shafts has contributed significantly to water control during sinking and hence to shaft sinking productivity and safety in general.

## 1952 – COMPREHENSIVE MANAGEMENT SYSTEMS FOR WATER CONTROL

Water control is an essential element of any mining activity. The control of water by pumping was already well established when the South African gold fields were discovered. The basic pumps and pumping systems used at the beginning of the 20th century such as electrically driven multistage centrifugal pumps are still in use 100 years later. Other means of water control such as doors, control dams etc., were also well established at this early stage.

Initially water control was achieved in a haphazard, reactive approach. However, by the mid 20th century comprehensive water management and control systems had been initiated and comprised the following elements:

1. An attempt to understand as far as possible the complete water regime of the mine (surface and underground). This necessitated a complete understanding of the geology and geohydrology of the mine and the dynamics of the water regime as a result of mining activity.
2. Tests and measurements to establish a water balance of the underground and surface drainage system.
3. Exhaustive measurement of the incidence of water in development and stoping.
4. Precautionary measures during drilling and grouting.
5. The development of grouting techniques and their evaluation with respect to their effectiveness and efficiency in the control of water.
6. Organization of management structures such as a water control board.
7. Comprehensive measures and cost evaluation to control water underground and on surface.

It is to be expected that some of the “watery” mines in the West Rand and Far West Rand, such as Venterspost and Blyvooruitzicht Gold Mines, were leaders in the development of comprehensive water control systems.

In 1938 the first shaft at Blyvooruitzicht Gold Mine reached the water table at 115m. Ten years later the mine had established a comprehensive water control system in addition to extensive cementation activities.

The control of operations was headed by a geologist who would be the “water officer” in charge of all planning (Curtin, 1952).

A surveyor who had graduated in mining was delegated full-time to the survey of diamond-drill holes, the keeping of records and up-dating of the water plan.

The main advantages of this arrangement were that:

1. Immediate decisions on the programme of the work were made and
2. the water problem was controlled on a continuous basis.

The manager was informed daily of the occurrences of water and the weekly meetings kept the underground managers in touch with progress in their sections and with the required preparation of sites for diamond drilling. The chief surveyor was available to be called in for consultation and matters other than routine were referred to the manager. Those present were:- assistant manager, underground managers, water officer, assistant water officer, the contractor's manager and foreman. A further meeting was held once a month by the manager to review general progress and policy.

Water plan – the position of every intersection of water, whether in a diamond-drill or pilot hole, was plotted, together with the quantity in litres per hour. All diamond-drill holes were shown with their serial numbers and angle of inclination from the horizontal. The scale was 1:1000 and in order to avoid overburdening the plan, the usual legal conventional signs such as the cross-hatching of country development were omitted. The lines of intersection of faults and dykes with the plane of the reef were drawn as soon as a geological correlation had been made of the exposures in development.

Water pumped to the surface – the quantity of water pumped to the surface is the acid test of the cementation process and no consideration of policy is possible without balancing the water pumped and the cost of pumping against the margin of pumping capacity and the mining delays occasioned by cementation work. An accurate record of the water pumped is therefore vital and this was attained by the installation of weirs with automatic recorders both underground and at the surface.

A comprehensive management control system for the mine must include the surface drainage system in the mine area. Neglecting the surface drainage system may have serious consequences as the following example shows.

In the area of the gold fields (Witwatersrand and the Orange Free State) precipitation typically appears as thunderstorms during summer. These down pours will wash down large tonnages of mine sand, slimes and fine coal. Some of these sand and slimes dumps may be from defunct mines. The erosion of slimes dams and the silting up of streams over the years causes a reduction in the flow rate of these streams, changes the river beds and the vegetation along the rivers and hence the run-off coefficients. In addition, old mine workings such as outcrop trenches, inclined defunct shafts offer ample opportunities for ingress of water into mine workings resulting in possible flooding of mines. The severity of such flooding was amply illustrated by the flooding of the South African and Exploration Co. Ltd in 1972 (SA Lands), (Jarvis 1972)

After torrential rains fell on 20 January 1992, 250 to 350 Megalitre entered the Vlakfontein Mine situated in the East Rand Basin and about 3500 Megalitre entered into SA Lands.

The surface floodwater poured into abandoned outcrop workings and flowed through many defunct mines in due course reaching the underground workings of SA Lands, Vlakfontein Gold Mines and Sub Nigel. The resulting damage was significant.

Therefore, the management of surface drainage systems is of vital importance in mining areas and is an integral part of the water control system of any mine.

## 1956 – THE WATER ACT NO 54 (AMENDED BY ACT NO 56 OF 1961)

The OFS gold fields were discovered during the thirties in the previous century, however, development slowed down during WWII. After WWII the development gained momentum again. During the fifties in some years, more than 30 shafts were being sunk at any one time.

Up to this time about 75% of all water used in South Africa was for agricultural purposes. However, the increasing use of water for mining and other industrial purposes resulted in constantly increasing uncontrolled use of water and the disposal of increasing quantities of polluted effluent. If allowed to continue uncontrolled, this situation would eventually have resulted in serious consequences for human and animal consumption as well as for agricultural production. The Irrigation and Conservation of Water Act, No. 8 of 1912 simply did not cater for this type of development and was inadequate for controlling the situation as it presented itself during the mid 20th century.

The realization of the situation and the mounting concerns on the water problem led to the promulgation of the Water Act No 54 of 1956.

The Act is a comprehensive document of legislation and was promulgated for the purpose of:

1. conserving the water resources of the country.
2. promoting the maximum beneficial use of the water resources AND
3. safeguarding public and private water supplies against avoidable pollution.

The concerns that led to the promulgation of the act also prompted an investigation into the main sources of pollution for identification purposes. It soon became apparent that pollution had reached alarming proportions and that the mining industry was the main culprit.

This realization and the fact that little was known about the act in the mining sector at the time, necessitated the formulation of regulations for which provisions had been made in the Act.

On the 20th February 1976, the Regulations made in terms of the Water Act No. 54 of 1956 were gazetted. The regulations defined responsibility, effluent control, environmental siting and stability of dumps and dams, water pollution, control plans, offences and penalties and water pollution control measures.

Towards the end of the 20th century, environmental awareness reached new heights. This is reflected in additional legislation. For example in terms of the new Minerals Act, No 50 of 1991, all South African mines have the responsibility to manage the effects of mining on the environment. In order to enforce this responsibility, the submission and approval of an environmental management programme (EMP) is required.

One of the most important long-term risks of contamination is acid mine drainage (AMD). The EMP concentrated in detail on the AMD potential and the long-term impact on ground water quality.

Also mine closure has been included in this environmental approach. Already in 1978, South Africa had 3000 defunct mines (Thomas, 1978). The water control and environmental aspects of this massive legacy of the mining industry create many problems. The new mining act endeavours to control this problem and place the responsibility where it belongs.

## 1960 – DEWATERING OF REGIONAL COMPARTMENTS

Water control in deep mines is naturally more hazardous mainly for two reasons being the high pressures at which water may occur and the high temperatures. Associated with these problems is the high cost of pumping water to surface.

Therefore, dewatering of entire regional compartments is an interesting option and has been successful particularly in the Far West Rand, which covers an area of approximately 1500 square kilometers to the south west of Johannesburg. Igneous intrusions in the form of dykes subdivide the area into reasonably watertight compartments, see Fig 2.1. (Kleywegt 1982, Heinz 1991)

In order to facilitate the dewatering of compartments and find equitable solutions for all parties concerned and to solve problems related to dewatering, legislation was introduced in 1956. The Water Act No. 54 of 1956 introduced the basic principle that the mine, which caused the problems such as sinkholes by dewatering, is to compensate the damaged parties.

Enormous strides towards the understanding of the effects of dewatering in dolomite have been made:

a) Many thousand boreholes have been drilled to considerable depths in the area;
b) Intensive gravity surveys have been made;
c) Data from shaft sinking operations and other mining activity have been collated and evaluated.

Risk assessments in these dolomites before dewatering have been made based on aerial surveys, geophysical data, borehole data and water table monitoring.

Preventive measures are now introduced where dewatering is to commence.

Research has indicated that the following factors affect subsurface stability, (see Fig 2.2):

- The position of the original water table.
- The presence of weak manganiferous residuum (Wad).
- The character of any overlying material.
- Steeply sloping bedrock contours.
- Bedrock pinnacles.
- Susceptibility to erosion of the ground profile.
- The ponding of surface water.

The last permission to dewater an entire compartment was granted in 1986 to dewater the Gemsbokfontein compartment.

For the first time in South Africa, significant preventive measures were taken before dewatering commenced. Indeed, the permission for dewatering was granted on the basis that the high-risk areas be treated by grouting prior to commencement of dewatering.

The Gemsbokfontein compartment is not densely populated, however, an important traffic route crosses the compartment. In order to protect this highway against possible sinkhole development a grouting technique was developed to stabilize the areas classified as high risk.

An extensive grouting programme was executed, where 44,000 m³ of grout was placed over 2.7 km of highway. Grout holes up to 30m were drilled. Since the start of dewatering no major subsidences or sinkholes have developed in the high risk areas which have been grouted. The grouting was regarded as successful.

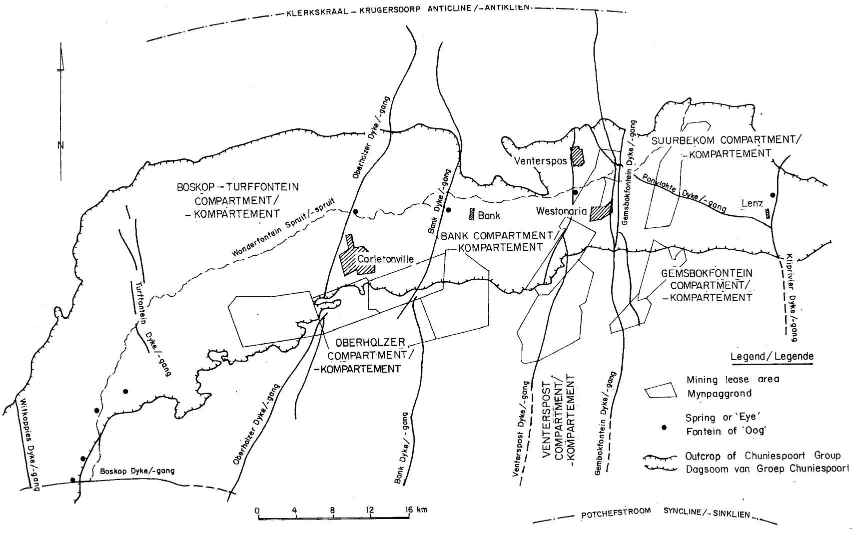

*Fig 2.1 Far West Rand Dolomitic Area. Bank and Venterspost Compartments are being dewatered (Kleywegt, 1982).*

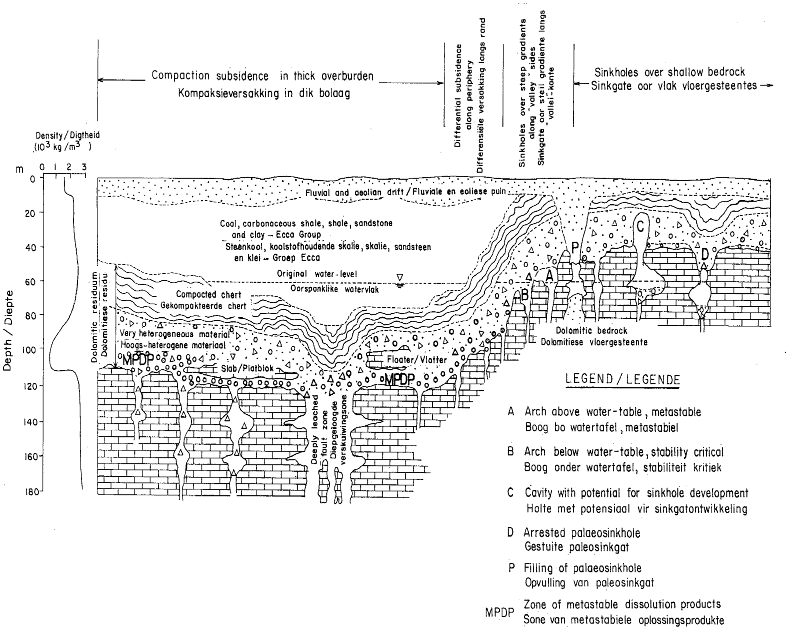

*Fig 2.2 Semi-diagrammatic section through the Far West Rand dolomite and overburden (Kleywegt, 1982).*

## 1991 THE MINERALS ACT, NO. 50

The Minerals Act, No. 50 of 1991 regulates inter alia the prospecting and optimal exploitation of minerals but most importantly the rehabilitation of the surface of land during and after prospecting and mining operations. The Act requires the holder of a prospecting permit or mining authorization to submit an environmental management programme (EMP).

The EMP is based on the principles of Integrated Environmental Management laid down in the National Environmental Management Act No 107 of 1998.

Section 38 of the Minerals Act, 1991, requires the holder of the prospecting permit or mining authorization to rehabilitate the surface of land concerned. Furthermore, Section 41 recognizes the fact that the management of the environment may change during prospecting or mining operations. It, therefore, requires ongoing assessment to limit any damage to the environment. Arguably the highest risk of long term contamination resulting from mining action is acid mine drainage (AMD). Acid mine drainage is related to water control, surface and underground, therefore, all aspects related to water pollution, control etc form a significant part of the EMP document.

It is also interesting to note that integration with other environmental control systems such as ISO14000 is encouraged and mines applying ISO14000 have greatly reduced reporting responsibilities in terms of the Act.

The impact of mining on the surface water and ground water regimes as well as the management of this vital resource plays a central role in the Mining Act, the Environmental Act and the ISO14000.

## CONCLUSION

The contributions to water control and mining grouting of the early mining grouting engineers in South Africa and elsewhere at the beginning of the previous century, have been greatly underestimated.

An important factor in the development of high pressure mining grouting in deep mines was the invention of the high pressure cementation pump by Albert Francois over 100 years ago.

During the previous century many innovations and developments originating in South African mines have been milestones in the mining industry and have contributed significantly to the safety and productivity within the industry as a whole.

This paper has endeavoured to present these important contributions in the mining industry as a small tribute to the early pioneers and mining engineers of the previous century.

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