Hydrodynamic Environments GENERAL REPORT

By G. L. BOYD

TECHNICAL SERVICES GROUP

CSR COAL DIVISION

A B S T R A C T

Nine of the ten accepted papers for Session 1, "Hydrodynamic Environments" were submitted for review. All papers relate to hydrogeological environments associated with underground excavations; eight deal with underground mining operations; six based on deep coal mines.

Two themes emerge from authors' treatment of the session title:

1. Factors and methods of assessing flow through stress dependent factures, and

2. The importance of scale in the accurate prediction of adverse mine-water interaction.

These themes are well described and developed using a number of hydrogeological settings, and focus on the need to better integrate our understanding with flow hydraulics and ground deformation about underground excavations.

INTRODUCTION

The international membership that is a feature of IMWA is truly evident in the submissions for Technical Session 1 "Hydrodynamic Environments" from Australia, India, China (3), Nigeria, Spain, Portugal, Zambia, West Germany and the United Kingdom. Eight of the nine papers submitted for review address the session theme through the interaction between underground excavations and groundwater. Six of the papers deal explicity with groundwater and underground coal mining operations. A departure from mine-water interaction is given in one paper concerned with hydrodynamic environment and groundwater contamination.

"Hydrodynamic Environments" has obviously been a successful title for this session, since nearly all papers reviewed have emphasised the complex interplay between natural (geological) ground features and (excavation) induced structures affecting groundwater flow. Authors have described this interplay over a variety of scales, from regional to district to a single identifiable geological feature. Together with the strong reliance on case history and observational data, much insight has been provided by authors into variations in scale of hydrological factors important to excavation design and inflow control. For this, the authors are to be congratulated.

REVIEW OF PAPERS

The central theme that emerges from most papers reviewed is the role of stress dependent fractures in groundwater flow toward underground excavations. In the papers by Onyemaobi, Klenowski and Phillips, Zhongling, Pei and Baijing et. al., the setting is underground coal extraction in mechanised mines, where the mining of the tabular orebody over a large areal extent results in volume distortion and fracture propogation through the undermined cover. Papers by Sweeney, and Carvalho and Rubio refer to this theme in the context of large underground metal mines.

Onyemoabi provides a digression into the frustration and futility of a poorly serviced mine dewatering programme, but the mine setting is a familiar one to the Australian scene; mining beneath back escarpment water resources, as investigated in great detail for water supply dams overlying coal mine workings in the Waranoora catchment area adjacent to the Illawarra Escarpment, eastern New South Wales. The author refers to inflows from overlying fractured ground recharged by prominent rivers, and to seepage from beneath stress deformed barrier pillars and adjacent workings. In the vicinity of major escarpments, described as up to 150 m in height, mining direction and layout relative to the back-escarpment stress field are fundamental to minimising complex interaction between mine openings and ground stresses. The reader is left pondering whether examination of mine layout and method of operation was ever considered in the context of the local geotechnical and hydrogeological setting of the mine, and some discussion along these lines would have been useful.

Awareness of these factors is well described by Klenowski and Phillips through investigation of inflow mitigation based on field experience and follow up evaluation. The difficulties with thick, water bearing sills over coal measure strata parallels early difficulties with relatively shallow underground operations in the Veneering Coalfield in South Africa. However, caving characteristics as described at German Creek Mine differ significantly, in that fracture flow due to excess tensile strain in dolerate sills some 70 m above the workings occurred after only 40 m retreat by the longwall during initial panel extraction. This compares with 160-210 m of retreat required in the South African Mines to develop sufficient strain to fracture the sills, which occurred 15-30 m above workings. The German Creek experience suggests early subsidence along pre-existing geological structures, and if so, carry implications for orientation of mine workings. Of additional interest is the observation that hydraulic parameters obtained from pump out test results allowed more accurate prediction of mine inflow rates using simple Darcy's Law. It would interest other investigations if the authors would elaborate on possible reasons why permeability derived from pump out tests is a better predictor of aquifer drainage.

The papers by Zhongling and Baijing et. al. continue the theme of stress dependent fracture flow but with an emerging sub-theme: the importance of scale of structures (or zone) initiating groundwater inflow. Both papers describe the reduction of considerable field data into empirical laws of association between observed inflow characteristics and mappable ground properties. Basic relationships so derived have been progressively re-analysed and re-stated in terms of quasi-rock mechanics principles. The common factors of interest linking these papers is the underlying need, in China, to solve the severity of pressures and flow quantities by control measures implemented at the mine face rather than ahead of mining. This is explained as due to limited infrastructure, particularly availability of power in most coal mining provinces of China that would otherwise permit sub-surface and surface pumping operations ahead of mining. Thus, emphasis has been placed at defining the hydrodynamic environment at the scale of the mine openings, from which Zhongling identifies different types of inflow structures ranked in terms of frequency of occurrence and level of discharge. Discharge rates are tabulated with discharge pressures to define categories of inflow severity, both at the point of inflow and within the radius of effect on the overlying ground surface. Numerical relationships establish the attenuation of discharge with time, which appears to be independent of structure type. It is probable that the decline (attenuation) coefficient <   > is related to structure type, and some discussion by the author of characteristics of structures affecting time related flow may have added to our knowledge on fracture flow.

Baijing et. al. view their considerable field data in terms of yield characteristics of layered strata subject to high horizontal stresses and penetration of the yield zone into adjacent aquifers. Repeating the approach described by Zhongling, simple empirical laws based on field observation and measurement are progressively transferred into relationships better describing rock mass deformation that ultimately taps water bearing zones. The approach clearly follows the concept of deep mine protective zones recognised by Kessurue in East European Coalfields, where yield about an underground opening is defined in three zones; the immediate zone of yield and rock mass deformation; a second, non-deformed zone (protective barrier) which behaves as an aquiclude, to the third zone representing the confined aquifer. Rock mechanics principles are introduced into groundwater control schemes by maximising the thickness of the protective barrier. The value of this contribution is extended by the short discussion into various mining methods and practices to best control ground deformation and minimise the risk and scale of in-rushes. A full discussion of the effect of mining method on in-rush control would warrant a separate technical session.

The papers by Cripps et. al. and Carvalho and Rubio carries on the theme of scale of hydrogeological investigations and observations for the accurate prediction of excavation inflows and seepage pressures. Describing the planning and construction of a large diameter, lined tunnel at shallow depth through a variety of topographical, geological and (mining) disturbed route intervals, Cripps et. al. have conveyed quite clearly the importance of regional versus local scale features important to groundwater control. Whereas regional hydrogeological models can be rapidly developed from data collected by surface investigation and numerical modelling, the authors correctly caution against ignoring structures at the local scale, i.e. the scale of the proposed excavation. A useful discussion on fracture characteristics affecting fluid flow backed by considerable technical data on hydraulic properties of structures typically associated with soils, sedimentary rocks and crystalline rocks renders this paper a useful reference for investigators concerned with fracture flow.

Carvalho and Rubio describe hydrological methods employed to differentiate amongst complex structural and lithostratigraphic factors affecting inflows into deep, massive sulphide mines in Portgual. The studies successfully identified structure sets that linked major rock mass units, and characterised flow capabilities of each set. This paper provides a useful description of approaches adopted in both the hydrogeological and hydrological phases of a large mine groundwater study.

To complete the cycle of scale as a common theme of this session, Pei and Sweeney return us to the importance of regional scale hydrogeological studies in the identification of controls groundwater migration through rock masses. Based on comparative statistics of mine pumping records and rainfall data for two principle mining districts in the Zambian Copper Belt, Sweeney shows how tectonic setting emerges as the major controller of the local hydrodynamic environment affecting mine water inflow and pumping requirements. Shallow workings about the nose of a broad open anticline in the Kabwe and Nampundwe orebodies with deep surface weathering of carbonate roof rocks, with inflow of meteoric waters the result. The high degree of statistical correlation between surface rainfall and mine pumping rates established a close hydraulic connection between surface drainage and the mine through the effects of deep weathering, and in places, sulphide leaching of host formations. In contrast, orebodies of the Konkola and Nkara type associate with more tightly folded formations resulting in steep dips and deeper mining operations. In this setting, mine pump rates are not correlatable with raintall, but are controlled by a more complex interaction between structure, orebody geometry and lithostratigraphy. By deduction, the author argues the importance of rock mass structures over all other influences in the propogation of mining induced fractures through overlying, stacked aquifers. In a similar vein, Pei uses a very large set of observational data to classify karstic aquifers in mineral provinces of China into three types; solution fissure aquifer, karst cave aquifer and karst stream aquifer. Groundwater migration through each of these aquifer types with respect to established flow laws are described, plus the importance of topographic setting of deep mine development with respect to the weathering base, and precipitation level. It is obvious the scale of mine water inflow associated with karstic geology is enormous, and the reader is left wondering what exploration and investigation methods are used to map macro structural features of the karst geology as part of mine development planning.

The paper by Fricke provides interesting commentary on natural hydrodynamic environment as a controller of water quality for human consumption. Using the heavy industrialised area of the Ruhr as a site of long term industrial contamination of groundwater, the author describes a combination of shielding by impermeable caprock and chemical filtering in underlying intermediate formations to describe the natural capacity of the system hydrology to form commercial deposits of pure mineral water at depth. The resilience of hydrological environments in preserving 'natural' groundwater qualities is well established from the statistics and scale of groundwater subject to contamination in the Ruhr Valley over the past 150 years.

SUMMARY

The nine papers reviewed mostly related the session title to case histories based on underground mining. Six of the nine papers dealt with underground coal mining. The scale of the problem defined were all large, with very high inflows up to 376 Ml/a, and instances of flooding and abandonment of whole mine areas, including equipment.

It is perhaps measure of advances being made in developing relational laws between groundwater hydraulics and the principles of rock mechanics that sees mention of mining method as a prominent factor in assessing severity and control of mine water inflows. It is to be hoped that research in this area continues based on the substantial reference to case histories that is a feature of papers submitted for this session.

In the long term, perhaps a more complete description of hydrodynamic environments affecting mine planning and development will result from a greater integration of the theories of seepage flow and strata control based on a two phase system aproach, as successfully developed and applied in soil mechanics.