Book reviews

● *Darwin Conference, 1984.* Parkville (Australia), The Australasian Institute of Mining and Metallurgy, 1984. $A15,00 (surface mail).

Reviewer: H.A. Simonsen

The theme of the Darwin Conference was 'The Mineral Potential of Northern Australia and Changing Concepts of Development', and the fifty papers that were presented commemorate the 'coming of age' of the Northern Territory of Australia.

Innovation and Change

The opening paper, by Des Rose *et al.*, deals with the problems associated with the provision of labour for the Argyle Diamond Mines, which are located in a remote area of Western Australia. A.D.M. personnel spent three years evaluating residential options before deciding to commute the workforce from Perth in chartered jet aircraft.

Queensland Mines Ltd, who operate a small uranium plant at Nabarlek, reached a similar decision in housing employees and their families in Darwin and flying the employees to the mine for work rosters. Although the scheme has proved to be most satisfactory, employees with young families find that the system places an additional strain and responsibility on their wives.

Mining and the Environment

In papers related to environmental protection, Leggate points out that a mine such as Ranger can pay real attention to environmental protection and its surveillance, and Bath details the changes that have taken place within the mining department to cope with unforeseen environmental developments.

Van Groenou, in a paper on mining and conservation strategies, suggests that rehabilitation and decommissioning should be made an integral part of the planning and production stages of a mine, and that an optimum profitability rather than a maximum production strategy should be followed to ensure the depletion of reserves.

Economic Considerations

In a description of the McArthur River project, Buchanan shows that a significant lead–zinc deposit can be rendered uneconomic by its remote location, inadequate processing technology, and the need for a large market penetration so that processing can be carried out on an adequate scale. However, a hydrometallurgical research laboratory is being established in Brisbane to develop techniques for the processing of McArthur ore.

In a paper on the financing of small mining projects, Legg suggests that an early involvement in a project by specialists in banks would improve the project's chances of being identified as a candidate for debt funding.

The financial attractions of Australian uranium deposits are suggested by Coleman in a paper in which he reports that uranium exploration in Australia has had a real internal rate of return (IRR) of 22 per cent since 1949. However, only 39 per cent of the deposits expected to be discovered in future will have a real IRR of more than 10 per cent, and exploration will be largely directed at the discovery of very large deposits, of which probably the top 17 per cent would yield an IRR of 15 per cent or more.

Aboriginal Land Rights

The problems of establishing and operating uranium mines in present-day Australia are detailed in a number of papers. Reynolds relates the progress of Koongoara over a 14-year period, and emphasizes the adverse economics caused by delayed production in an environment of declining commodity prices and escalating development costs. Ellis describes the role and policies of the Aboriginal Sacred Sites Protection Authority, and provides some comment on the application of these policies to development proposals in the Northern Territory. Lauer and Lewis suggest that many of the existing difficulties in the exploration of Aboriginal land could be overcome by the adoption of a positive administrative approach on the part of Land Councils.

Diamonds

Although diamonds were first reported in Australia in 1851, near Bathurst in New South Wales, exploration for primary sources in Western Australia have been carried out only since 1968. The discovery of the Argyle kimberlite has emphasized the potential of this commodity on the Australian minerals scene. The diamond-exploration techniques used at present in Australia are reviewed by Hickling. The need for large bulk samples for testing has led to the development of transportable bulk-testing plants, which are described in a paper by Miller.

Indicator minerals are considered to be of value in the exploration for diamond deposits, but minerals similar to the indicator minerals are widespread in the Cainozoic alkali basalts of northern Queensland. In a paper dealing with this problem, Jones points out that kimberlitic indicator minerals are richer in chromium and magnesium and poorer in aluminium than their basaltic counterparts, possibly owing to the fact that they come from greater depths.

In a description of the discovery and geology of the Argyle diamond deposits, Atkinson *et al.* point out that the mining of the AKI deposit will result in the annual production of 25 million carats of diamonds, which will make Western Australia the largest producer of natural diamonds (by weight) in the world. A metallurgical evaluation of the AKI orebody has been made on a 40 t/h pilot plant, which is described in a paper by Plaisted and Mack.

Uranium Treatment

The use of Caro's acid as an alternative oxidant in the recovery of uranium at Queensland Mines Ltd is described in a paper by Fulton. It is anticipated that the capital costs involved in the installation of a Caro's acid plant will be recovered well within the operating life of the mines.

The Narbarlek uranium-treatment plant, designed to treat the 600 kt of ore that are mined and stockpiled in a single four-month period, is described in a paper by Lucas *et al.*

In a paper on some design and operating aspects of the Ranger uranium-treatment plant, Baily emphasizes the role played by environmental considerations. Because of the conservative approach adopted in the selection of equipment and engineering standards, the plant was able to achieve design performance in less than three months from the date of commissioning.

The use of a sub-aerial technique for the disposal of Olympic Dam tailings has been studied in the laboratory. This technique permits the maximum removal of water from tailings deposits during operations, an important point in arid climates such as that of Roxby Downs. Seepage is minimized, and rapid access can be provided for rehabilitation.

Uranium Geology

In an examination of the relationship between mineralization and depositional environment in early Proterozoic metasediments of the Pine Creek Geosyncline, Needham and Stuart-Smith suggest that most of the significant mineralization is strata-bound. However, within this broad stratigraphic control, other parameters such as local lithological variations and structures can be seen to influence the distribution of the mineralization. Thus, dolomitic sediments host many of the lead–zinc–silver deposits, whereas many of the uranium–gold deposits of the South Alligator Valley have strong structural controls.

The geology and mineral potential of the Ranger project area are examined by Danielson, who points out that the uranium is associated strongly with chlorite, of which there are at least five textural varieties.

The Westmoreland uranium deposits occur in the upper member of the Westmoreland Conglomerate. Hochman and Ypma suggest that this uranium was remobilized in a conventional cell system, possibly triggered by the intrusion of dolerite dykes. Pitchblende was then precipitated where suitable reducing conditions existed.

The veinlike uranium deposits in the Rum Jungle area are described by Pagel *et al.* A number of Rum Jungle type deposits will have to be located to comprise a collectively economically viable target. It is believed that such a zone may exist south of the Waterhouse Complex, where primary uranium mineralization has been discovered at three localities.

Base Metals

The necessity to extract copper ore from greater depths at Mount Isa Mines has necessitated a review of existing methods and equipment in an attempt to contain costs and improve working conditions. Dixon describes the employment of the Robbins MM120 Mobile Miner and the use of a surface refrigeration plant to reticulate drilled water underground.

The commissioning and operation of an 800 t/h heavy-medium cyclone plant at Mount Isa Mines is described by Fiedler *et al.* Although the consumption rate of medium is low, severe wear has been a problem and a search has been instituted for better materials to be used in high-wear situations.

Henley *et al.* describe the application of process control to the lead and copper smelters of Mount Isa Mines. A significant increase in production rates is claimed as a result, with a concommitant improvement in plant hygiene.

A process has been developed by Peko Mines for the separation of copper and bismuth. A paper by Colbert describes this as fluid-bed sulphation roasting of bismuth concentrates, which converts the copper minerals to a form in which they are soluble in water or weak acid. Copper recoveries of 89 per cent are achieved.

Geological evidence has suggested that the bismuth content of Warrego copper ore would increase to a point at which copper concentrates would be produced with unacceptable bismuth contents. Bench and pilot-scale tests showed that sodium or zinc cyanide could be employed to ensure the removal of a flotation concentrate containing 12 to 17 per cent bismuth, thus reducing the bismuth in the copper concentrate to between 0,4 and 0,8 per cent.

The Soldiers Cap group and Kuridala Formation, in north-western Queensland, contain at least eight significant deposits of stratiform lead–zinc (–copper) mineralization included within an iron formation. Vaughan and Stanton propose that the Pegmont-deposit model for the deposition of base-metal sulphides within restricted basins of iron-rich chemical sediment should be employed in further exploration in the mineralized belt, particularly since the superficial deposits covering the Soldiers Cap Group and Kuridala Formation make exploration somewhat difficult.

The geology and mineralization of the Jervois Range is discussed in a paper by De Boorder *et al.* Base-metal mineralization in this area includes chalcopyrite–pyrite lodes in magnetite–chlorite–garnet rocks, argentiferous galena and sphalerite in manganese-rich calc–silicates, and scheelite in marbles and calc–silicates.

Stratabound silver–lead and copper–zinc deposits located in the eastern part of the Arunta block are discussed by Mackie. The Green Parrot deposit contains galena, sphalerite, and bornite in broadly zoned mineralization. The Reward deposit consists of galena, chalcopyrite, sphalerite, and pyrite, and is contained within garnetiferous sericite–quartz schist. This deposit contains 32 kt of ore with 18 per cent lead and 250 p.p.m. of silver. The Green Parrot deposit contains 300 kt of ore with a lead concentration of 8 per cent and a silver level of 160 p.p.m.

Hydrothermal minerals are the dominant type of deposit in the Cullen Mineral Field and, as such, are important sources of tin, tungsten, gold, silver–lead, zinc, and copper. Stuart-Smith and Needham suggest that the distribution of vein-type deposits within a contact aureole defines a district-scale metal zonation, uranium being closest to granitoid, through tungsten, copper, tin, and silver–lead to gold with increasing distance from granitoid contacts. This zonation probably reflects decreasing temperatures within the contact aureole during granitoid emplacement and, at the time of generation, a variety of metal-bearing fluids.

Ypma, in a paper on the lead–zinc mineralization at Box Hole Bore, disclaims the common notion that such mineralization represents a variant of the Mississippi Valley type. Instead, he proposes a new model that gives greater importance to the confining faults. The lead and zinc trace-element content of the carbonate, even out-side the mineralized area, suggests that the mineralization fluids derived their metal content from a local source, possibly aided by evaporitic concentrations of the tidal to supratidal sequences.

The Woodcutters deposit, 65 km south-southeast of Darwin, consists of a series of veins of pyrite, sphalerite, and galena with some silver, cadmium, antimony, and arsenic minerals. In his paper on the geology of this deposit and its environment, Taube proposes that the Woodcutters mineralization represents a late-stage manifestation of strata-bound or stratiform mineralization that occurs at the same contact at depth beneath the known deposits.

Gold Mineralization

Many mid-Proterozoic fluvial sediments around the world are considered to contain large-tonnage low-grade gold deposits. Although a significant area of the Northern Territory of Australia is covered by such sediments, there has been little exploration for gold. Ahmad *et al.* suggest that the sedimentary environment of the mid-Proterozoic Westmoreland Conglomerate is similar to other early and mid-Proterozoic examples that contain economic palaeoplacer deposits. Limited heavy-mineral sampling of this Conglomerate has indicated the presence of a cassiterite–wolframite–gold and heavy-mineral suite in the sediments. It is suggested that disconformities provide the most likely sites for large-tonnage palaeoplacer concentrations in the formation.

Gold in New Guinea was first referred to by the Portuguese in 1525. Following the lifting of a three-year moratorium on new exploration areas in 1982, gold exporation has increased dramatically. Bulk low-grade gold has been discovered on Lihir Island, north of Bougainville, and a number of other promising areas are being drilled.

In his paper on the status of gold exploration in Papua, New Guinea, Loudon points out that the production of gold is likely to expand from 600 000 ounces in 1984 to 1,3 million ounces in 1985 with the opening of OK Tedi. Further developments could increase the output to more than 2 million ounces by 1990.

Exploration for gold at Pine Creek, Tennant Creek, and Halls Creek by use of a fluid-inclusion decrepitation technique is described in a paper by Burlinson. The decrepitation technique is a rapid means of measuring abundances, temperatures and, to some extent, the fluid compositions of fluid inclusions in transparent and opaque minerals. The method involves the heating of a small sample (1 g) of crushed, sized grains up to as high as 800°C. The fluid inclusions within the grains develop sufficient internal pressure to burst physically, the temperature at which bursting occurs being dependent on the type of fluid and the prevailing temperature at the time the inclusion was entrapped.

The early Proterozoic Pine Creek Geosyncline hosts a large number of gold showings. 'Mineralisation types include stratiform, synsedimentary deposits within iron formation and carbonaceous mudstone; disseminations in granophyric intrusives; and quartz vein related concentrations in the form of shear fillings, saddle reefs and stockworks'. In their paper on gold minerlization controls in the Geosyncline, Nicholson and Eupene suggest that stratiform gold deposits formed preferentially near penecontemporaneous faults during periods of basin instability. Later intrusive basic magmas would have assimilated some stratiform mineralization, with subsequent redeposition within differentiated phases.

The Granites Goldfield is located 550 km northwest of Alice Springs. In their description of the geology and mineralization of these deposits, Ireland and Mayer categorize them as banded iron formations (bif), but with some important differences from classical bif orebodies.

Gold mineralization at the Enterprise Mine, located 230 km south of Darwin, occurs within folded and metamorphosed sediments of the Lower Proterozoic Burrell Creek Formation adjacent to the Cullen Granite. In their discussion of the geology of the Enterprise Mine, Dann and Delaney record that five persistent sets of veining have been recognized and are interpreted as having developed successively during progressive phases of deformation.

Gold Mining

The Mount Bonnie gold–silver project is based on the gossan of a stratiform and stratabound polymetallic sulphide deposit. The gossan, which contains some 100 kt of ore grading 8 g/t of gold and 230 g/t of silver is mined in an open cut, the ore being transported to a stockpile 1 km away. The extraction process, as described by Rich, Cheong, and Eupene in their paper on the project, includes the precipitation of silver sulphide with sodium sulphide and the adsorption of gold onto carbon, from which it is removed by methanol desorption and then recovered by electrowinning.

Finally, the mining and beneficiation of a low-grade gold orebody in the Wau valley of Papua, New Guinea, is described in a paper by Eltham. Because of the limited experience of the workforce, some care was taken in the design of the extraction plant, which uses simple but technically efficient equipment. In spite of the fine size of the gold and the use of jigs, spirals, shaking tables, and amalgam barrels, a recovery of 63 per cent is achieved from a head grade of 2 g/t.

● *Rockbursts and seismicity in mines,* edited by N.C. Gay and E.H. Wainwright. Johannesburg, The South African Institute of Mining and Metallurgy, *Symposium Series* no. 6, 1984. 363 pp. R75,00 excl. GST, £50, US$65.

Reviewer: E.T. Brown

Reviewing the proceedings of conferences or symposia is an uncertain and unrewarding task, and one that is usually best avoided. However, because of the interest and coherence of its subject matter and its pleasing and professional presentation, the present volume provides a welcome exception to the general rule.

The difficulties caused by mining-induced seismicity and the associated rockburst hazard in the deep-level gold mines of South Africa are well known. By a concerted industry-sponsored research effort over a period of about 30 years, major advances have been made in understanding the nature of rockbursts and in devising mining strategies to ameliorate their devastating effects. Nevertheless, the problem is still far from being resolved, and fatalities from rockbursts and rock falls remain unacceptably high.

Against this background, the South African National Group on Rock Mechanics, in collaboration with The South African Institute of Mining and Metallurgy and with the financial support of the Chamber of Mines of South Africa, decided in 1981 to organize the First International Symposium on Seismicity in Mines. The Symposium, which brought together mining engineers, rock-mechanics specialists, and seismologists from a number of countries, was held in Johannesburg in September 1982. The long-awaited proceedings have now been published.

The 36 published papers are presented in six groups dealing with mechanisms of seismic events; monitoring of seismic events; geology, mining, and seismicity; rockburst damage; strategy in mine design; and precursive phenomena. There are, in addition, seven short papers or summaries of papers that deal mainly with monitoring instruments and systems and that were presented in the poster session. The Symposium was truly international in that papers were presented by authors from nine different countries (Australia, Canada, France, West Germany, Poland, South Africa, Sweden, U.K., and U.S.A.). As might be expected, the home team provided a high proportion of the contributions (17 papers), but the U.S.A. was also well represented (9 papers).

Although the papers were prepared by many different authors and concerned a wide range of mining activities, several general themes and conclusions emerge from them. Perhaps because I am an engineer, the most significant feature of the volume for me is its demonstration of the close relationships that now exist between studies of natural and mining-induced seismicity. Several authors, including Hanks and McGarr, argue that there are no systematic physical differences between mining-induced tremors and natural or tectonically-driven earthquakes. It is shown in a number of papers, including those by Bath, Gibowicz, Hanks, McGarr, and Spottiswoode, that seismic-source mechanism studies based on analyses of bodywave spectra can add considerably to our knowledge and understanding of mining-induced seismic events. These analyses add to the information customarily obtained from first-motion analyses, and are especially useful when a seismic network provides insufficient data for P-wave first-motion analysis. McGarr argues that various measures of the seismic-source mechanism of mine tremors, such as magnitude, seismic moment, stress drop, apparent stress, and seismic efficiency, can be used directly in an assessment of the underground hazard associated with the strong ground motion of large seismic events. As others have done, he questions the use of the energy-release rate as a hazard indicator. Further developments in this debate will be keenly awaited.

The volume contains evidence of significant advances and achievements in a number of areas. The design of suitable and reliable underground seismic monitoring networks is now well developed and widely practised. In a most useful paper, Green discusses design and selection criteria for transducers and associated signal-conditioning equipment. However, as Blake and Leighton each point out, these monitoring systems do not yet provide the predictive capability that some would seek from them. Several papers give accounts of the measures that have been taken to ameliorate the damaging effects of rockbursts, which are well illustrated by Ortlepp. Blake reports the effective use of destressing by blasting in advance of mining in the Coeur d'Alene mining district, U.S.A. Wagner presents a masterly analysis of support-system requirements for rockburst conditions, while several authors report reductions in seismicity associated with the use of stabilizing pillars in longwall mining operations. Finally, but not least significantly, a number of papers highlight the control exerted on mining-induced seismicity by geological structural features and by *in situ* stresses in a wide range of mining environments.

This well-presented volume is a credit to the Symposium organizers, the editors, the contributors, and the publishers. It provides the most comprehensive and up-to-date statement available on its subject, and points the way to some of the further advances that will be required before it can be claimed that the scientific and engineering problems associated with mining-induced seismicity have been resolved. While it may not provide the most suitable introduction to the subject for beginners, this volume should be included in any library that aims to provide an up-to-date coverage of mining engineering, rock mechanics, and seismology.

● *Black sands,* by Ian Morley. St Lucia (Australia), University of Queensland Press, 1981.

Reviewer: P.W.J. van Rensburg

This volume, by a long-serving former state mining engineer and chief inspector of mines in Queensland (1940 to 1969), provides a wealth of information, written in the form of a fascinating and very readable story, not only on the facts and figures but also on the people who built up the unique mineral-sands industry on the east coast of Australia. That country is by far the largest producer in the world of rutile and zircon. Although this book was written some time ago, it has only recently come into our hands.

The book begins with an exposition of how these heavy-mineral deposits were formed at many places along the coast stretching northwards from Sydney for over 1000 km, with the major deposits in the Brisbane area. Various sources are proposed for the three principal minerals: zircon and rutile, which are highly resistant to chemical composition, and ilmenite, which is subject to weathering and alteration. The beginning of mining on these beaches followed the discovery in 1870 of a number of black-sand deposits with fair quantities of gold, which were worked over the next twenty-five years, at which stage the heyday of the mining of black sands for their gold content came to an end. Many prospectors and adventurers continued the search for gold for the first thirty years of this century, with negligible results.

The story then turns to the depression years of 1930, when a process for the separation of zircon from the other beach minerals was discovered. A number of small operators developed the industry until the outbreak of war in 1939, which gave new impetus to the growth of the industry. The production of rutile and zircon rose rapidly, and, by the end of the war, the industry was on a firm basis.

Improved processes and mining demand saw a vast increase in output from 1950 to 1970, with larger dredgers, new metallurgical plants, floating concentrators, and new designs of spirals, cores, and electromagnetic and electrostatic separating units. After the boom years, a great deal of rationalization took place in the industry, and the author tells many stories of the people and the companies that were involved. He knew many of these people intimately. He also tells the story of clashes between the industry and the conservationists. Today, many of the more-recent mining areas have been re-established and re-invigorated, showing practically no signs of mining activities there.

Illustrations, maps, diagrams, and photographs contribute to this interesting and readable story. Besides his intimate knowledge of the industry, the author shows himself to be an extremely able and thorough researcher.

From a South African point of view, there is a fairly large interest in the beach-sand industry; that of Consolidated Gold Fields has grown from its first investments in the early 1960s, and there have been subsequent investments by other South African mining houses. The comparatively recent establishment of similar mining operations at Richards Bay adds to the picture. This is a fascinating story, which will be of great interest to many members of the SAIMM.

• *Gravity concentration technology,* by R.O. Burt assisted by Chris Mills. London, Elsevier Science Publishers, 1984. Volume 5 in the series Developments in Mineral Processing.

Reviewer: D.A. Viljoen

The three main sections in this book embrace laboratory techniques and theoretical aspects, unit processes, and plant practice. The contributions of many specialists in the field of gravity concentration are also included. The book fills a void in the technical literature since it is years since a book devoted to gravity concentration has been published in the Western World.

Gravity concentration has dominated mineral processing for 2000 years, and only during the twentieth century has it made way for processes such as flotation, magnetic separation, and leaching. However it is still the dominant processing route in many countries, especially in the beneficiation of coal and iron ore.

Modern developments, including the simplification of previous techniques and the evolution of high-capacity, highly efficient, inexpensive equipment, are described.

The authors draw attention to the savings in energy that would result if more thought were given to the liberation size of valuable minerals. The incorporation of a gravity-concentration step ahead of flotation or leaching often provides economic advantages.

The economic viability of most low-grade placer deposits depends upon techniques that rely upon the differences in the relative densities of the contained minerals. Gravity concentration, it is pointed out, works best for rich ores, for those showing a large liberation size, for placer deposits, for pre-concentration, and for processing in remote areas or where the situation dictates the least expenditure of money. The diverse range of minerals recovered by gravity concentration includes andalusite, zircon, coal, diamonds, mineral sands, metal oxides, industrial minerals, and precious metals.

Section 1 deals with fundamental theoretical aspects. After an introduction to the subject, the book describes the development of flowsheets, associated mineralogical aspects, techniques of heavy-liquid separation, and theories of heavy-medium separation and gravity concentration.

Section 2 provides up-to-date coverage of available unit processes. The simplicity and efficiency of gravity processing have in recent years led to a re-examination of classical gravity-concentration devices, and to the development of modern variants of these and completely new high-capacity low-cost units.

Section 3 deals with plant practice, highlighting the world-wide importance of gravity concentration. All the most modern devices and their appications are described, and flowsheets are provided for a wide variety of minerals.

The book is sequenced logically, and is well-illustrated, as well as containing valuable author and subject indexes.