



Nuclear Techniques in Exploration, Extraction and Processing of Mineral Resources

There is a growing concern throughout the world about the limited known resources of raw materials for industry and energy production. Nuclear techniques and instrumentation are contributing to the exploration of minerals and their efficient extraction and processing. In 1968, the IAEA convened a symposium in Buenos Aires on nuclear techniques and mineral resources. Since then, there has been substantial development in the application of nuclear techniques and the Agency felt it would be timely to review new concepts and developments as applied to oil, gas, coal, metallic and non-metallic minerals.

In the 1977 symposium, the session on oil and gas was devoted to the quantitative determination of hydrocarbon saturation (and associated depth of investigation) by the use of pulsed-neutron-capture, gamma-ray logs and logs based on measurements of gamma rays from inelastic neutron scattering; the combined use of a borehole gravity meter and formation density log to detect hydrocarbons up to tens of metres distant from the borehole; the use of natural gamma-ray spectral logs; new developments in nuclear logging instrumentation and applications; the use of stable isotope measurements in oil exploration; and the present status of radioactive tracer surveys.

Applications of nuclear techniques in the coal industry were reviewed by Clayton (UK). Following early applications, such as density and level gauges, nuclear techniques are now being used in a more sophisticated manner, especially in coal exploration and in coal preparation. Borehole probes incorporating radioisotope sources and radiation detectors now occupy a dominant position in borehole logging and their success has greatly reduced the need for core analysis. In coal preparation plants, on-line ash monitors are now an established application and other on-line measurements are currently being developed.

In the session on mineral exploration and mining, many points of view were put forward on the various techniques to be used for geochemical analysis of soils and stream sediments, borehole logging, sea-bed surveying, sample analysis for mine control, and evaluation of geothermal resources.

Several papers describing new borehole systems and techniques were presented by participants from Australia, Canada, France and Poland. Selective gamma-gamma logging appears to be a useful, though limited, method for grade control in certain massive ore deposits. Logging equipment based on the measurement of neutron capture gamma-rays is now available for routine use, and successful applications to lateritic nickel, porphyry copper, iron and sulphur deposits were reported.

Eight papers dealt with the use of neutron activation analysis (NAA) or energy dispersive X-ray fluorescence (EDXRF) techniques.

NAA techniques are usually employed in fundamental geochemical investigations in which high accuracy, precision and sensitivity are required. A few papers dealt with prospecting for gold and tantalum, and revelation of the genesis of minerals. McGinley (USA) discussed the use of very high output 14 MeV neutron generators for rock and ore sorting.

One paper noted that EDXRF equipment incorporating a small, low-power X-ray tube and a high resolution Si (Li) detector has an analytical capability permitting simultaneous multi-element analysis of soil and stream sediment samples in the field during geochemical surveys.

Radioisotope EDXRF techniques are now accepted for a variety of routine applications in mine control and are being considered seriously for *in situ* analysis of the sea-bed. Wogman (USA) described *in situ* XRF and NAA for marine and terrestrial mineral exploration. Some 20 to 30 elements can be measured with either technique. A towed sea-bed gamma-ray spectrometer for continental shelf surveys was also demonstrated by a participant from the UK.

The development of the earth's geothermal resources is expected to contribute to the utilization of alternative energy sources in the next two decades. Wollenberg (USA) discussed various nuclear techniques which are applicable to phases of geothermal exploration and resource assessment. Potential applications of gamma-ray resonance scattering and new thermoluminescence techniques to mineral exploration were reported by participants from Australia and the USA.

The most important capability of nuclear techniques in mineral processing is for continuous on-stream or on-line measurement, particularly for density, mass flow and element concentration. In the session on mineral processing, Watt (Australia) presented a review of nuclear techniques for on-line measurement in the control of mineral processing. Donhoffer (Austria) demonstrated a low-cost XRF system for on-stream analysis of slurries that was developed under an IAEA Research Contract. The utilization of radioactive tracers in the investigation of the copper ore dressing process was discussed by a participant from Poland. Two papers by participants from Denmark and the Federal Republic of Germany dealt, respectively, with a nucleonic weighing system and with the determination of conveyor flow parameters.