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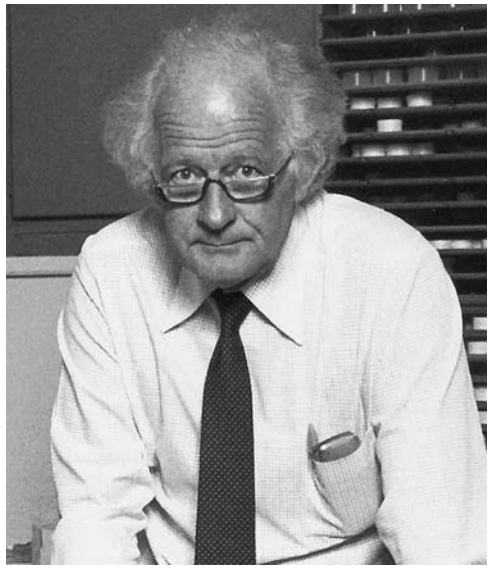
Dr KEITH NORRISH (1924–2017)



Dr Keith Norrish passed away peacefully in Adelaide on 13th September, 2017 aged 93. His scientific work represents a major contribution to world soil science, agriculture and the mining and minerals industries; he specialized in soil science, clay mineralogy, crystallography and X-ray spectroscopy. Keith was a long-time Chief Research Scientist in CSIRO and a friend and mentor to CSIRO staff for over 60 years (he retired in 1989 after 44 years and honorary post-retirement fellow of more than 20 years). For his achievements in soil science, Keith was awarded the prestigious Prescott Medal of Soil Science by the Australian Society of Soil Science in 1977. He was elected a Fellow of the Australian Academy of Science in 1977 and received the Commander Officer of the Order of Australia (AO) in 1989. Other honours have included the Australasian Institute of Mining and Metallurgy operating technique award in 1995, the Birks Award made by the Denver X-ray Conference in 1988 for excellence in X-ray spectrometry, The Bailey Distinguished Member Award from The Clay Minerals Society in 2001, Honorary Doctor of Science (Hon DSc) from the University of Western Australia in 2002 and the mineral norrishite was named in his honour.

Keith was born on a farm in Kojonup, Western Australia, on July 9, 1924 and was an only child. He was educated at the Christian Brothers College in Perth where he was Dux of school in 1941. In 1945 he graduated with a BSc with first class honours in physics at the University of Western Australia. He went on to complete his MSc in 1946, involving X-ray studies on crystal structures of minerals and analyses of rocks and soil colloids in Western Australia.

Keith's first job was in CSIRO Soils, Adelaide, in 1946 to set up X-ray diffraction equipment for clay-mineral determinations of soils. Keith was awarded a CSIRO Studentship from 1950 to 1952 to work in the Pedology Department of Rothamsted Experimental Station in the UK where he completed his PhD at the University of London. He returned to the CSIRO Division of Soils as Head of the newly formed Clay Mineralogy Section, which he built into a group of international repute in soil mineralogy and geochemistry.

As a soil scientist and clay mineralogist, apart from developing suitable equipment and methods for carrying out mineral analyses, Keith studied the chemical and physical properties of the minerals so that the properties of soils could be better understood in terms of their components. Most of his studies have been truly pioneering works and have provided new

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insights concerning problems in agriculture, geochemistry and colloid chemistry. He did structural studies on micas, montmorillonites, chlorites, iron oxides and other minerals. His studies also led to the discovery and naming of the new mineral, priderite. Keith's work on the crystalline swelling of montmorillonite is notable for the ingenious use of low-angle X-ray diffraction techniques and for the theoretical analysis used, which is based on diffuse double layer theory. This study greatly aided our understanding of the swelling of clays and soils. Keith also showed that the potassium in soil micas could be released to plants because the exchange of potassium for other ions is diffusion-controlled and he elucidated the factors in the mica, and in the external solution, that controlled potassium release. Keith and his associates were the first to identify crystalline manganese oxides in soils and to show that these minerals were responsible for retaining native cobalt and for fixing that Co applied as a fertilizer. These results had important practical implications in animal husbandry. His studies on phosphate minerals in soils were among the first to quantify the extent to which these important soil minerals accommodate heavy metals. He also showed that very stable complex barium aluminium phosphates were present in many soils. These minerals are very insoluble and explained the phosphorus deficiency in many soils.

Keith pioneered the use of X-ray fluorescence spectrometry (XRF) for chemical analysis. His seminal work with colleagues John Hutton (CSIRO) and Bruce Chappell (Australian National University) established, for the first time, accurate methods for the analysis of a wide range of geological materials using XRF. Keith and John's paper published in *Geochemica et Cosmochimica Acta* in 1969 entitled 'An Accurate X-ray Spectrographic method for the analysis of a wide range of geological samples', which covered the theory and practice of a robust XRF fusion method, using a Li borate flux with heavy X-ray absorber (La_2O_3) and matrix correction factors, formed the basis of XRF analysis at most laboratories across the world. Keith also developed many innovative design modifications to commercial equipment, and these have subsequently been incorporated into current commercial instruments. His research also concentrated on the applications of the technique for accurate analysis of ores, beneficiated mineral products and plant materials. His theory and methodology have been transferred very effectively to industry through close collaboration, participation with the work of the Standards Associations, and *via* the Australian X-ray Spectrometry Schools. As a consequence, all major mining and mineral-processing industries in the world now use his technique. His standard methods have formed the basis for quality control and thus value-at-sale of iron ores, and this work continues, which is worth billions dollars to mining and mineral-processing industries world-wide. Keith also adapted the XRF technique to analyse plant materials for nutrient and contaminant element concentrations, and in this capacity has made a very significant contribution to agriculture.

Keith was an outstanding scientist who ensured that his work was applied effectively to general areas of critical importance. His contribution is an excellent example of the way a first-class scientist perceives the versatility and great generality of scientific knowledge, and of determination to see that knowledge applied widely and effectively.

To work with Keith was great fun because he was never afraid to challenge current thinking and had a healthy disregard for bureaucracy. He was also a very modest, motivated and innovative scientist. He was a powerful champion to people who needed help and was always immensely loyal to his profession and colleagues. Scientists will miss a colleague from whom they learnt much.

Keith is survived by his wife Betty, five children, seventeen grandchildren and six great-grandchildren.

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