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Schürmann Symposium on the Early Archaean. Introduction

Utrecht, November 22, 1996

The first Schürmann Symposium on November 22, 1996, was devoted to the geology of the Archaean, particularly to research projects that are sponsored by the Schürmann Foundation. The Foundation is named after the late Dr. Heinrich Moritz Emil Schürmann, an impressive personality and eminent representative of the pre-Second-World-War generation of geologists, who under the nick-name 'Doc' was famous in the international oil world. He died in 1979, 88 years old. Dr. Schürmann worked his whole industrial career for Royal Dutch/Shell, the last 20 years until his retirement in 1951 as director of exploration. But his interests were not confined to the geology of hydrocarbon deposits. Next to his industrial activity he carried out scientific work in several other fields of the earth sciences. He took a particular interest in the petrology of the igneous rocks in Egypt, but also elsewhere in the world. Later in his life he became interested in the Precambrian, particularly the Precambrian basement of Egypt and northern Africa, on which he published two monumental monographs*. Both are still often cited.

Dr. Schürmann bequeathed his inheritance to the foundation that he had himself established, primarily to accomodate his many collections, but later also to promote geological research in the Precambrian. The Foundation has sponsored since then research in Precambrian terrains all over the world, but aims particularly at the promotion of research in the Archaean. The key project under auspices of the Schürmann Foundation has become a major long-term research programme in the Pilbara Craton of Western Australia, a large area of exposed Archaean crust with a geological record going back prior to 3.5 billion years ago and continuing to some 2.8 billion years ago. This period spans a crucial time in the geodynamical evolution of the early Earth. The Pilbara Project is carried out by teams of the Faculty of Earth Sciences of Utrecht University under the supervision of Stan White and Wout Nijman, both faculty staff. During the morning sessions reports of their work were presented. The afternoon's sessions were mainly devoted to the geology of Archaean terrains in southern Africa, comparable in age, rocks and tectonics to the Pilbara Craton. A number of research projects going on in this part of the world is also sponsored by the Schürmann Foundation.

The geological behaviour of planet Earth has changed radically during geological time. Over the nearly 4.6 billion years that have passed since its birth, the internal heat production has steadily diminished by some 85% because of the radioactive decay of the heat-producing elements. This implies, for example, that the plate-tectonic models for the modern Earth are not automatically relevant for the Archaean crust and mantle. It is a fundamental problem in geology whether plate-tectonic processes can be extended back into the Archaean, a question that has caused considerable, occasionally even heated discussion. This controversy has led to many contrasting views about the evolution of the Archaean crust and mantle. Some of these did also crop up during the meeting. But contrary to the gradual *cooling* of the Earth's interior, the incoming solar energy that drives most environmental systems has steadily *increased* by some 30 to 40% in the course of time. This is because the Sun, according to the standard model of stellar evolution, was faint in its infancy and has brightened ever since. Nevertheless, despite the increasing solar luminosity, water-laid sediments are known from the whole 3.8 billion years recorded in sedimentary rocks. Also, over all that time Earth was teeming with life. The temperature conditions at the surface in the Archaean thus never differed much from those today. This implies that in the Archaean, under a cooler Sun, the climate-controlling factors that regulate the temperature of the lower atmosphere must have been operating at scales that are differing from those today.

It is evident that the doctrine that the 'present is the key to the past', which can be applied quite satisfactorily to the latter part of the history of the Earth, is not automatically valid for the study of the early history of our planet. Over the first half of its 4.6 billion years history, the Earth must have passed through a succession of stages during which the internal and external geological behaviour differed from earlier and later stages.

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* H.M.E. Schürmann 1966 The Pre-Cambrian along the Gulf of Suez and the northern part of the Red Sea – E.J. Brill, Leiden, 404 pp.
H.M.E. Schürmann 1974 The Pre-Cambrian in North Africa – E.J. Brill, Leiden, 351 pp.

Unfortunately, a veil falls across the Earth's history at around 4 billion years ago. The oldest known terrestrial rocks are dioritic orthogneisses in northwestern Canada with an age of nearly 4 billion years. The oldest rocks that can tell us something about the conditions prevailing at the surface of the infant Earth are from a sedimentary sequence in western Greenland, with an age of 3.8 billion years. It is customary to take the onset of the Archaean Epoch at 4 billion years ago, when recorded geological history begins. The preceding 600 million years are the 'Dark Ages' of the Earth. The geological evolution in that period cannot be unraveled by direct observation, but has to be deduced, firstly, from the geological knowledge gained during the last decades from the Moon and other planets, where, contrary to our planet, information regarding the earliest history has been preserved; secondly, from isotopic and geochemical characteristics of the oldest preserved terrestrial crust, which can tell something about the preceding evolution of the crust; and, thirdly, from geophysical modelling.

There is a nearly general consensus that the Earth and the other terrestrial planets were formed by accretion in a gas-free environment from dust, debris and rock fragments, including objects exceeding the size of Mars. This process took some 5 million years after the formation of the solar nebula, 4.57 billion years ago. An inevitable consequence of the accretion hypothesis is that much of the Earth's mass melted during the accretion and that in the melt the metallic core settled out. By the end of the accretion the Moon formed as the result of the collision with the Earth of an object with a size of at least 15% of the earth-mass. But there are conflicting views about the subsequent crystallization history of the molten mantle. In analogy with the crystallization history of large ultramafic bodies like Skaergaard and Stillwater, one might expect the production of layers of differing mineralogy. There is well-documented geochemical evidence that the Moon underwent something similar. Also in analogy with the Moon it is proposed that the geological evolution of the new-born Earth after the completion of the accretion started with a 'magma-ocean', involving much and possibly the whole mantle. The 'magma ocean' was overlain by a thin basaltic crust and should have gradually consolidated downwards because of the cooling of the Earth, until in our time only local pockets of magma are left. But whatever the geochemical evolution of crust and mantle of the infant Earth, there is consensus again, on the basis of observations on the other planets, that impact cratering must have played an important role in the early history of the Earth. From the Moon we know that by some 4 billion years ago, and maybe most of the preceding time, the Earth underwent a heavy bombardment by interplanetary debris of all sizes, including giant bodies. The protocrust must have been continuously brecciated and modified by the impacts, while it seems probable that heat released by the major impacts generated huge volumes of basaltic magma, as was the case in the maria on the Moon.

Anyhow, in the beginning of the Archaean most violence had quieted down. The Archaean Earth apparently had only very little continental crust, but the thickness, geothermal gradients and petrological characteristics of that early continental crust were much the same as today. At the surface were oceans that were teeming with bacterial life and in which sedimentation processes took place that were very similar to those today. The atmosphere did not yet contain free oxygen. This Archaean Earth gave way to the modern Earth between 3 billion and 2.5 billion years ago, when most of the present continental crust was generated and free oxygen began to accumulate in the atmosphere. Somewhat later the evolution of higher life forms took off. All these changes are taken to mark the transition from the Archaean to the Proterozoic, the boundary usually being set at 2.5 billion years ago.

It is only recently that one began to realize that the environmental conditions prevailing at our planet in Archaean time, particularly in the early Archaean, may have been very similar to those prevailing at the same time on our neighbour planet Mars. This is the reason that nowadays there is considerable interest in the terrestrial Archaean from the side of planetologists, particularly those engaged in the Mars research programmes. This became manifest again in 1996 with the fuss around the Mars meteorite ALH 84001 and the discussion about the possibility of ancient life on Mars.

At the meeting, reports were presented on down-to-earth geological research in a number of Archaean terrains. It is only through such studies of well-preserved Archaean crust by earth scientists from different disciplines, that we can step-by-step gain knowledge about the geological evolution of the young Earth, as well as the geological processes and environmental conditions at that pristine time.

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