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GEOLOGICAL (AND RELATED) MEMORIES OF SIX DECADES WITH REINHARDT FUCK

Umberto Giuseppe Cordani

Universidade de São Paulo (USP), Instituto de Geociências (IGc). Rua do Lago, 562 - Cidade Universitária, São Paulo - SP, 05508-080.
E-mail: ucordani@usp.br;

Abstract - *Reinhardt Fuck was awarded the title of Professor Emeritus by the University of Brasília in recognition of the magnitude of his scientific contributions. In his honor, this article was written to highlight his legacy to Brazilian geology. Fuck graduated in Porto Alegre in 1963 and, in 1964, joined the Geological Map Commission of Paraná, which was preparing a systematic program for that state. This work, nicknamed the "map-making machine", produced numerous geological sheets that remain highly useful for mineral exploration programs today. In 1969, Fuck joined the University of Brasília. Somewhat later, he successfully defended his Doctorate at the University of São Paulo in 1973 and completed a postdoctoral fellowship at the University of Durham, in 1975. During his time in Brasília, he participated in various geological projects that contributed to the understanding of the Brazilian Midwest. In 1985, he became a Full Professor. Retired since 2010, Fuck remains affiliated with the university as a Collaborating Researcher. Through his work over the past five decades, he has gained international recognition as one of Brazil's most important geoscientists, known for his expertise and creativity in geoscientific research.*

Keywords*: Professor; Geoscientist; Collaborator*

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1. INTRODUCTION

This is a work dedicated to my esteemed friend Reinhardt Fuck, who has built an outstanding scientific and professional life in the field of Geology. Decades pass quickly, and I realized that I have known him for over 60 years. It is possible that our first meeting occurred at one of the annual congresses of the Brazilian Society of Geology (SBG) in the 1960s. During these occasions, in addition to the activities related to the congress sessions, students from the five geology programs that existed at the time (São Paulo, Porto Alegre, Recife, Belo Horizonte, and Rio de Janeiro) organized indoor soccer matches. My memories suggest that he and I, both in our early 20s, met while competing in one of these matches between São Paulo and Porto Alegre. In truth, my memories are not very reliable nowadays, and neurons might even suggest things that never existed. On the other hand, that game remains vivid in my memory, and I dare to specify the place and date: SBG Congress in Porto Alegre, 1962. At that time, Reinhardt was still a third-year geology student from Rio Grande do Sul, and I was an instructor in the Geology Department at USP, but I still played with the students. As the Italians say, “se non è vero, è ben trovato”. In any case, it’s likely that Fuck and I were together during the SBG congress sessions in 1963 and 1964 or even at other geological events, but at that time it seems that we didn’t have many opportunities to exchange ideas.

Reinhardt Fuck graduated in 1963 with a degree in Geology from the Federal University of Porto Alegre, RS. Soon after graduating, he briefly worked as a professional geologist for the government of Ceará, conducting geological surveys and locating groundwater wells. Between 1964 and 1968, he participated in the systematic geological mapping carried out by the Geological Map Commission of Paraná, an initiative by the state government in partnership with the Federal University of Paraná. In 1969, he accepted an invitation from the University of Brasília, following his calling as a professor and researcher, and joined the faculty of the geology program. Over the years, he completed the full academic career path to become a Full Professor, and to this day, he remains at UnB, retired, as a Collaborating Researcher. Through his work over the past five decades, he has become internationally recognized as one of the most important Brazilian geoscientists. Many of his works, especially on tectonics, geophysics, and crustal evolution in various Brazilian regions, are exceptional. In my view, as I closely followed his work as a professor and as a professional geologist, I witnessed his competence in geoscientific research, his creativity in advising researchers, and his dedication as a mentor to students in their respective theses. As of September 2024, on the “Research Gate” platform, Reinhardt Fuck is listed with over 300 scientific articles published in specialized journals, nearly 14,600 citations, and a H-index of 51, which corresponds to a high level of scientific output with international relevance. The award of the title of Professor Emeritus by the University of Brasília is institutional recognition of his prolific career.

Fuck received many awards and honors during his scientific career. In my opinion, the most important were the “Grand Cross of the National Order of Scientific Merit”, from the Brazilian government, and the “José Bonifácio de Andrada e Silva Gold Medal” from the Brazilian Geological Society.

2. MAP-MAKING MACHINE

In the 1960s, the government of the State of Paraná, in partnership with the Federal University of Paraná (UFPR), established the Geological Map Commission of Paraná (CCGP) with the goal of preparing a systematic geological mapping of eastern Paraná. Understanding the regional geology was necessary not only to assess the feasibility of planning mineral exploration programs but also for the planning of other state government activities.

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In 1964, the CCGP hired several newly graduated geologists from the Federal University of Rio Grande do Sul, including R. A. Fuck, O. Marini, E. Trein, A. Muratori, and J. Lopes; They worked under the guidance of the already renowned researchers from UFPR, J. J. Bigarella and R. Salamuni. Nicknamed the "map-making machine", this team, in just a few years, produced and published three dozen geological sheets at scales between 1:50,000 and 1:70,000, which are still highly useful today for mineral exploration programs and the planning activities of the state government. The wealth of data collected significantly increased the understanding of the Precambrian and Paleozoic geology of eastern Paraná and led to the publication of numerous studies on regional geology, most of which were published in the *Boletim Paranaense de Geociências*. The article by Fuck et al. (1969) provides a solid synthesis of the extensive work carried by the team.

Due to a series of circumstances, I had the honor of directly participating in the "map-making machine", contributing to the CCGP along with my colleague Vicente Girardi, by producing one of the geological sheets, the Morretes Sheet.

How was it possible?

Graduated in 1960, I was invited by D. Viktor Leinz, a full professor and head of the Geology Department at the Faculty of Philosophy, Science and Letters at USP (FFCL-USP), to join as an instructor in early 1961. At that time, the instructors would soon begin preparing for their doctorate, and Dr. Leinz suggested that I study an occurrence of iron ore in the municipality of Antonina, on the coast of Paraná, which could potentially become my doctoral thesis. For about two years, I conducted several studies that included geological mapping of the area and the characterization of the petrography and structures of the regional rocks.

However, at the beginning of 1963, I had to abandon this doctoral program due to an unexpected event of great importance for the University of São Paulo, which would determine not only a change in the theme of my doctorate but also the future characterization of my life. During that year, the department would receive a complete laboratory for geochronological analyses using the Potassium-Argonium method, donated by the University of California. The professor responsible for the project, the renowned physicist John Hamilton Reynolds, had requested the presence of a young researcher from USP to undergo a five-month internship in Berkeley, with the aim of learning to operate a mass spectrometer. Since I was one of the youngest instructors in the department, Dr. Leinz chose me for this task, and two weeks later, in May 1963, I found myself in Berkeley, beginning a specialization in geochronology that would last five months. In October 1963, Reynolds and I went to São Paulo, and the laboratory was installed in less than three months. The first K-Ar age was obtained in January 1964.

With Dr. Reynolds at the USP during his sabbatical year in 1964, my scientific life definitively turned toward geochronology, with the responsibility of operating the laboratory and publishing works related to the application of geochronology to the geologic evolution of the Brazilian territory. Since then, the Geochronological Research Center at USP has become a reference for rock dating in South America, and many geological researchers, including Fuck at UnB, have undoubtedly collaborated in this turning point in my scientific life.

As a result, I distanced myself from the iron ore studies in Antonina. However, somehow, possibly in early 1965, the CCGP became aware of the incomplete work I had conducted. Since this work fell within the area covered by the Morretes Sheet, I received an invitation from Dr. Bigarella to carry out the complete mapping of that sheet.

I accepted the invitation, as the field geology data I already had from Antonina corresponded

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to about ¾ of the Morretes Sheet. With approximately two weeks of fieldwork, I could complete the geological reconnaissance. Shortly thereafter, in Curitiba, I had the opportunity to have extensive discussions with the geological team, particularly with Fuck, about the correlation with the sheet adjacent to Morretes, as well as the surveys needed to complement the geology of the sheet. In these discussions, in addition to identifying small sections that could be easily covered, we found that there was an important profile missing, approximately 25 km long, precisely along a stretch of the Curitiba-Paranaguá railway, between Piraquara and Morretes, passing next to Pico do Marumbi. This stretch included several long tunnels and various suspended bridges. A few days after our conversation, armed with the train schedule, I was excited to walk this profile, which remains vivid in my memory. Once the field surveys were completed, I invited Vicente Girardi, a fellow geologist from USP, to conduct the petrographic analysis of the collected samples, and we would publish the resulting scientific article together (Cordani & Girardi, 1967).

Some time later, I spoke with Fuck about the Doctorate I was finishing, now under the supervision of Professor José Moacyr Coutinho, possibly the best-prepared Brazilian researcher in petrology at the time. During our conversation, Fuck considered the possibility of pursuing his doctorate at USP as well, under the same supervisor, utilizing some of the knowledge he had gained during the geological mapping of Paraná. I made the necessary contacts, which were positive, and Fuck successfully defended his doctorate at USP in 1973 with the work titled “Geology of the Tunas Alkaline Massif, Paraná, Brazil”.

3. UNIVERSITY OF BRASÍLIA

Starting in February 1969, Fuck joined the faculty of the geology program at UnB in the Department of General and Applied Geology as an Assistant Professor. He quickly became involved in undergraduate teaching, as well in the research and development activities. At that time, the program was undergoing changes in its structure, curricula, and programs, as well as the establishment of laboratories and the reorganization of research lines. Before long, the program gained recognition for the quality of its faculty and students, which led to the establishment of graduate studies.

Professor Fuck’s experience in geological surveys, along with his deepening knowledge in petrology through his doctoral thesis, was complemented in the following years by the incorporation of tools such as geochronology, lithogeochemistry, and structural analysis, making him a well-rounded researcher in the activities of the Geosciences. In 1974, Fuck became an Associate Professor, and in 1975, he completed a postdoctoral fellowship at the University of Durham (England). Upon returning to UnB, alongside colleagues such as M. Dardenne, J. Danni, O. Marini, O. Leonardos, H. Jost, and also with students, he participated in numerous projects that significantly contributed to the understanding of geological environments in the Brazilian Midwest. These projects focused on the regional geology of Precambrian terrains, where extensive geological surveys were conducted, accompanied by petrographic, geochemical, geochronological, and structural analyses. On the other hand, at the same time, Fuck was a co-author of one of the main publications related to the South American Platform, in collaboration with professors Fernando Marques de Almeida and Benjamin Bley de Brito-Neves, in which the main structural provinces occurring in Brazilian territory were characterized (Almeida et al., 1981).

In 1983, at the invitation of Carlos Walter Marinho Campos, then Director of Exploration at Petrobrás, Fuck and I participated in a research project of great interest to the company, regarding the influence of basement structures on the tectonic evolution of the largest sedimentary basins in Brazil. In this research, alongside Fuck and myself, B. B. de Brito-Neves,

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A. Thomas Filho, and Petrobrás geologists R. Porto and F. M. B. Cunha also participated. The work was primarily conducted at CENPES, the Research, Development, and Innovation Center of Petrobrás in Rio de Janeiro, and the results were published in the Journal of Geodynamics (Brito-Neves et al., 1984).

In 1985, Reinhardt Fuck became a Full Professor at UnB.

In that year, at my invitation, he spent 12 months as a Visiting Professor at the Institute of Geosciences (IGc) at USP, supported by a scholarship from the São Paulo Research Foundation. During this time, he engaged in various activities in the institute's graduate courses and gave several lectures on the geology of the Brazilian Midwest. Since Fuck and I have always had similar geoscientific interests, particularly related to the geotectonics of South America, and my scientific career has been dedicated to geochronology applied to the crustal evolution of the South American Platform, his stay at USP was crucial for our intense interactions.

A very important one was the opportunity to discuss the results of a geochronological study conducted the previous year by Márcio Martins Pimentel, under my supervision, at the Geochronological Research Center of USP (CPGeo-USP). Márcio, who graduated in Geology from UnB in 1982, was enrolled in a master's program at the same university under Fuck's supervision. At CPGeo, he determined the K-Ar ages of several samples to include in his dissertation, which he defended in 1985, titled "The Volcanic-Sedimentary Sequence of Arenópolis-GO: Igneous and Metamorphic Petrology, Geotectonic Context and Preliminary Metallogenic Considerations". These results, which were significant for understanding the tectonic evolution of the Brazilian Midwest, led to a co-authored publication (Pimentel et al., 1985), marking Márcio Pimentel's first direct contribution to geochronology in Brazil.

Márcio Pimentel, who unfortunately passed in 2018, was one of the leading figures in national geology, with a significant scientific contribution. He was a Researcher 1A at CNPq, a full member of the Brazilian Academy of Sciences, and a fellow of the Academy of Sciences for the Developing World. As a Full Professor at the Institute of Geosciences at UnB, he was the creator and head of the Laboratory of Geochronology and Isotope Geology. He also gained prominence in the fields of regional geology and geotectonics. With a geochronology laboratory at UnB under Márcio Pimentel's leadership, many regional projects were conducted, especially in the Brazilian Midwest, almost always with Fuck's participation. One such publication was the article by Pimentel and Fuck (1992) regarding crustal accretion in Central Brazil, which I believe was possibly the most significant achievement at the beginning of the UnB laboratory.

As a faculty member and principal researcher at the Institute of Geosciences at UnB, Fuck was invited by the National Council for Scientific and Technological Fellow, to undertake several institutional activities, such as Coordinator of Earth Sciences (1986-1989) and Advisor to the Presidency (1997). Similarly, he was invited by the Coordination for the Improvement of Higher Education Personnel (CAPES) of the Ministry of Science to serve as a consultant and advisor between 1985 and 1997.

Retired since 2010, Fuck remains affiliated with the Institute of Geosciences at UnB as a Collaborating Researcher, continuing his research activities and advising faculty and students. In 2011, he was deservedly awarded the honorary title of Emeritus Professor at the University of Brasília, in recognition of the high level prominence he achieved in his academic career and the magnitude of his scientific output. One of his most recent publications, co-authored with B. B. de Brito-Neves and G. A. C. Campanha (Brito-Neves et al., 2022), was selected by the Brazilian Geological Society the

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"Fernando Flávio Marques de Almeida" award for the article titled "The Statherian Taphrogenesis of the South American Platform", recognized as the best article published in the "Brazilian Journal of Geology" in 2022.

4. THE LEGACY OF REINHARDT FUCK

Since the 1960s, Reinhardt was one of my best friends and I have witnessed the excellence of his professional life and his prolific scientific career, which has significant international relevance.

Fuck applied everything he learned in his Geology course in Porto Alegre during his long time participating in the "map-making machine" to conduct geological surveys in eastern Paraná, as mentioned above. In addition to the 30 geological sheets produced, Fuck and other team members published several scientific articles in the *Boletim Paranaense de Geociências*. As examples, I highlight three contributions published in volumes 23/25 of this bulletin: Marini et al. (1967), Fuck et al. (1967), and Trein et al. (1967). The first addresses the characterization of the Açungui Group, which covers a large area in the region; the second describes the granite rocks of eastern Paraná; and the third deals with the intrusions of alkaline rock masses within the regional metamorphic rocks.

In the 1970s and 1980s, as noted in the previous chapter, Fuck played an important role alongside fellow faculty members from UnB and students in various geological studies in regions of the Brazilian Midwest. In my view, the article by Danni et al. (1982) aptly represents the work being carried out during this phase. Two articles, Leonardos et al. (1975) and Almeida et al. (1981), gained international relevance by characterizing the structural provinces present in Brazilian territory. Additionally, some geochronological studies, such as those by Pimentel & Fuck (1987) and Fuck et al. (1989), with dating conducted both at UnB and CPGeo-USP, marked the beginning of Fuck's connection with geochronology, which developed from that point forward.

The neo-geochronologist Reinhardt Fuck, starting in the 1990s, greatly benefited from the newly established geochronology laboratory at UnB, and his partnership with Márcio Pimentel, which began with the previously mentioned article by Pimentel & Fuck (1992), proved to be very fruitful. Among the more than 20 articles published by Fuck, Pimentel, and other co-authors, I will highlight four of them here, each with clear international significance. The first is the article by Pimentel, Fuck, and Alvarenga (1996), which provides numerous datings of granitic rocks in the Central-Western region of Brazil. The second, by Pimentel et al. (1997), reinforces the conclusions of the previous work (Pimentel & Fuck, 1972) regarding crustal accretion in Central Brazil, with datings obtained in the Tocantins Province. The third, by Pimentel, Fuck, and Botelho (1999), includes another series of datings related to the Brasiliano Orogenic Cycle, indicating the history of the Brasília Belt in the Neoproterozoic. Finally, the fourth, by Pimentel et al. (2000), refers to the basement of the Brasília Belt and its relationships with the Goiás magmatic arc, resulting from the Neoproterozoic crustal accretion event in Central Brazil.

In the early years of the 21st century, Fuck had significant interaction with professor Renato de Moraes from IGc-USP and several other researchers regarding the study of medium to high-grade metamorphic rocks from the Anápolis-Itauçu Complex in the Brasília Belt and the volcanic rocks of the Juscelândia sequence in Goiás. I would like to highlight the work of Moraes et al. (2003), which addresses the transition between the continental rift situation and the oceanic basin in the Juscelândia region.

During this period, Fuck also contributed to at least three significant articles regarding the configuration of the supercontinent Rodinia in the early Neoproterozoic. Two of them were co-authored by Brito-Neves (Brito-Neves et al.,

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1999; Fuck et al., 2008). The third article (Li et al., 2008), published in the "Precambrian Research" journal and receiving a substantial number of citations, is possibly the most important paper related to Rodinia. It includes 13 international authors from various backgrounds and provides a synthesis of the configuration and history of this supercontinent.

In the first two decades of the 21st century, professor Fuck's experience in Earth Sciences, which already encompassed cartography, petrology, lithogeochemistry, structural analysis, and more recently geochronology, was complemented by geophysics through his interactions in Brasília with J. Berrocal and R. Vidotti, among others. They utilized data from seismology, gravity, and terrestrial magnetism. For example, Berrocal et al. (2004) and Soares et al. (2006) addressed the characteristics and models of the crust and upper mantle of Central Brazil, primarily using deep seismic refraction.

I would like to highlight some articles that focused on the northeastern region of Brazil, which had become professor Fuck's primary interest. Initially, Arthaud et al. (2008) studied the geology of the Borborema Province in the northern part of northeastern Brazil, indicating its correlation with the African region of the Gulf of Guinea in the northwestern part of the African continent. Following that, Nogueira et al. (2010) characterized the chronology of intraplate faulting in the Quaternary in northeastern Brazil, while Bezerra et al. (2011) investigated the active faults of Borborema using seismic data. De Castro et al. (2013) characterized the crustal structure beneath the Parnaíba Basin through gravity and magnetism studies. Lima et al. (2015) described a deep seismic refraction experiment conducted across northeastern Brazil, while Pedrosa et al. (2015) characterized the structure of the Jaibaras Rift using various geophysical data.

In 2013, I had the opportunity to be a co-author with Fuck and Pimentel on two significant publications for Brazilian geology. In both cases, the topics were related to the geotectonics of the South American continent, making the formal support of researchers in the field essential for such matters. The first, Cordani et al. (2013a), dealt with the formation of the West Gondwana orogen through the union of Brazil and West Africa along the Transbrasiliano-Kandi Lineament at the end of the Neoproterozoic. The second, Cordani et al. (2013b), was a discussion regarding the Clymene Ocean, which we believe was merely an epicontinental sea in the central part of the South American continent.

At the same time, B. B. Brito-Neves and R. A. Fuck published three important articles for understanding the geotectonics of the South American Platform. The first, Brito-Neves & Fuck (2013), addresses the tectonic evolution of the Neoproterozoic that affected the older basement. The second, Brito-Neves et al. (2014), discusses the Brasiliano age amalgamation, indicating that it occurred in four pulses with ages of 800-740 Ma, 660-610 Ma, 590-560 Ma, and 560-520 Ma. This article characterized the structural provinces in West Gondwana and suggested that the last pulse occurred only during the Pampeana and Búzios orogenies. The third article, Brito-Neves & Fuck (2014), proposes that the ancient basement of this platform is formed by two parts: the Laurentian domain to the N-NW and the Gondwanian domain to the E-SE. Moreover, in the same year, Fuck et al. (2014) published an excellent article discussing the crustal evolution of the Tocantins Province basement, including a suggestion for the reconstruction of the Atlantic supercontinent in the Paleoproterozoic.

In recent years, now retired but continuing to contribute to UnB as a Research Collaborator, Fuck published a paper co-authored by B. B. Brito-Neves and G. A. C. Campanha, addressing ancient basement nuclei in the Brasiliano structural provinces of South America (Brito-Neves et al., 2021). With the same co-authors, he published the article on the Statherian Taphrogenesis of the South American Platform

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(Brito-Neves et al., 2022), which, as mentioned earlier, received the “Fernando Flavio Marques de Almeida” award for recognition as the best article published in the journal “Brazilian Journal of Geology” in 2022. These publications highlight Fuck’s continued impact on Brazilian geology and his ability to collaborate and conduct research even after retirement. Finally, he is fully recognized by the Brazilian academic community with the honorary title of Professor Emeritus as mentioned above.

5. FINAL REMARKS

Reinhardt Fuck and I graduated in geology in the early 1960s. Our lives have been entirely dedicated to the geological sciences, and we have had over 60 years of interaction, sharing many national and international events of a scientific, social, political, and sports nature. Now retired, we continue to be active as professors and researchers at our respective universities, UnB and USP.

In geology, we share the same research interests, particularly in the context of the crustal evolution of the South American continent, which has allowed us to participate jointly in conferences, congresses, and other scientific events.

Our curricula include several occasions where we had specific collaborations, both in excursions and fieldwork, as well as in the production of co-authored scientific articles. Fuck has always been a high-level collaborator, highly skilled in petrology, structural geology, and more recently in geophysics. In my specific field of study, Fuck has become an expert in interpreting geochronological data in terms of regional tectonic evolution.

Highly respected internationally, Fuck is a special friend.

We have already lived through eight decades (!), and surely we can both look back with a sense of satisfaction and nostalgia. I hope life will still allow us to continue our geological collaborations for some time and have many more cordial and pleasant encounters.

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