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Introduction

1.1 Preamble

The Arabian-Nubian Shield contains the remnants of the Neoproterozoic basement in the Middle East and NE Africa (Figure 1-1). This shield was formed between ca. 900 Ma and ca. 560 Ma. The hydrocarbon industry has performed much research in the Phanerozoic sedimentary cover of the Middle East due to its high contents of oil and gas. Occasionally, the research into the petroleum geology of the Middle East also involved research in its Neoproterozoic basement. A study of the Neoproterozoic sediments of the Arabian-Nubian Shield in Egypt was one of the first assignments of dr. H.M.E. Schürmann at Royal Dutch/Shell in the 1920s. This study was performed to allow differentiation between the oil-bearing Phanerozoic sediments and the "dry" Neoproterozoic sediments. In recent times, the understanding of the Neoproterozoic structures in the Middle East was regarded as a crucial part of petroleum geological research (e.g. Husseini, 2000). However, geological research in the Arabian-Nubian Shield started much earlier than any of the oil-industry related research.

The Nubian part of the Arabian-Nubian Shield (current day Egypt, Sudan, Eritrea and Ethiopia) is actually the location of the earliest known geological research to have been recorded. The pharaonic Egyptians explored their country for gold and found this in the Neoproterozoic basement of their country, the Nubian part of the Arabian-Nubian Shield. A map that describes the geology of the Wadi Hammamat area in the Eastern Desert was made by the Theban scribe Amennakhte at ~1150 B.C. during the reign of Ramesses IV (Harrel and Brown, 1992). The map (Figure 1-2) contains different colors which can be correlated with different rock-formations in the field as the granites, siliclastic sediments, volcanics and serpentinites of the area (Harrel and Brown, 1992). The map highlights gold-workings and a quarry for decorative stones (Harrel and Brown, 1992).

Another landmark of Arabian-Nubian geology, was the recognition of Neoproterozoic ophiolitic sequences in the 1970s. A number of authors (e.g. Garson and Shalaby, 1976; Shackleton, 1977 and Bakor et al., 1976; Shanti and Roobol, 1979) interpreted sequences of ultramafics, gabbros and marine sediments in Egypt and Saudi Arabia as ophiolites. Until the late 1980s, the ophiolites of the Arabian-Nubian Shield (dated at ca. 800-900Ma) were thought to be the oldest in the world and consequently this shield was believed to contain the oldest remnants of plate tectonics as we see it today. However since then, ophiolites have been found in the Late Archean and Early Proterozoic (Stern, 2005).

The presence of the ophiolites led most authors to view the Neoproterozoic tectonics of the Arabian-Nubian Shield as being associated with continuing compression that was associated with the obduction of the ophiolites. It was in recent years, that the importance of tectonic regimes other than compression has been proposed (e.g., Greiling et al., 1994; Stern, 1994). Another reason that makes the Arabian-Nubian Shield a very interesting area for geological

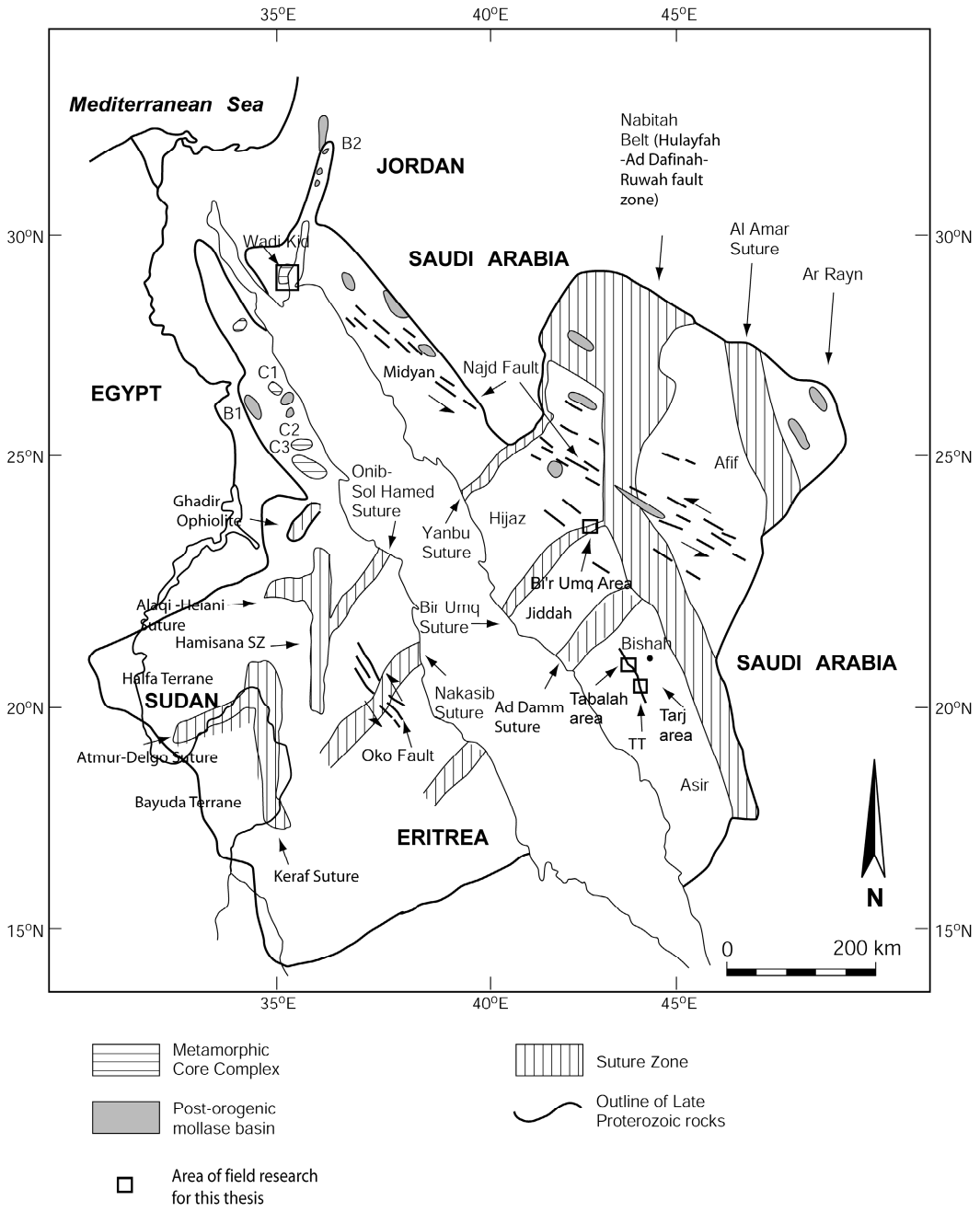

Figure 1-1 A map showing the main Neoproterozoic features in the Arabian Nubian Shield. WK = Wadi Kid Complex, C1 = Meatiq Dome, C2 = El Sibai Dome, C3 = Wadi Ghadir Complex, C4 = Hafafit Dome, C5 = Taif area, C6 = Abha Complex, B1 = Basin with Hammamat sedimentary sequence, B2 = Basin with Saramuj Conglomerate. Compiled from maps by Vail (1985); Stoeser and Camp (1985); Brown et al., (1989) , Greiling et al., (1994) and Abdelsalam and Stern (1996).

research is the fact that it contains a very high percentage of outcrop. This makes the area also suitable for the study of fundamental geological problems such as the interplay between compression and extension during the tectonic development of an orogen. This problem will be discussed in this thesis.

1.2 Aims

The aim of this study is to improve the understanding of the Neoproterozoic geodynamic development of the Arabian-Nubian Shield. To achieve this, the different tectonic phases in the evolution of the Arabian-Nubian Shield and their relationships will be evaluated in order to define a tectonic model for the Neoproterozoic of the Arabian-Nubian Shield. Blasband et al. (2000) identified three main tectonic phase: 1) the oceanic phase; 2) the arc-accretion phase; 3) the late orogenic phase. The main structural trends in the Arabian-Nubian Shield are NE-SW, N-S to NNE-SSW, NW-SE and sub-horizontal structures that are associated with the late orogenic phase (Blasband et al. 2000). Most of previous the studies in the Arabian-Nubian Shield focused on petrology and geochemistry data however detailed kinematic studies are rare. These studies are crucial for a full understanding of the tectonic development of the shield. Detailed field-based structural research, with limited geochemical and geochronological research, was undertaken in three key areas of the Arabian-Nubian Shield (Figure 1-1):

1. The Bi'r Umq Complex – a complex that contains an accreted ophiolitic sequence and is thought to represent an ophiolitic suture, a relict of the oceanic phase (Pallister et al., 1988). This area contains a large NE to ENE trending shear zone.
2. The Tabalah and Tarj area – an area that contains remnants of an island-arc and major NNW ductile shear zones (Greenwood et al., 1986).
3. The Wadi Kid Complex – a complex that contains one of the "gneissic domes" of the Arabian Nubian Shield (Habib et al., 1985).

Geochemical and geochronological research was performed to allow correlation with other studies in the Arabian-Nubian Shield. The integration of data from the studied areas forms the basis for the construction of a tectonic model for the Arabian-Nubian Shield.

1.3 Outline of thesis

Chapter 2 contains a review of published data of the Arabian-Nubian Shield and the ideas on its tectonic development. In chapter 3, a detailed structural study of the Bi'r Umq Complex in Saudi Arabia is presented. Chapter 4 describes a structural study of the Tabalah and Tarj areas Saudi Arabia. Geochemical and geochronological data, in addition to the structural data, are used to define a tectonic model for this area. Chapter 5 presents the structural data for the Wadi Kid Complex, Egypt. This chapter was published as Blasband et al. (1997). In chapter 6, the data presented in the chapters 3-5 are integrated together with published data from key-areas in the Arabian-Nubian Shield, to form the basis for a new geodynamic model for the Neoproterozoic of the Arabian-Nubian Shield. Chapter 6 also includes the conclusions of this thesis and recommendations for further research. Appendix 1 contains structural, geochemical and geochronological data from research that was performed after the publication chapter 5 as Blasband et al. (1997). Appendix 2 presents a detailed metamorphic study of the Wadi Kid Complex by Brooijmans et al. (2003) of which I was co-author. The results of this metamorphic study add information regarding the evolution of the Wadi Kid Complex.

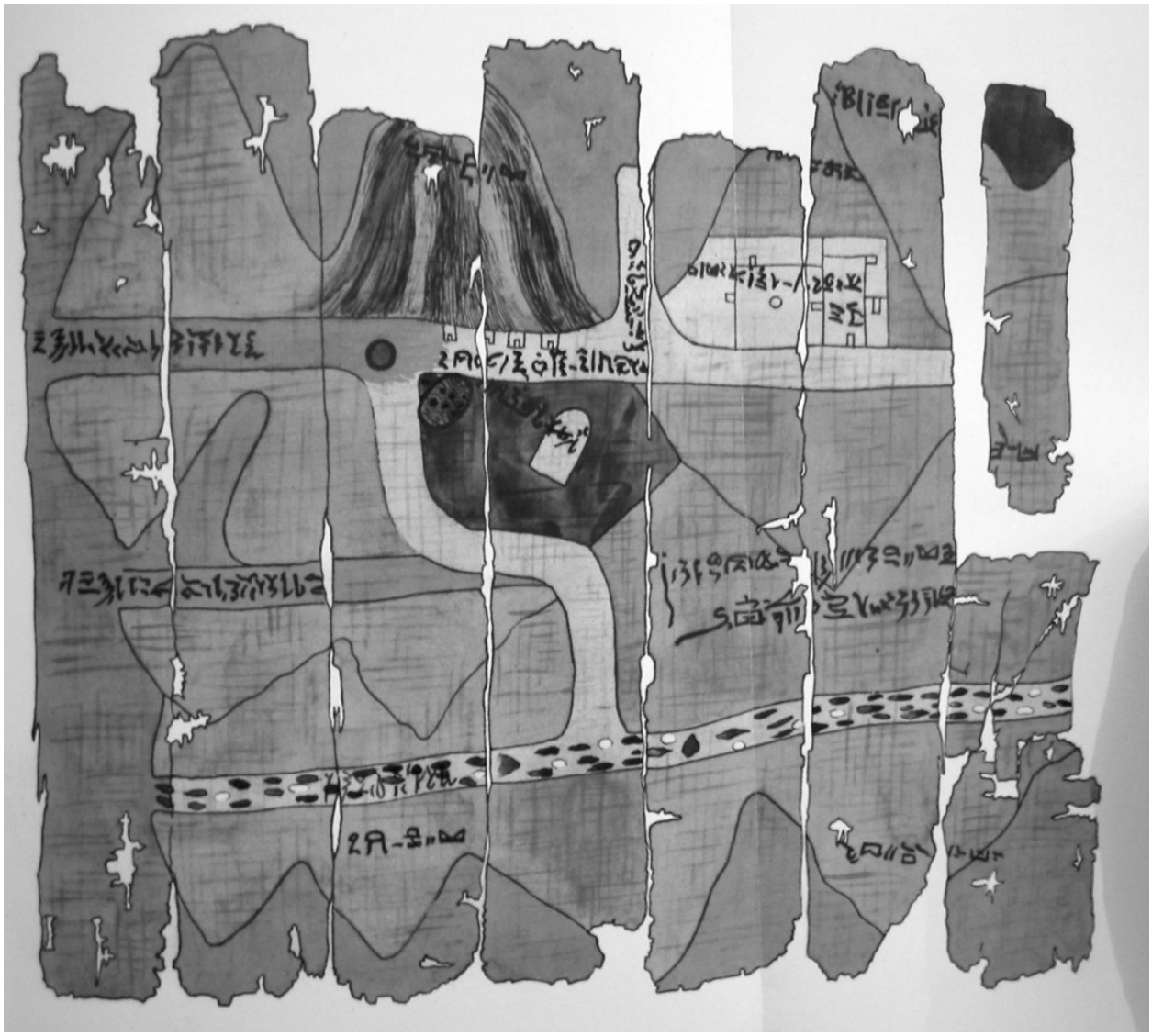

Figure 1-2 A photo of the oldest geological map in the world: the Wadi Hammamat map that was prepared at ~1150 B.C.