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Editorial

Introduction to the JEBEL volume of *Precambrian Research*

The Arabian-Nubian Shield (ANS) is one of the largest tracts of juvenile Neoproterozoic crust on Earth, extending >3500 km north–south and >1500 km east–west over parts of Jordan, Saudi Arabia, Yemen, Israel, Egypt, Sudan, Eritrea, Ethiopia, Somali, and Kenya (Fig. 1). It is the product of a ~300 million year cycle of crustal growth, bracketed by break up of the supercontinent Rodinia and assembly of the supercontinent Gondwana, and composed of ophiolitic complexes, oceanic arcs, granitoid plutons and batholiths, and terrestrial to shallow-marine volcanosedimentary basins. Formation of the shield began with the creation of early Cryogenian oceanic crust some 10 km thick in the Mozambique Ocean between rifted parts of Rodinia and ended with a block of Ediacaran lithosphere comprising continental crust some 45 km thick and lithospheric upper mantle some 80–120 km thick.

At times, divergent national scientific objectives and differing priorities of geoscience organizations have made systematic geologic study and synthesis of the entire ANS problematic, but the breadth and detail of current geologic research and developing opportunities for transnational cooperation are fostering clearer insight into the geologic evolution of the shield. The present volume is an outgrowth of a five-year collaboration by geologists from Jordan, Egypt, Saudi Arabia, Sweden, Norway, Germany, Australia, and the United States of America within the JEBEL Project. JEBEL was funded by the Swedish International Development Agency specifically to promote scientific exchange with the Middle East and North Africa (SIDA-MENA). Our collaborative work has been facilitated by national geoscience organizations and institutions. Among these, we particularly wish to thank the Saudi Geological Survey, the National Materials Authority of Egypt, and the University of Jordan for hospitality and logistical help.

Geologic investigations in the ANS are making a fundamental contribution to knowledge of Neoproterozoic Earth history. The shield rocks are well exposed and easily accessible, they are mostly less deformed and metamorphosed than contemporary rocks elsewhere in the world, and retain unambiguous evidence of their depositional, volcanic, intrusive, and structural character and relationships. The region is a prime natural laboratory for researching: (i) the origins and character of Neoproterozoic oceanic crust; (ii) depositional and magmatic processes in Neoproterozoic subduction systems; (iii) changes in Neoproterozoic weathering conditions; of isotopic excursions in Neoproterozoic seawater and atmosphere; and (iv) the effect on structure and magmatism of a Neoproterozoic tectonic transition from unstable coalescing volcanic arcs to stable continental crust.

Tectonically, the ANS is an accretionary orogen, part of the larger East African Orogen encompassing the ANS in the north and the Mozambique Belt in the south. The shield has a reasonably well-defined margin with the Archean-Neoproterozoic Saharan Metacraton in the west and with high-grade metamorphic rocks of the Mozambique Belt in the south. To the east in Kenya and southern Ethiopia, the shield is in contact with the Azania ribbon continent, a belt of Archean-Paleoproterozoic schist and gneiss that extends from Madagascar into Somalia. In Arabia, Archean and Paleoproterozoic gneiss is also present and may represent a northward continuation of Azania. However, the structural character of the Archean-Paleoproterozoic gneiss changes from south to north. In Yemen, Archean-Paleoproterozoic gneiss is structurally intercalated with Neoproterozoic arc assemblages, and in Saudi Arabia is pervasively reworked, as evidenced by small exposures of intact Paleoproterozoic granite, gneiss and schist and the imprint of Paleoproterozoic lead, strontium, and neodymium isotopes on Neoproterozoic granite. The Yemen exposures are referred to as the Abas and Al Mahfid terranes; reworked pre-Neoproterozoic crust in Saudi Arabia is referred to as the Khida terrane. Another change is that Neoproterozoic juvenile arc rocks re-occur east of the Archean-Paleoproterozoic gneiss in northern Somali, Yemen, and Saudi Arabia, where they reflect subduction in a late Cryogenian-Ediacaran ocean east of Azania. In the north, isotopic and geochronologic data strongly indicate a contact with pre-Neoproterozoic crust at the far northern edge of shield exposures in Sinai or in basement beneath Phanerozoic rocks farther north.

The time-space history of the ANS is based on a comprehensive data set of U–Pb and Rb–Sr ages and a smaller number of Sm–Nd and $^{40}Ar/^{39}Ar$ ages. Current U–Pb dating programs in the shield mostly utilize Secondary Ion Mass Spectrometry (SIMS), Thermal Ionization Mass Spectrometry (TIMS), and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) analyses of single zircons. Some programs use Pb/Pb evaporation techniques on zircon or U–Pb spot methods on titanite.

Early-middle Cryogenian arc assemblages dominate the southern part of the ANS, locally enclosing small amounts of Tonian arc rock in the Makkah batholith (Mk: Fig. 1); Erkowit batholith (E); the Kurmut Series (K); and in the Bulbul region of southern Ethiopia (Bu). Middle to late Cryogenian arc rocks dominate the north and east, and late Cryogenian-Ediacaran assemblages occur in the farthest most east in the Arabian Shield (Ar Rayn terrane) and the farthest most west in the Nubian Shield (Aswan area). Oceanic crust in the shield, represented by mostly forearc ophiolite complexes, ranges from 845 to 675 Ma; arc assemblages range from ~870 to 615 Ma. Arc amalgamation and suturing occurred between ~780 and 600 Ma, and accretion between the ANS and

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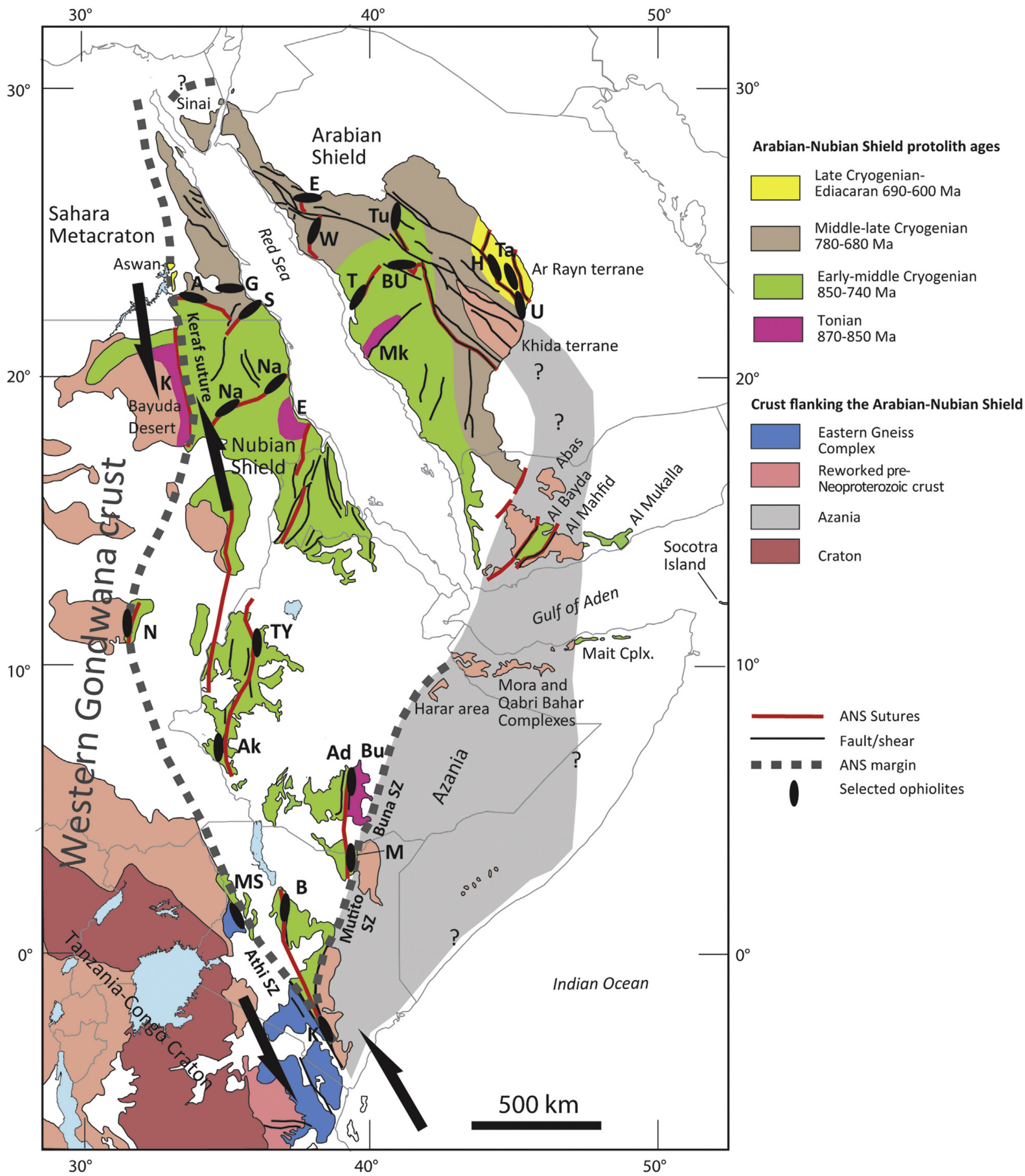

Fig. 1. The Arabian-Nubian Shield showing its exposure in Arabia, Northeast Africa, and the East African coast and illustrating its relation to older crust on its margins (after Fritz et al., 2013). Ophiolites schematically shown after Berhe (1990). A, Allaqi; Ad, Adola; Ak, Akobo; B, Baragoi; BU, Bi'r Umq; Bu, Bulbul; E, Jabal Ess; G, Gebel Gerf; H, Halaban; K, Kinyiki; M, Moyale; MS, Moroto-Sekerr; N, Nuba; Na, Nakasib; S, Sol Hamed; T, Jabal Thurwah; Ta, Jabal Tays; Tu, Bi'r Tuluhah; TY, Tuludimtu-Yubdo; U, Jabal Uwayjah; W, Jabal Wask. Arrows show sense of sinistral transpressive shear during final collision of ANS and the Saharan Metacraton.

the Saharan Metacraton reflecting terminal collision of the ANS and western Gondwana blocks, occurred ~650–580 Ma. Recent dating campaigns help clarify the magmatic history of the ANS. Six pulses of magmatism and, in some cases, associated migmatization and deformation, are recognized in the Nubian shield in Egypt: (1) 705–680 Ma, (2) ~660 Ma, (3) 635–630, (4) 610–604, (5) 600–590, and (6) 550–540 Ma (Lundmark et al., 2012). High-resolution ion-probe dating shows that post-tectonic granitoids in Sinai result from early Ediacaran calc-alkaline magmatism at ~635–590 Ma and middle Ediacaran alkaline magmatism at ~608–580 Ma (Be'eri-Shlevin et al., 2009). Significantly, the ages define a 15 million-year overlap of the two magmatic types at ~605–590 Ma such that the onset of alkaline magmatism apparently coincides with transitions in the calc-alkaline suite from mafic to felsic magmatism and a voluminous pulse of granodiorite to granite plutonism at 610–600 Ma. This refined dating demonstrates that a commonly accepted model