1- Geochemistry, provenance, and metamorphic evolution of Gabal Samra Neoproterozoic metapelites, Sinai, Egypt

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Abstract:

Metapelites are exposed at Wadi Ba'ba, east of Abu Zenima city; represent the northwestern extension of the Fieran-Solaf Metamorphic Complex, Sinai Peninsula, Egypt. The metapelites are characterized by qtz + pl (An(24-28)) + bt + grt +/- crd +/- sil mineral assemblage, indicating upper amphibolite facies with peak metamorphic conditions of 700 degrees C and pressures of 7 kbar, as determined by conventional geothermobarometeric methods. This resulted in incipient migmatization, forms patches of leucosomes and melanosomes. Geochemical investigation indicates that the precursor sediments of the metapelites had been deposited as immature Fe-rich shales from source materials of dominantly intermediate composition. Source area exhibited weak to moderate chemical weathering in a tectonically active continental marginal basin within a continental-arc system. A strong shallow-dipping foliation, characterizing the metapelites, was folded around an open antiform with sub-horizontal south plunging hinge.

Phase equilibria calculations in the KFMASH system indicate that the peak metamorphic conditions formed at 730-750 degrees C and 6.8-7.9 kbar. This was followed by a retrogression formed at 770-785 degrees C and 3.9-4.5 kbar. Hence, this implies an isothermal decompression and rapid exhumation of the metapelites from depth (25-29 km) in the lower crustal level at peak conditions, continuous to include shallow to middle crustal level (14-17 km), at overprint retrograde conditions. Subsequent isobaric cooling took place at 720-750 degrees C and 3.6-4.5 kbar. The resulting isothermal decompression followed by isobaric cooling clockwise P-T path of the metapelites is more likely, in which the high-temperatures attained maximum conditions during isothermal decompression were enhanced by heat flux, due to the presence of an active magmatic arc that formed on top of subducting young lithosphere. This is supported by a moderate geothermal gradient of 27-43 degrees C/km and dating compatibility of the Sinai granitoids and the metamorphic complexes. The P-T path segment records the tectonothermal histories of crustal thickening as a result of the East and West Gondwana collision at the metamorphic peak. This was subsequent by extensional and crustal thinning with syn-metamorphic magmatic intrusions, during P-T path retrogression, which resulted in the final assembly of the Arabian-Nubian Shield during Neoproterozoic.

Author Keywords: Metapelites; Sinai; Feiran-Solaf Metamorphic Complex; Provenance; P-T pseudosection

KeyWords Plus: CONSISTENT THERMODYNAMIC DATA; PARTIAL MELTING EQUILIBRIA; UPPER CONTINENTAL-CRUST; ROCK-FORMING MINERALS; ARABIAN-NUBIAN SHIELD; SEDIMENTARY-ROCKS; SOUTHERN ISRAEL; EASTERN DESERT; SE SINAI; MIXING PROPERTIES

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2- Geochemistry, geochronology, and Sr-Nd isotopes of the Late Neoproterozoic Wadi Kid volcano-sedimentary rocks, Southern Sinai, Egypt: Implications for tectonic setting and crustal evolution

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Abstract:

The Kid Group is one of the few exposures of Neoproterozoic metavolcano-sedimentary rocks in the basement of southern Sinai in the northernmost Arabian-Nubian Shield. It is divided into the mostly metamorphosed volcaniclastic Melhaq and siliciclastic Urn Zariq formations in the north and the mostly volcanic Heib and Tarr formations in the south. The Heib, Tarr, and Melhaq formations reflect an intense episode of igneous activity and immature clastic deposition associated with core-complex formation during Ediacaran time, but Urn Zariq metasediments are relicts of an older (Cryogenian) sedimentary sequence. The latter yielded detrital zircons with concordant ages as young as 647 +/- 12 Ma, which may indicate that the protolith of Urn Zariq schist was deposited after similar to 647 Ma but 19 concordant zircons gave a Pb-206/U-238 weighted mean age of 813 +/- 6 Ma, which may represent the maximum depositional age of this unit. In contrast, a cluster of 11 concordant detrital zircons from the Melhaq Formation yield a weighted mean Pb-206/U-238 age of 615 +/- 6 Ma. Zircons from Heib Formation rhyolite clast define a Pb-206/U-238 weighted mean age of 609 +/- 5 Ma, which is taken to approximate the age of Heib and Tarr formation volcanism. Intrusive syenogranite sample from Wadi Kid yields a Pb-206/U-238 weighted mean age of 604 +/- 5 Ma. These constraints indicate that shallow-dipping mylonites formed between 615 +/- 6 Ma and 604 +/- 5 Ma. Geochemical data for volcanic samples from the Melhaq and Heib formations and the granites show continuous major and trace element variations corresponding to those expected from fractional crystallization. The rocks are enriched in large ion lithophile and light rare earth elements, with negative Nb anomalies. These reflect magmas generated by melting of subduction-modified lithospheric mantle, an inference that is further supported by epsilon Nd(t) = +2.1 to +5.5. This mantle source obtained its trace element characteristics by interaction with fluids and melts from subducting oceanic crust during the Late Cryogenian time, prior to terminal collision between fragments of East and West Gondwana at similar to 630 Ma. Positive epsilon Nd(t) values and the absence of pre-Ediacaran zircons in all but Urn Zariq metasediments indicate minor interaction with Cryogenian and older crust. A model of extensional collapse following continental collision, controlled mainly by lithospheric delamination and slab break-off is suggested for the origin of the post-collision volcanics and granites at Wadi Kid. No evidence of pre-Neoproterozoic sources was found. Kid Group Ediacaran volcanic rocks are compositionally and chronologically similar to the Dokhan Volcanics of NE Egypt, which may be stratigraphic equivalents.

Author Keywords: Arabian-Nubian Shield; Sinai; Neoproterozoic; U-Pb zircon; Sr-Nd isotopes

KeyWords Plus: ARABIAN-NUBIAN SHIELD; EAST-AFRICAN OROGEN; NORTHWESTERN SAUDI-ARABIA; TABA METAMORPHIC BELT; ISUA GREENSTONE-BELT; U-PB ZIRCON; SE SINAI; TRACE-ELEMENT; CALC-ALKALINE; SUNDA ARC

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3-Geochemistry and metamorphism of the Pan-African back-arc Malhaq volcano-sedimentary Neoproterozoic association, W. Kid area, SE Sinai, Egypt

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Abstract

The northern part of the Kid metamorphic complex, SE Sinai Peninsula, Egypt, comprises a thick sequence of volcano-sedimentary association, defined as Mahlaq Formation. It is composed predominantly of rhyodacitic to andesitic, less commonly of subalkaline basaltic metavolcanics and metatuffs interbedded and intercalated with metapelites and metagraywackes. Their bulk rock chemistry indicates that the magmatic rocks have calc-alkaline affinity, and derived from island are - mid-oceanic ridge transitional regimes, presumably in a back-arc setting. Their peak mineral assemblages, mineral chemistry and calculated P-T metamorphic conditions indicate that the Malhaq association underwent metamorphism of lower amphibolite facies (480-570 degrees C/3-4 kbar), except the extreme northeastern part of upper amphibolite facies (645 degrees C/4.5-5.5 kbar). Geothermal gradients of the investigated metamorphic rocks range from 37 to 43 degrees C/km, may indicate that metamorphism took place in the upper plate of an active continental margin. Three deformation phases, D-1 to D-3, are recognized at the Malhaq nappe area, where peak metamorphic conditions occurred synchronous with the NW-directed thrusting during the D-2 phase. Possible heat sources during metamorphism is that resulted from heating contributing from the mantle derived magma in the documented arc environment in addition to the shear "stress" heating released during thrusting and stacking of the Malhaq nappe pile onto the older continental crust during the Pan-African orogeny. Metamorphic conditions increase northward coincident with NW-ward stacking propagation of the Neoproterozoic nappe that formed when the Mozambique Ocean had closed as a result of the assembly of East and West Gondwana during the Pan-African Orogeny. (C) 2008 Elsevier Ltd. All rights reserved.

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4- Metamorphic evolution of Neoproterozoic metapelites and gneisses in the Sinai, Egypt: Insights from petrology, mineral chemistry and K-Ar age dating

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Abstract:

Petrology, mineral chemistry, and age dating of the metapelitic schists and gneisses in three metamorphic complexes of Sinai have been studied and reported with the aims of characterizing the nature, type, and age of metamorphism as well as the metamorphic evolution of the Sinai metamorphic complexes. Nine representative samples of metapelitic schists, migmatites, and gneisses from the Taba Metamorphic Complex (TMC), the Kid Metamorphic Complex (KMC) and the Feiran-Solaf Metamorphic Complex (FSC) in southern Sinai Peninsula have been analyzed by electron microprobe for their mineral assemblages and K-Ar geochronological methods for biolite separates. Garnet from the metapelites and migmatites are almandine-rich and usually show zoning with variable X-Fe values.

The estimated P-T metamorphic conditions of the TMC range from 560-578 degrees C/3-4.5 kbar for the metapelitic schists, to 685 degrees C/5.3 kbar for the migmatites, while those for the metapelitic schists in the KMC are 590 degrees C/4-5.9 kbar in the Umm Zariq Formation, and 636 degrees C/4.7 kbar in the northern part of the Malhaq Formation. The P-T metamorphic conditions of the hornblende-biotite gneisses from the SZ of the FSC are 634-641 degrees C/4-5 kbar. These P-T conditions and mineral assemblages indicate amphibolite facies conditions of the LP/HT-type of metamorphism.

The K-Ar biotite cooling ages range from 594 to 617 Ma for the TMC, from 593 to 609 Ma for the KMC, and from 589 to 602 Ma for the FSC. It could be suggested that the cooling metamorphic ages of all complexes lie at approximately 600 Ma, and thus point to a uniform and single metamorphic event for the whole complexes in the southern Sinai Peninsula.

The estimated geothermal gradient is in the range of 30-50 degrees C/km. Such a steep gradient and the LP/HT mineral assemblages suggest that they were formed in an extensional setting and a heat flow was transferred from nearby granite intrusions. (c) 2007 Elsevier Ltd. All rights reserved.

Author Keywords: metamorphic complexes; K-Ar age dating; neoproterozoic; Sinai; Arabian-Nubian Shield

KeyWords Plus: ARABIAN-NUBIAN SHIELD; MOZAMBIQUE BELT; SOUTHERN ISRAEL; SOUTHEASTERN SINAI; EASTERN DESERT; WADI KID; SE SINAI; CORE COMPLEX; AFRICAN; PENINSULA

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5- The texture and composition of tourmaline in metasediments of the Sinai, Egypt: Implications for the tectono-metamorphic evolution of the Pan-African basement

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Abstract:
Accessory tourmaline in metasediments from the Sinai crystalline basement exhibits textural and chemical signatures that relate to the evolution of regional metamorphism and deformation during the Pan-African orogeny and testifies to different P-T path segments. Tourmaline inclusions in various porphyroblasts were formed during the prograde phase of metamorphism; acicular to prismatic crystals in the matrix, oriented sub-parallel to, and enveloped by, the main foliation crystallized syntectonically under prograde and peak metamorphic conditions; tourmaline cross-cutting the main foliation may have formed just after the peak or during the retrograde phase of metamorphism. Some of the cores in tourmaline crystals, showing different colours, are interpreted as former detrital grains. The abundance of tourmaline decreases with increasing peak metamorphic conditions. The tourmaline investigated belongs to the schorl-dravite(ss) group, generally with X-Mg of 0.42-0.73 and X-Ca = Ca/(Ca+Na+K+square) of 0.02-0.24, typical of tourmalines in metapelites and metapsammites; whereas detrital cores have been derived from various sources, including former tourmaline-quartz and pre-existing high-metamorphic rocks. Tourmaline of the Sinai metasediments was formed during metamorphism of the sedimentary precursors, essentially in a closed system, where clay minerals and organic matter, together with detrital tourmaline, served as the source of boron. Although a metamorphic facies should be defined by characteristic mineral assemblages present in metamorphic rocks, tourmaline chemistry is a good monitor of P-T conditions in the metapelites and semi-metapelites investigated, showing an increase in X-Mg with increasing metamorphic grade, where X-Mg(tur) = 0.60 distinguishes between greenschist and lower-amphibolite facies, while X-Mg(tur), = 0.65 could distinguish lower- from middle- to upper-amphibolite facies. The results of tourmaline-biotite geothermometry compare well with our former temperature estimates using conventional geothermometry and phase-diagram modelling.

***Author Keywords**: tourmaline; Pan-African; Sinai; metasediments; metamorphic grade; tourmaline-biotite geothermometry; boron*

***KeyWords Plus**: ROCK-FORMING MINERALS; ARABIAN-NUBIAN SHIELD; SOUTHEASTERN SINAI; CRUSTAL EVOLUTION; WADI KID; SE SINAI; BELT; PENINSULA; EAST; GEOTHERMOMETRY*

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Orthogneisses from the Taba Metamorphic Belt, SE Sinai, Egypt: Witnesses for granitoid magmatism at an active continental margin

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Abstract

The gneisses of Taba Metamorphic Belt (TMB) are classified in terms of field, structural, mineralogical and geochemical criteria into two suites of different ages. The older suite, concentrated in the northern part of the study area, comprises three relatively highly deformed gneiss types of predominantly quartz-dioritic to tonalitic composition. These orthogneisses are composed of oligoclase-andesine, amphibole, biotite and quartz with occasional almandine-rich garnet in the older two types. Amphiboles occurring in these gneisses range from edenite to paragasite for type-II; actinolite to magnesio-hornblende for type-III. Geochemically, the older suite is calc alkaline, and strongly to mildly peraluminous. P-T conditions of the older gneiss suite estimated for the garnet bearing samples, conform to the medium-pressure amphibolite facies. Individual samples yielded average temperatures between about 620 and 660 degrees C and average pressures between 4.6 and 6.2 kbars.

The younger suite comprises three less deformed gneiss types ranging in composition from quartz-monzonite to alkali-granite. In contrast to the older suite, these gneisses are concentrated mainly in the southern part of study area, except for the youngest type that intrudes older gneisses of the northern part. The main mineral phases are plagioclase, K-feldspar, quartz and biotite. In addition, the quartz-monzonitic gneisses of type-IV contain amphiboles of edenite to ferro-edenite composition. The plagioclases are oligoclase to albite in type-V and -VI and andesine to oligoclase in type IV. The abnormal mineralogical and geochemical characteristics of type-IV are attributed to the assimilation of gabbroic rocks, documented in mafic xenoliths. The younger orthogneisses have alkaline to transitional calc-alkaline and mildly peralumious to metaluminous affinities.

The Taba gneisses are derived from calc-alkaline, subduction-related are granitoids which were emplaced along an active continental margin during the pre- to syn-collision stage. Gneisses of similar provenance an known from other occurrences in the Sinai Peninsula and the Eastern Desert in the Arabian-Nubian Shield of Egypt.

Author Keywords: orthogneisses; geochemistry of meta-igneous rocks; mineral analyses; geotectonic setting; P-T conditions of metamorphism; Arabian-Nubian Shield

KeyWords Plus: CRUSTAL EVOLUTION; EASTERN DESERT; ROCKS; CLASSIFICATION; CONSTRAINTS; INDICATORS; HORNBLENDE; PRESSURE; COMPLEX; ORIGIN

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Metapelitic assemblages in the Umm Zariq schists, central western Kid Belt, Sinai Peninsula, Egypt

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Abstract:

The Kid Belt, one of the four metamorphic belts constituting the Pan-African basement of the Sinai Peninsula, underwent two main phases of ductile deformation and regional metamorphism ranging in grade from the greenschist facies in the south to the upper amphibolite facies in the northeast. In the central western part of the Kid Belt, metapelites of the Umm Zariq Formation display the following mineral assemblages (always + quartz + plagioclase An(20-38) + ilmenite):

(i) garnet + biotite + muscovite +/- andalusite,

(ii) garnet + staurolite + biotite + muscovite +/- cordierite +/- andalusite,

(iii) garnet + cordierite + biotite + muscovite andalusite (rare) sillimanite, testifying to the low pressure type of metamorphism under PT-conditions of the lower amphibolite facies. Conventional geothermobarometry yielded peak metamorphic temperatures around 570 degreesC and pressures of about 4 kbar. Conformable results were obtained from a petrogenetic grid, calculated in the system KMnFMASH and applied to a sample with the low-variance assemblage (ii). The PT-area for the formation of the near-peak assemblage andalusite-staurolite-garnet-biotite extends from some 3 to 4 kbar and 540 to 590 degreesC. Calculations on this mineral assemblage (+ plagioclase + muscovite + quartz) with the internally-consistent thermodynamic data set of HOLLAND & POWELL (1998) yield similar PT-conditions of 4.2 +/- 0.9kbar and 591 +/- 28degreesC (2delta).

Author Keywords: Kid Belt; Sinai; Umm Zariq schists; metapelites; geothermobarometry; petrogenetic grid

KeyWords Plus: CRUSTAL ACCRETION RATES; ARABIAN-NUBIAN SHIELD; SOUTHEASTERN SINAI; TRIPLE POINT; SE SINAI; MUSCOVITE; GEOTHERMOMETRY; TECTONICS; COMPLEX; BIOTITE

Contact metamorphism and metasomatism at a dolerite-limestone contact in the Gebel Yelleq area, Northern Sinai, Egypt

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Abstract:

At the northeastern flank of Gebel Yelleq, northern Sinai, pure limestones of Upper Cretaceous age were subjected to a thermal overprint, caused by a c. 80 m thick Tertiary olivine dolerite sill. Metasomatic supply of Si, Al, Fe, Mg and Ti was greater to the c. 7 m wide upper than to the c. 25 m wide lower thermal aureole. The greater width of the lower aureole is possibly due to a longer duration of the thermal overprint at this contact. Mineral assemblages in both aureoles are (from the contact outward):

(i) clinopyroxene + garnet +/- wollastonite + calcite

(ii) garnet +/- wollastonite + calcite;

(iii) wollastonite + calcite.

In places, late stage xenoblasts of apophyllite and witherite overgrow these assemblages. Garnets are grandites to melanites with Grs(56-86)Adr(14-42)Sch(0-2)Sps(0-0.2)Prp(0) in the lower, and Grs(29-94)Adr(5-64)Sch(0-12)Sps(0-0.2)Prp(0-1.7) in the upper aureole. Close to the upper contact, clinopyroxene is virtually pure diopside with X-Mg = Mg/(Mg + Fe2+) = 0.97-1.0, whereas clinopyroxenes farther away from the upper contact and in the lower aureole have X-Mg-values of 0.49 and 0.53, respectively.

The minimum temperatures reached during contact metamorphism in the upper and lower aureole are defined by the lower stability limit of wollastonite. The temperatures are inferred with a calculated T-X(CO2) projection in the system CMASCH and are estimated at c. 290 degreesC and 380 degreesC for X(CO2) values of 0.05 and 0.25, respectively. A pressure of roughly 100 bar is estimated for the lower dolerite-limestone contact. As indicated by one-dimensional thermal modelling, a maximum temperature of 695 degreesC was attained at this contact, assuming a magma temperature of 1150 degreesC. Further modelling results indicate (i) wollastonite, which occurs first 13 m away from the lower contact, formed at a maximum temperature of c. 575 degreesC, (ii) there, wollastonite formation lasted for approximately 170 years and, (iii) at the outer rim of the lower aureole, the maximum temperature reached was 480 degreesC, and temperatures sufficient for wollastonite formation lasted for about 140 years.

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