Precambrian evolution of Afro-Arabian crust from ocean arc to craton: Discussion

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In a highly interesting and informative paper on the evolution of the Afro-Arabian crust, Engel and others (1980, p. 700) contend that the lithologic features of the Pan-African system of the Arabian-Nubian Shield "are similar in most respects to the much older greenstone belts that characterize many of the Archean terranes of the Earth." This is true in the sense that the Pan-African of Egypt and Saudi Arabia is dominated by volcanic rocks and volcanogenic sediments, but in detail, the similarity is less evident; many facies represented in the Nubian Shield are perhaps more similar to those characteristic of the Apalachian and Alpine systems. The following points are made in favor of the Appalachian analogy.

KOMATIITES IN THE NUBIAN SHIELD

Engel and others (1981) stated that large volumes of mafic to ultramafic magmas were intruded, mainly as sills, into the wacke-rich matasediments of the Eastern Desert, the sills approximating basaltic komatiite in composition with MgO values of 20 wt %. However, it seems doubtful that komatiitic rocks are quantitatively very important in the Eastern Desert—if they exist at all. Most ultramafic rocks represent parts of dismembered ophiolites occurring as olistoliths, tectonic intercalations, and, perhaps, sedimentary serpentinites. The ultramafic rocks that might be referred to as komatiite represent a small group of relatively fresh ultramafic-mafic cumulate sequences which often carry nickel sulfides. Along with the bodies of El Genina and Gabbro Akarem (A.M.A. Hafez, unpub. data) the occurrence described by Dixon (1979) at G. Dahanib is but one of a series of intrusive bodies located along a west-northwest line extending toward Kom Ombo on the Nile. On the map of Egypt (El Ramly, 1972), they are identified as "gabbros."

The composition of olivine associated with massive chromite (sample 114-D in Table IV-4a of Dixon, 1979; Dixon, 1981, Table 2) of the G. Dahanib body varies from Fo 93.8 (114-D) to Fo 88.7 (114D-3). Using a Kd FeO/MgO value of .3 (Roeder and Emslie, 1970), the minimum and maximum FeO/Mg values of the corresponding liquid would be .39 and .75, respectively. Although the value of .39 is commensurate with the FeO/MgO value of .37 estimated by Dixon on the basis of an outcrop weighted average of the major rock types, it should be remembered that olivine and chromite readily exchange FeO and MgO under subsolidus conditions. (For example, the composition of olivine associated with massive chromite in ultramafic rocks of the Finero Massif of the Alpine Ivrea zone varies from Fo 96.2 for olivine inclusions within chromite layers to Fo 91.5 for olivine away from the chromite layers.) Consequently, the FeO/MgO value of .75 may be more representative of the primary liquid composition, and, given the uncertainties in estimating liquid compositions from area-weighted abundances, the case for widespread Egyptian komatiites similar in chemistry, petrography, and stratigraphic disposition to Archean komatiites requires clarification. Chemically, the G. Dahanib cumulates are similar (high An plagioclase with relatively low Fo olivine) to the island-arc cumulates described by Stern (1979) from the Marianas.

OPHIOLITE OBDUCTION AND EXOGEOSYNCLINAL FLYSCH

Ultramafic-bearing rock units of the Eastern Desert of Egypt designated as "geosynclinal metasediments" on the geological map of Egypt (El Ramly, 1972) include graphitic shale, mudstone, turbidite, cobble (Atud) conglomerate, and olistostrome units. The latter contains blocks and cobbles of ophiolitic material, including kilometre-size olistoliths of serpentinite, as well as blocks of dynamothermally metamorphosed amphibolite, chert, black carbonate, granitoids, felsic volcanic rock, and quartz-rich graywacke (El-Bayoumi, 1980; El-Sharkawy and El-Bayoumi, 1979). As such, the "geosynclinal metasediments" resemble (Church, 1979) the early-stage "exogeosynclinal" flysch deposits of the Appalachian (Stevens, 1970; Williams, 1979) and Alpine systems (Elter, 1971; Hall, 1980). Rock assemblages of this kind have not been described from the Archean.

The blocks of quartzose graywacke are of particular interest because they contain clastic grains of both chromite and quartz, as well as felsic volcanic rock and mica schist. Similar quartz-rich graywackes are also prominent in the allochthonous sequences of the western margin of the Appalachian system (Stevens, 1970; Hiscott, 1979) and have also recently been described among sedimentary units structurally underlying ophiolites of the Jabal Idsas region of the eastern part of the Saudi Arabian Shield (Anonymous, 1980, p. 55). In the case of the Appalachians, the graywackes are generally conceded to have been derived in part from the ophiolite and underlying continentally derived slope and rise sediments of an oceanic nappe complex that attempted to move over the collapsed western continental margin of the Appalachian system dur-

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ing the early Ordovician (Stevens, 1970; Williams, 1975; Hiscott, 1979). While it is understandably tempting to interpret the mélange units and serpentinites of the Eastern Desert as accretionary prism rocks (if such indeed exist!), the Alpine-Appalachian obduction model of ophiolite-nappe emplacement (or continental-margin subduction) may well provide a more valid rationalization of their origin. In either case, analogy with Archean geology is not evident.

ORIGIN OF THE NUBIAN SHIELD "BASEMENT" METASEDIMENTS

Geologic relationships in the Marsa Alam region (the most easterly part of the Eastern Desert; Church, 1979, Fig. 1), although much complicated by faulting, suggest that less-deformed proximal sediments structurally overlie more-deformed distal sedimentary units and intercalated volcanic sequences and that the relatively more-coherent ophiolite sheets of the region tend to form the uppermost units of the nappe pile. This has been corroborated by the mapping of El Bayoumi (1980) and Mr. F. Basta to the southeast of Marsa Alam and by Shackelton and others (1980) in the Barramiya region. Downward within the nappe sequence, high strain zones that involve the development of mylonites become more prominent, and metamorphic grade appears to increase relatively rapidly within the psammitic, calc-siliceous, and amphibolitic "basement" rocks of the Hafafit (southeast of Marsa Alam; Hashad, 1980; Hassan, 1973; Abdel-Khalek, 1979) and Meatiq (east of Quseir; Hashad, 1980, Fig. 4; Church, 1979, Fig. 1) domes. In Wadi Miyah of the Barramiya region (34° 33′; 25° 12′; Hafez and El-Amin, 1981), a thin ophiolitic slice occurs intercalated with pebbly psammitic and andalusite-rich pelitic schist, whereas at Hafafit chromiferous actinolite schist, representing residual reaction rims to serpentinite slivers, are commonly present as lenses in garnet-bearing psammitic and metavolcanic schists. Such occurrences are a feature of psammitic and metavolcanic units of supposed slope and rise facies beneath the internal ophiolite/olistostrome units of the Appalachians [for example, within the westernmost (highest) structural units of the Fleur de Lys Supergroup of Newfoundland; Williams, 1977; Church, 1978; and the Sutton Bennet schist belt of Quebec and Vermont]. In the latter region, downward within the structural succession, ophiolitic rocks become progressively more disrupted and metamorphosed, and relict blueschist assemblages are present in the lower units (Laird and Albee, 1981). In contrast, the highest ophiolite slice is overlain by a relatively coherent flysch sequence containing a component of ophiolitic debris; in this respect, analogy may be stuck with the well-preserved Bir Fawkhir ophiolite of the Eastern Desert and the Jebel Ess ophiolite of northwest Saudi Arabia (Shanti and Roobol, 1982, Map 1, "Shale and laminated Chert" unit).

Consequently, even though it may well eventually prove true that the metamorphic gradient was initially continuous through the geosynclinal "cover" into the Hafafit-Meatiq "basement," the former presently being separated from the latter by a décollement–listric-fault thrust zone (or zones of quite different ages and vergence; Abdel Khalek and Abdel-Wahed, 1982; Kroner and others, 1982; Struchio and others, 1982) located either at or near the "basement-cover" contact, field relationships in the case of the Eastern Desert do not support the view that the higher metamorphic grade schist units structurally overlie on a regional scale rocks of the ophiolitic "geosynclinal sequence." In this case, the Hafafit, Meatiq, and Abu Swayel (marble-pelite-amphibolite terrane) schists, as well as equivalent rock units (Kashebib) in the Sudan (Anonymous, 1981; Vail, 1982), even if not "old basement," may nevertheless represent continentally derived shelf or slope-and-rise deposits intercalated with mafic-felsic volcanics of presently undetermined affinity. A Sm-Nd radiometric study of the psammitic-pelitic metasediments of the Hafafit and Abu Swayel regions may help to resolve the uncertainty.

PAN-AFRICAN PLATE TECTONICS

Pan African development in the Eastern Desert of Egypt may be neither strictly ensialic or ensimatic. Rather the geology as we presently see it is perhaps the end product of a complex sequence of events involving the development of one or several rift zones propagated within a zone of more general intracontinental crustal attenuation. In this case, partial analogy might be sought with the Australia–New Zealand-Tonga-Papua region of the southwest Pacific, or the overlapping (in time and space) Appalachian-Hercynian systems of Western Europe and eastern North America. Re-thickening of the crust would result from compression and the addition of granitoid material obtained by fractional melting of mantle-derived tholeiitic rock plastered underneath the reconvergent plates. Other Pan-African systems, containing little or no volcanic component, may represent the abortive scars of less-successful attempts at continental fragmentation—a possibility that applies equally to many early Proterozoic systems. The nature of orogeny—oceanic crust or no oceanic crust—may therefore reflect differences in the nature, size and efficiency of the convecting system, particularly the degree of focus of the heat-transfer system.

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