Megaconglomerates of the Pan-African Orogeny – Intramontane-Freshwater-Basin-Deposits? With special emphasis to the Central Eastern Desert, Egypt.

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Abstract. Megaconglomerates are characterised in this paper as sedimentary load with average coarse to pebble size grained clastics and occurrences of very coarse boulder after the definition of BLAIR & McPHERSON (1999). In this paper two examples of megaconglomeratic depositions of several areas within the Pan-African orogeny are compared with an approach to prove the deposition in intramontane basins. The conglomerates of the Late Proterozoic Hammamat successions in the Central Eastern Desert, Egypt are similar and of the same age like the Saramuj conglomerate of southwestern Jordan and deposited in an alluvial fan controlled environment. Evidences for glacial influences within the Snowball-Earth event were not found in the Hammamat sediments and Mn-enrichment in the Saramuj conglomerate proves a subtropical climate.

Introduction

In a German-Egyptian-Research Project, in which the volcanological succession and their geochronological context of the late Proterocoic Dokhan volcanics is being investigated, several section logs were taken. During this recent field trip huge successions of megaconglomerates have been documented and will be investigated now more in detail to show the synvolcanic sedimentation of molasse-type Hammamat sediments in an intramontane freshwater basin in the course of the Pan-African orogeny.

The evolution of the Pan-African Orogeny includes the closing of three paleooceans (Trans-Sahara-Ocean, Adamaster-Ocean and the Mozambique-Ocean) (SCHANDELMEIER et al. 1999) between 900 and 550 Ma (UNRUG 1992).

During the Panafrican Orogeny (Tectono-Thermal Event; according to OSMAN 1996), the Arabian-Nubian Shield (ANS) was formed by accretion of parts of north-east Africa (Eastsahara-Craton, Nile-Craton), parts of Arabian Peninsula (POHL 1998) and other terranes.

According to POHL (1998) the ANS formation is divided into three cycles: The first, 1200 to 780 Ma (DIXON 1981), describes an E-W tending flat-angle subduction, connecting with island-arc magmatism.

The second cycle (780 to 650 Ma) is characterized by a weak regional metamorphosis (greenshist). Calc-alkaline granitoids migrated on tectonic pathways through the continental crust (KHALAF 2002, POHL 1998).

The final cycle (600 to 540 Ma (POHL 1998; KHALAF 2002) is characterized by a general uplift of the crustal blocks, causing NW-tending strike-slip faults, strong extensions and followed by bimodal magmatic activity, and sedimentation of synorogenic sediments (molasse type sediments) (POHL 1998; KHALAF 2002).

Geological Setting

The study area is located west of the Red Sea at the northern exposure of the Neoproterozoic basement around the area of Gabal el-Urf and Gabal el-Kharaza (Fig.1).

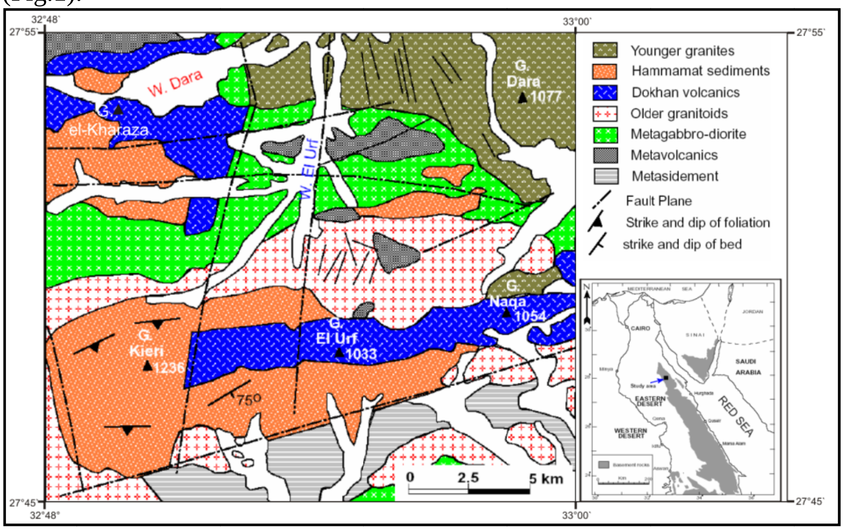

Figure 1 Geological map of the study area around Gabal el-Urf and Gabal el-Kharaza, Wadi Bali is situated more southward and not marked in this map (according to ELIWA 2007).

GABI et al. (1990) distinguished the basement in three rock groups. The first group are the pre-Panafrican, higher metamorphosed rocks e.g. migmatites and granite-gneisses (JAHN 1996).

This group is overlain by a Panafrican rock assemblage, which is usually determined by island arc and ophiolite complexes (OMV) (GABI et al. 1990). GABI et al. (1990) also counted a tectogenetic rock association (YMV) to this group, which is determined by JAHN (1996) as a Cordilleran-stage association in the late Precambrian. A bimodal magmatism with acid plutonites (pink granites), volcanites and subvolcanites (Dokhan Volcanites, post-Hammamat felsites and molasse-type Hammamat Sediments) is characteristic (JAHN 1996).

The last group is the Phanerozoic alkaline rock association (mostly intruded S-type granites and restricted volcanic rocks), which describes the basement complex after the Panafrican orogeny to the Paleogene.

Due to the northward motion of Africa towards Laurasia, beginning in early Eocene, the rifting of the Red Sea and Gulf of Suez was mostly initiated in the Oligocene (MESHREF 1990). Therefore formations of Egyptian Proterocoic are comparable with those is exposed on the Sinai and Arabian Peninsula.

Hammamat Sediments occur interfingered with the upper member of the Dokhan Volcanics (Khalaf et al. 2000; STOPORA & ZIMMERMANN 2007) and display characteristic structures of intramontane, freshwater basin sedimentation (AHMED et al.1989; KHALAF 2004; ABDEEN & WARR 1989; STOPORA & ZIMMERMANN 2007).

The Megaconglomerates within the Hammamat formation occur in the study area around Gabal el-Urf and Wadi Bali, more southward of Gabal el-Urf (STOPORA & ZIMMERMANN 2007). Other Megaconglomerates are described in southwest Jordan as the Saramuj Conglomerates (JARRAR et al. 1991, 1993).

Conglomerates of Gabal el-Urf and Wadi Bali

Structure and texture

The described megaconglomerates at Gabal el-Urf appear with an approximately thickness of 20 meters, interrupted by several andesitic dyke intrusions. In the area of Wadi Bali the megaconglomerates expose a thickness of about 30 meters (Fig. 2).

The conglomerates show a polymictic, clast supported and ungraded character, whereas differences in matrix composition are visible (STOPORA & ZIMMERMANN 2007). These coarse grained conglomerates have an average grain size between 15 and 30 cm, nonetheless blocks up to 2 meter in diameter are common, especially in Wadi Bali. The upper and the lower base are sharp and erosive, partly interfingered with coarse grained volcanoclastic deposits. In generally the conglomerates are massive and ungraded (STOPORA & ZIMMERMANN 2007). The clasts as well as the matrix components are well to very well rounded.

The composition of the components is mainly characterized by ca. 40 % volcanoclastics (including ca. 60 % ignimbrite, ca. 30 % andesite); ca. 20 % white-grey granite; ca. 10 % metamorphic rocks (Fig. 3).

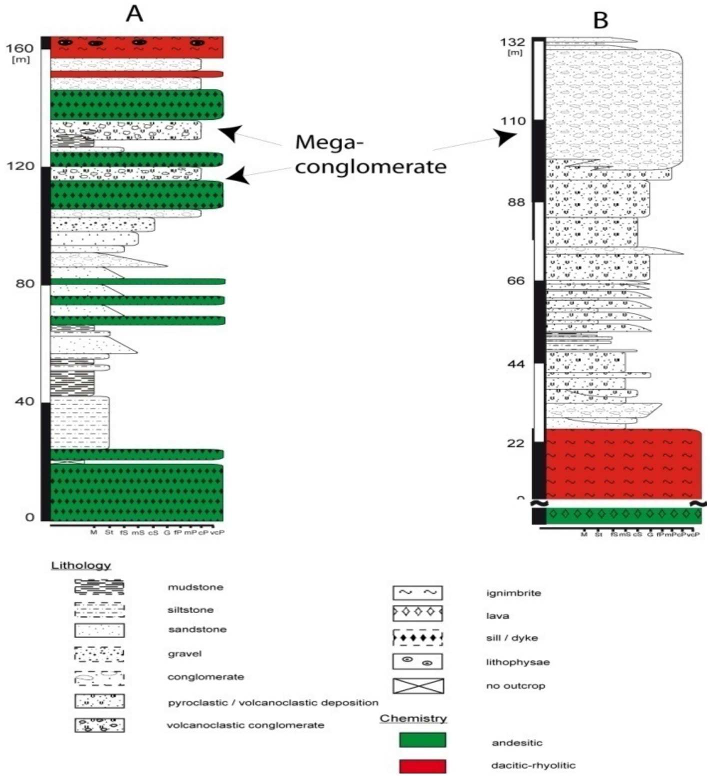

Figure 2 Columnar sections of exposure at A) Gabal el-Urf and B) Wadi Bali. The andesitic dykes in A intruded in the conglomeratic strata later (According to STOPORA & ZIMMERMANN 2007)

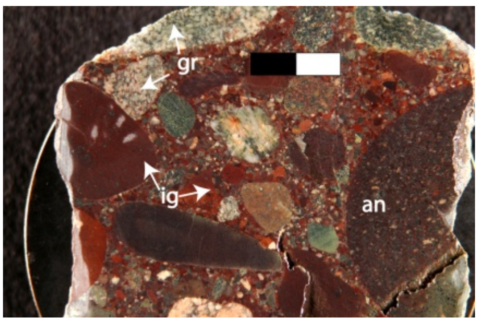

Figure 3 Section photography from conglomeratic strata near Gabal el-Urf (gr-granite, an-andesite, ig-ignimbrite)

Conglomerates of Southwest Jordan

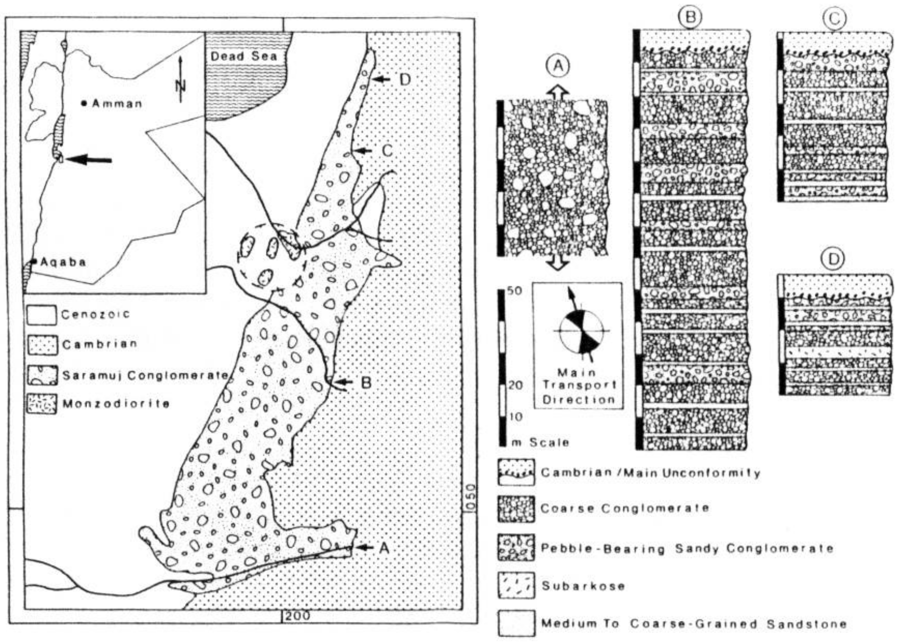

Figure 4 Columnar sections within the type locality of the Saramuj conglomerate, and paleoflow direction. The paleoflow direction was determined by cross-stratified sandstones, pebbly sandy conglomerates and imbricated coarse conglomerate horizons (JARRAR et al. 1991).

Structure and texture

The polymictic Saramuj conglomerates are exposed with an thickness of about 200 meters and have been distinguished by JARRAR et al. (1991) into three lithofacies types: 1) Ortho-conglomerates (massive or horizontally stratified, clast-supported coarse conglomerates); 2) Para-conglomerates (pebble-bearing sandy conglomerates); 3) Medium to coarse-grained sandstones.

The clast supported Ortho-conglomerates are characterized by an average grain size of 5 to 30 cm, but blocks up to 4 x 2 m are also mentioned. The conglomeratic unit varies from less than 1 m up to 30 m with sharp lower and upper contacts. Similar to the Egyptian conglomerates the Saramuj conglomerates appear massive with no significant differences in grain-size changes vertically and laterally.

The roundness of the clasts ranges from well rounded to sub-angular, whereas the degree of roundness decreases with decreasing of clast-size (JARRAR et al. 1991).

A sandy matrix-supported, unstratified monomictic conglomerate is described as deposition in the vicinity of megablocks and contain angular to subangular adamellitic clasts.

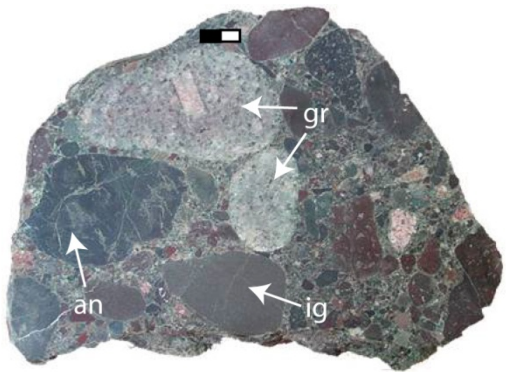

Figure 5 Burj conglomerate from southwest Jordan. An example of the Saramuj conglomerate within the Araba complex (gr - granite, an - andesite, ig - ignimbrite)

The composition mostly consists of granite (white-grey granites and monzogranites), volcanics (latites (9 %); dacites (24 %); rhyolites (14 %) and metamorphic rocks (1 %) (JARRAR et al. 1991).

Depositional Conditions of Megaconglomerates

Sediments can be transported either as suspension, solution or as bed load. The structures, textures and the maximum particle size (MPS) record the conditions of sedimentation of these deposits.

The MPS of both examples ranges from 2 m (Wadi Bali) to 4 m (southwest Jordan), so that the physical sediment transport processes were restricted to 1) Bed load of water gravity flows; 2) Ice gravity flows as push, entrained or raft load; 3) Sediment gravity flows as debris flow, slide or slump; 4) rock gravity flow and 5)Volcanic-Ejecta gravity flows (BLAIR & McPHERSON 1999).

Including the structural and textural informations, the deposition is limited to fluvial environments and debris flow alluvial fans (JARRAR et al. 1991; BLAIR & McPHERSON 1994; COLLINSON 1996). BLAIR & McPHERSON (1994) consider for alluvial fans most typical slope values of 2° to 12°, and for hydraulic effects a well suited drainage basin to provide huge masses of water either from snowmelts or major precipitation events.

According to JARRAR et al. (1993) the depositional time span of several Pan-African molasse sediments (including the Hammamat Sediments of Egypt and the Saramuj Conglomerates of southwest Jordan) is relatively short with ca. 10 Ma, what indicates a strong upheaval (JARRAR et al. 1991).

Collision-Related Basins

Three collision-related basins can be distinguished in intramontane basins, basins resulting from continental extrusion and Pannonian-Type basins (EINSELE 2000).

Intramontane basins evolve in a late orogenic cycle and suppose to be elongate and narrow in shape. In spite of strong strike-slip components, syn-depositional basin segmentation these basins primary results from extension and late compressional phase. The high sediment supply is recorded during the opening phase by a fining upward and following coarsening upward megasequence and is caused by a high-relief sediment source (EINSELE 2000). Volcanics and volcaniclastics are common and contribute to the rapidly filling.

Basins resulting from continental extrusion generally result from gravitational orogenic collapse and lateral extrusion and are normally dominated by transtension (EINSELE 2000). According to EINSELE (2000) they show in many aspects a similar occurrence as the intramontane basins.

Pannonian-type basins, located on thinned continental crust, are more complex, while subbasins may show a diachronous subsidence and different coeval depositional environments of their sediment fills (EINSELE 2000). The sedimentation tends to be uniform, contributing to the late-stage evolution, and mostly characterised by fluvial, lacustrine to deep-marine deposition (EINSELE 2000).

Discussion and Conclusion

The described conglomeratic depositions are difficult to compare without considering the whole lateral and vertical extensions of the units, what seems to be difficult because of the restricted distribution especially of the Hammamat sediments resulted from the development of the Najd shear system during the late Pan-African and even more during the recent Red Sea rift (WILDE & YOUSEF 2002). The deposition took place during a short time period between 600 and 590 Ma (JARRAR et al. 1993) and within the late orogenic cycle of the Pan-African orogeny.

JOHNSON (2002) noticed that it has been generally accepted that the Ediacaran events in the East-African orogeny where driven by the global convergence of East and West Gondwana, connected with broadly east-west shortening and mostly northwest strike-slip movements. For the core of the East-African orogeny JOHNSON (2002) presented a foreland basin system in west Saudi Arabia during the late second cycle of the Pan-African orogeny before general uplift. He mentioned for these basins (<670 to >650 Ma) shallow marine clastic and carbonate deposits.

The marine influence is disappeared in the final stages of the Pan-African orogeny as the examples had shown, either on the east or west side of the orogeny belt. The section logs give also no significant evidences for subaquatic deposition, although water supply and drainage system may have played an important role as the lower part of the sedimentary successions in Egypt and the imbricated conglomeratic strata of Southwest Jordan revealed. These deposits are closely connected to braided river systems or overbank deposits of distal and proximal alluvial fan deposits.

For this investigated examples the deposition by ice movement while Snowball-Earth event is not credible because of the missing of characteristic structures of components. Furthermore JARRAR et al. (1991) mentioned a MnO_2 content up to 58 % in sandstones, what he interpretated as a result of a subtropical climate.

It is to presume that the depositional conditions are characterised by a well formed drainage system and active tectonic uplift or strong subsidence with very high slope values ranging from at least 2° to maximum 25° (BLAIR & McPHERSON 1994).

Provenance analyses could solve the question of deposition in an intramontane basin or deposition in basins resulting from continental extrusion, but northwest tending strike-slip movements should be clear determined before. This is difficult to realize because of the isolated outcrops depending on Wadi incisions. WILDE & YOUSEF (2002) presumed that the Hammamat successions were deposited in a northward tending more than 1000 km long interconnected basin system with an southerly provenance. Furthermore provenance analyses may show if there is a connected basin system or a system of isolated basins.

- The deposition in a tectonic active basin system is proved by the connected volcanics and volcaniclastics, the high amount of sediment supply (for Saramuj conglomerate a sedimentation rate of approximately 0.6-0.8 mm/a) (JARRAR 1991) and the very high slope value.
- To distinguish whether it is an intramontane basin or continental extrusion caused basin deposit the structure and texture analyses at isolated outcrops is not enough.

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