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IMPORTANCE OF THE PETROLOGICAL APPROACH IN STUDIES OF THE DESERTIFICATION IN NORTHERN SAHARA

Abstract: Desertification including dune field expansion depends on the changes of the natural environment. Recognition of the reasons of this process is possible from the dune material studies. The petrological analysis evidenced that a local material is the sediment source in the most of the dune fields in the Sahara northern margin. Appreciable contents of the minerals poorly resistant to abrasion and similarity of the dune material to the basement sediments are the indicative features.

Keywords: mineralogical-petrological composition, desertification, dune, northern Sahara

INTRODUCTION

The rate of desertification, especially formation and expansion of dune fields, depends on the amount of the material available for deflation, properties of the material, wind velocity and direction, humidity of the deflated area and vegetation type, and morphometry of the basement (Coque 1962). Many of these factors are variable even in short time and within one dune field. The studies performed in 1994 in the Sahara northern margins aimed at the reasons and rate of desertification, determination of the sedimentation environment type, source of the sediments and eolization degree (Mycielska-Dowgiałło 1995).

The source of the material and the eolization degree may be determined from textural features and mineral composition of the sediments. This is dependent on the mode of transport of the dune material, most strongly abraded during eolian processes (Kuenen 1960). Eolian abrasion quickly removes the components of poor mechanic resistance, yielding material consisting of resistant minerals. The studies concerned light fraction (quartz, feldspars, gypsum) and lithic components (marls, various limestones and ferruginous-clayey clasts). The heavy fraction was studied especially carefully.

Type of granulation, average grain size and sorting degree are the basis of the eolization degree estimation (Mycielska-Dowgiałło 1995). Intense coating of grains in hot climate (unlike absence of coating in temperate climate) precludes the use of matt surface of the grains as the eolization index (Kuenen 1960).

Several quickly expanding dune fields in the territories of Morocco, Tunisia and Egypt, of variable environments and changeable eolization intensity, were selected for the studies.

INVESTIGATION METHODS

Microscope determination of the mineral and lithologic composition of the dune sediments and basement rocks in granular preparations, heavy fraction inclusively, was the main investigation method (*see e.g.* Barczuk 2002; Chlebowski, Lindner 1992). The studies

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were performed on the sandy samples not separated into granular fractions because the ranges of the drain dimensions in the samples were very narrow. The composition of the heavy mineral fraction was studied in the grain class 0.1-0.2 mm. Structure, texture and mineral composition were investigated by means of various techniques of the polarisation and scanning electron microscopy, as described *e.g.* by Borkowska, Smulikowski (1973).

Granulometric analysis was made by use of the sieve set and laser particle probe „Analysette 22" (Mycielska-Dowgiałło 1995). The results yielded the frequency and cumulative curves drawn in the probability scale, further used to calculate the granulometric indices according to Folk, Ward (1957).

MINERALOGICAL-PETROLOGICAL COMPOSITION OF THE DUNE FIELDS

Quartz is the prevailing component of the sediments of all the studied dune fields. Its content increases along with the ongoing eolian process due to its high mechanic resistance. Change of the quartz grain content is a good index of the distance of the dune sediment from its source. In the dune sands of the Sahara northern margins the quartz grains are uniform and relatively small (well rounded fine sand with occasional clayey fraction). Impurities in grains are rare, iron compounds absent, fluid inclusions found occasionally. Grains are commonly coated, what masks the matt surface yielded by eolian transport.

Gypsum is an important component of the studied eolian sands. It comes from evaporating seasonal water pools of high salinity. Due to its low hardness and perfect cleavage gypsum is a very good index of the distance from alimentation areas – its presence indicates very close evaporate sediments as the source of the material. Moreover, gypsum in dune sands evidences a young age of the dunes. In the studied region of Sahara the gypsum content in the eolian material of the individual dune fields is very variable.

Feldspars are relatively susceptible to the abrading transport factors, thus they indicate not very distant alimentation areas. Usually their sources are in granite or gneiss massifs, rarer in outcrops of other magmatic or metamorphic rocks (syenite, rhyolite, crystalline schists). If dune sands contain mainly plagioclases, basalts or andesites might have been the alimentation areas. Feldspars occur in the studied material in minor amounts.

Lithoclasts (marls, chemogenic and organogenic limestones) have very low mechanic resistance. They may come from directly adjacent limestone formations, though small clasts may be transported from more distant sources. Marls are gray and brownish gray poorly rounded grains of the fine sandy to clayey fractions, which consist of a mixture of microcrystalline or micrite carbonates and clay minerals; the texture of marl is random. Limestone clasts have the same grain size ranges. The chemogenic variety consist of subhedral or rounded sparry calcite grains, single or sometimes forming clusters; their content equals few percent. Organogenic limestone clasts (fragments of recrystallized organic remnants) due to low mechanic resistance occur in trace amounts.

Ferruginous-clayey clasts form probably in small ephemeric recent or past water pools which appeared due to very rare but heavy rains. Flowing water carries fine detritus with iron oxide and hydroxide particles common in the desert sand. The clasts are very good indices of their environment of formation and point to very short eolian transport, because they are extremely fragile to abrasion. In the studied dune sediments they occur as brown aggregates of parallel shaly texture. Their content is variable, but may achieve 90%.

Heavy minerals are very useful in determination of the dune material source and duration of the eolian processes. The duration is estimated from the content of the minerals of various resistance to wind abrasion and chemical dissolution, habits of the grains, contents of the grains of various specific weight. Zircon, rutile, tourmaline, staurolite and kyanite are the most resistant ones, whereas amphiboles, pyroxenes, biotite and chlorite are

the least resistant grains. Apatite, epidote, garnet and sillimanite are moderately resistant. Chemical weathering connected with the humidity of the sediments influences the duration of eolian processes. This duration may be also estimated from the contents of the flaky minerals: biotite, muscovite and chlorite, because the contents gradually decrease due to selective blowing out (Chlebowski *et al.* 2000). The investigations revealed that in most sediments from the dunes of the northern Sahara margins the highly resistant minerals (zircon, tourmaline, rutile, staurolite and kyanite) commonly appear, though the moderately resistant minerals (garnet and epidote) are also present. There are as well many dune fields with dominating minerals which are poorly resistant to abrasion (amphiboles, carbonates, micas and much rarer andalusite, apatite, chlorite, pyroxenes and phosphates). In these fields the lower degree of eolization of the sediments is apparent.

PETROLOGICAL INDICES OF THE DUNE FIELD DEVELOPMENT

Dune fields of northern Sahara display large variability of mineralogical and petrological composition. Nevertheless, the performed studies indicated that dune fields are mostly connected with the local alimentation sources.

A close source of the dune material in southern Morocco (the region of Coude du Dra) is indicated by numerous poorly resistant components of relatively large grain size transported mainly by saltation, the mode causing strong abrasion (Barczuk, Dłużewski 2003). Ferruginous-clayey clasts, derived from local ephemeric pools, are numerous, feldspars and carbonate lithoclasts are common. Frequently euhedral habit of well-preserved feldspars and euhedral carbonate crystals with sharp edges ale additional evidence of short transport. Moreover, abundant micas in the heavy mineral fraction confirm this conclusion.

Studies of the dune strips in Egypt (Kharga Depression) migrating to the south revealed relatively small mineralogical variation (Barczuk, Dłużewski 2001, 2002). Quartz is the basic component of the sediments, however, its content decreases during migration of the dunes. The components which content increase, are less resistant to eolian abrasion, thus coming from local sources. They include feldspars, lithoclasts of various carbonate rocks and ferruginous-clayey clasts. The increasing importance of the local material in dunes during their migration to the south is also evidenced by gradually growing contents of micas and decreasing amounts of the abrasion-resistant minerals.

Dune sediments of the southern Tunisia (Chott el Djerid region) display exceptionally small variation of the mineral composition in the southern and western parts, but to the east the sediments became more variable with increasing content of the local material (Barczuk, Dłużewski 2004). In the southern and western parts quartz dominates with minor other components, though gypsum is common in the dune basement. Thus, these dunes formed from multiply redeposited material, and the lithological coincidence with the material of the dunes of the Great Erg points to the latter as the source region. The mineral-lithological compositions of the sediments in the eastern part, especially significant amounts of poorly-resistant gypsum and ferruginous-clayey clasts evidence short transport and young age of the dunes. The fragile components clearly came from the local basement of the dunes; the characteristic sediments of the chott were the most effective source of the dune material there. The above conclusions were confirmed by the analysis of the heavy mineral fraction. The total contents of the minerals resistant to the mechanical abrasion in the sediments of the dunes in the southern and western parts of the studied area are distinctly higher than in the eastern area.

CONCLUSIONS

On the basis of the mineralogical and petrological analysis of the dune sediments of northern Sahara, the source of the dune material may be determined unambiguously. The obtained results are confirmed by textural features, especially the sorting degree of the dune sands and sand grain size distribution. The recognised local sources of a variable part of the dune material indicates changes of one or few factors of limited surface extension, which caused more intense deflation and thus more dynamic development of the dune fields or even formation of new dune areas. These factors stimulating deflation usually include lowering of watertable and degradation of vegetation, what results from improper local human activity. Among the studied dune fields of northern Sahara only the development of several areas in Tunisia is not related to the local sources of the dune material, thus their formation may be mainly explained by the global changes of the natural environment.

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