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Summary

Properties and distribution of kaolin deposits in northern Sudan have been investigated as a contribution to the Special Research Project 69 (Sonderforschungsbereich 69) "Geoscientific Problems in Arid and Semiarid Areas". The study of these supergene raw materials aims to reveal both the processes of formation and the possibilities of practical application.

During five field campaigns a wide variety of kaolin occurrences has been studied in North Sudan, belonging to in-situ primary and transported types. An Early Paleozoic lateritic weathering crust of about 25 m thickness is preserved in situ on top of metabasalts and metapelites in the Jebel Tawiga area of NW-Sudan. The weathered rocks are equivalents of the Proterozoic Jebel Rahib ophiolite complex further north. The laterites are overlain by shallow marine sandstones which contain trace fossils indicating a Late Ordovician to Early Silurian age. According to their strong lithification, high density, and hardness together with the particularly good crystallinity of the kaolinite these bauxitic laterites can be characterized as flint clays. The free alumina phases (boehmite; gibbsite, diaspore) partly have been converted into kaolinite by a resilication process which led to the development of the flint clay character. The average concentrations of boehmite and gibbsite in the laterite now are less than 4%, but in places up to 30% of boehmite have been preserved in the upper parts of the lateritic profiles. Alteration products, initially interpreted as hydrothermal kaolins, are exposed in metarhyolites of the Red Sea Hills near Derudeb, NE-Sudan. They occur in narrow, structurally controlled zones and consist mainly of feldspar, quartz, clinochlore, sericite and only minor amounts of kaolinite.

Lithified secondary, transported kaolins of up to 60 m in thickness and probably of Cretaceous age are widely distributed in eastern Sudan, mainly between the town of Gedaref and the Ethiopian border. Preliminary estimations point to resources of some billion tons. The kaolins are part of a sedimentary fining upward sequence (Gedaref formation) which was deposited in a fluvial-lacustrine environment. They are overlain in places by Oligocene (31,6 Ma) basalt flows. Diagenetic processes have strongly changed the original character of the kaolins. SiO_2-rich weathering solutions infiltrated the sediments and led to an intense silification, which is responsible for the "flint clay" character of the kaolins. Besides low contents of detrital quartz, the bulk of SiO_2 is present in form of opal-CT and chalcedony which constitute more than 40% of the whole rock composition. Additionally, a metasomatic alteration of the kaolins occurred during the Eocene due to acid sulphate-rich solutions which have led to the formation of alunite [$KAl_3(SO_4)_2(OH_6)$]. In more than 40% of the analyzed samples alunite is a constituent of the kaolins. High alunite contents of up to 70% were detected in kaolins of the border area between Sudan and Ethiopia. The mineral is concentrated mainly in distinct zones of stratabound mineralization, but also in vertical fissure fillings of Na-K-zoned alunite crystals. According to the majority of geological and mineralogical features as well as the alunites` isotopic pattern ($\delta^{34}S$=12,2-14,9%.; $\delta^{18}O$=15,8-16,4%.), alunitization may be the result of epithermal processes already active during an early stage of volcanism within the Gedaref basin. K-Ar ages of alunite (51,2 Ma) and of the overlying basalts (31,6 Ma) suggest that the main phase of basalt extrusion, which corresponds to the huge Ethiopian trap-basalts, does not correlate with alunite formation.

Small lentiform kaolin bodies are widely distributed in the continental Cretaceous sandstones of North Sudan, and are particularly exposed in the Nile area west and north of Khartoum. Genetically, they can be classified as fluvial overbank deposits. In the deposits near Omdurman, at Jebel Umm Ali and in the vicinity of Salawa these fluvial kaolins show similar mineralogical and chemical properties and are of the same age (Alb - Cenomanian).

Altogether, the appearance of kaolinitic basement rocks in North Sudan is strongly related to warm and humid climates. During the Early Paleozoic, and particularly during Cretaceous times, when NE-Africa was in a position close to the equator, favourable climatic conditions led to the formation of a deep weathering crust. Due to subsequent erosion, the autochthonous kaolins were largely removed and transported by rivers mainly to continental sinks. Redeposition of the weathering products in fluvial-overbank and fluvial-lacustrine environments has produced distinct types of kaolin deposits, different in size, shape and quality. The suitablility of the kaolins for different practical applications has been evaluated by laboratory tests as well as on the basis of an extensive set of geochemical and mineralogical data, which was treated by multivariate statistical techniques. The tests clearly indicate that the possible use of the kaolins is strongly depending mainly on type and degree of post-sedimentary alteration.

The use of bauxitic laterites from Jebel Tawiga as a potential source for the production of aluminum can be excluded due to insufficient Al_2O_3-contents and the presence of reactive silica in form of kaolinite. On the other hand, those boehmite bearing laterites which contain only minor amounts of Fe_2O_3 seem to be applicable as refractories e.g. chamotte products, but the extreme remoteness of the deposit and the lack of any infrastructure preclude mining activities. Also the hydrothermal alteration products of Derudeb containing only small amounts of kaolinite are unsuitable for practical uses.

For the secondary kaolins, dispersion tests, firing tests with different mixtures of kaolin, feldspar and soda, determinations of the fired colour, firing shrinkage, water absorption capacity, dry strength and plasticity tests were carried out to evaluate the suitability as a raw material used in various fields of ceramics. Based upon these results all tested secondary kaolins are suitable for the production of wall and floor tiles. Moreover, the overbank kaolins, which easily slake in water can be used for the production of sanitaryware and whiteware as well. Concerning a possible use of alunite, which according to its chemical composition could be a source for potassium sulfate, sulfuric acid and alumina, elaborate techniques already exist. Economic feasibility of the Sudanese alunites, however, is not predictable under the given conditions.