Provenance, genesis and paleogeographical implications of microminerals occurring in sedimentary rocks of the Jordan Valley area

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SUMMARY

One of the foremost purposes of this study is to establish whether a relationship exists between formation of microminerals and conditions in sedimentation basins and on the interland. Existence of such a relationship would make it possible to draw conclusions about the paleogeography and the paleoclimate.
This study includes under microminerals those crystalline constituents which, due to their small sizes, cannot be identified by means of light microscopy. Such fine-grained minerals have been identified by means of X-ray diffraction and electron microscopical investigation mainly.
Of the formations occurring in the area investigated - the Jordan Rift Valley and adjoining areas - primarily the microminerals were investigated in the clay fractions of the HCl insoluble residue of marls and limestones dating from the Upper Cretaceous and Paleogene and of fluviatile and lacustrine sediments dating from the Neogene and Quaternary. The micromineralogical investigation is aimed at especially the study of the clay minerals palygorskite, smectite, kandite and illite and at fine grained anatase and quartz. An attempt has been made to establish whether these minerals occurred in the sediments as detrital or authigenic constituents. Investigation to this effect has to precede a paleogeographical and paleoclimatological interpretation.

A short description of the geography and the climate is followed, first by a synopsis of the geology of the area investigated as well as the adjoining regions and further by a discussion of the tectonic development of the Jordan Valley.
In view of their importance to the weathering conditions on the hinterland, data have been collected on the paleoclimate. The greater part of these data point to a warm humid climate prevailing in the regions bordering the Tethys from the beginning of the Mesozoic into the Neogene.

Palygorskite, a hydrated Mg-Al-silicate is the most striking mineral in the area investigated. A survey has been given of the literature covering the occurrence and genesis of this mineral. Some five possible modes of formation may be distinguished. It has been demonstrated that palygorskite in the area investigated is a detrital constituent in late Tertiary fluviatile sediments and in Quaternary, fluviatile and lacustrine sediments and neither a pedogenic formation under arid conditions nor a formation in saline lakes.
The mineral originates from Upper Cretaceous and Paleogene marine marls and limestones, in which it occurs as a synsedimentary, authigenic formation. The conditions required for such a mode of formation are considered to be: a shallow basin with an alkaline, oxidizing environment and a scarce supply of clastic material, surrounded by a tectonically stable, low lying hinterland on which intense weathering took place under a warm humid climate. The weathering products transported in solution contributed to a significant degree to the formation of palygorskite. During the Upper Cretaceous and Lower Tertiary these conditions were en-

countered in many basins around the African Shield, in South France, the Middle East and probably also in other basins communicating with the Tethys.
It is postulated that the conditions required for formation of extensive, marine, authigenic palygorskite-bearing sediments are not met with in recent times.
For palygorskite from the area investigated as well as for the standard mineral from Attapulgus, Georgia, in view of X-ray and electron diffraction investigation, a new space-group is suggested.

Further, attention has been paid to the genesis and occurrence of the group of clay minerals to be indicated as smectite. According to the mode of formation a first distinction has to be drawn between smectite formed due to transformation from related phyllosilicates, and authigenic smectite. An attempt has been made to determine the ways in which these two varieties of smectite can be distinguished. Given the diagnostical properties on X-ray diffraction investigation, to be attributed to a low layer-charge, smectite in the area investigated shows a mainly authigenic character. The foraminifera found are also evidence demonstrating that the dioctahedral smectite in the Quaternary sediments investigated originates especially from Middle Eocene and Upper Cretaceous marine marls and limestones. Smectite, without volcanic material playing a part in its formation, probably has been formed in shallow marine basins with supply of dissolved weathering products of a tectonically stable, warm humid hinterland, during the Upper Cretaceous and Paleogene. Chamosite found has been formed under similar conditions. A trioctahedral smectite and celadonite have been described as weathering products of basalt. Authigenic smectite occurring in pellets has been discussed, which in shape and mode of formation show resemblance to glauconite pellets, but are highly divergent with respect to mineralogical composition.

Kandite in the Quaternary and Neogene sediments investigated is not a product of contemporaneous weathering but is derived from eroded sediments of the 'Nubian' Formation, in which it is present primarily as a detrital constituent of an intense weathering of the Arabo-Nubian Massif. This type of weathering was of frequent occurrence during the Mesozoic. In addition several examples have been given of kandite formed postsedimentarily. Further results have been given of a morphoscopical investigation by means of the light, the X-ray projection and the electron microscope of quartz grains from kandite-rich sediments. There is some doubt as to the alleged usefulness of morphoscopical analysis as a means of determining the transport agent of quartz sands.

Illite and interstratifications with illite constitute a group of microminerals formed due to weathering of muscovite. Illite well-ordered in the direction of the c-axis is rather scarce in the clay fractions of the sediments investigated. Weathering products of illite, identifiable by their non-basal reflections, are frequently met with, especially in kandite-rich sediments. Notable is the absence of illite in several autochthonous smectite- and palygorskite-rich sediments.
The assumption is that the glauconite investigated, although bearing resemblance to illite, is derived from low-charged, authigenic smectite.

As a micromineral, anatase, although in small amounts only, is rather common in the clay fractions of the sediments investigated. Investigation of clay and silt fractions points to a positive correlation between the occurrence of the kandite mineral kaolinite and anatase, which may be traced to a common genesis from the weathering products of mica minerals. The amount of anatase in the clay fraction may be a measure for the amount of kaolinite formed from mica. Both minerals may have grown together epitaxically with resultant formation of anomalous mixed crystals. Unlike with the kandite mineral halloysite no indications have been found of Ti occurring in the structure of kaolinite.

Some interesting data were obtained from investigation of quartz, considerable amounts of which occur as a micromineral in the fraction $<1\,\mu$ of the HCl insoluble residue of a number of calcareous sediments. An attempt has been made to determine the way in which this fine grained quartz is formed. The conclusion was that only an authigenic mode of formation may be considered. Authigenesis occurred in Upper Cretaceous and Lower Tertiary marly sediments, deposited in shallow basins in which an appreciable part of the necessary silica has been supplied in solution as a weathering product of a warm humid hinterland. To distinguish between authigenic quartz from clay and silt fractions and terrigenic quartz, criteria are given inferred from the results of X-ray and electron diffraction technique, electron and X-ray projection microscopy and differential thermal analysis. Further the occurrence of authigenic K-feldspars has been discussed, which are also distinguishable from detrital K-feldspars by means of X-ray diffraction.
Finally, a brief summary has been given of the data on tobermorite-like minerals, which probably are the product of artificial formation from constituents present in calcareous sediments.