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GLAUCONITE AND CHAMOSITE AS DEPTH INDICATORS IN THE MARINE ENVIRONMENT

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SUMMARY

In tropical areas chamosite develops in the remains of organisms and in faecal pellets in the marine environment shallower than about 60 m, but occasionally down to about 150 m. Glauconite, not restricted to tropical areas, develops likewise, but at greater depths: in larger amounts generally between 30 and 2,000 m and in tropical areas in larger amounts deeper than about 125 m. So far, known occurrences of Recent chamosite are restricted to shallow marine environments in the tropics and this may indicate that warm (> 20°C) bottom water is essential for its formation. Temperatures lower than about 15°C tend to be favourable for the formation of glauconite.

INTRODUCTION

Various iron minerals can develop in the surface layer of bottom sediments in the marine environment. Is has long been recognised that iron-rich sediments thus formed in the open marine environment or in restricted marine basins fall into four major facies groups based on the dominance of oxide, silicate, carbonate or sulphide, each facies corresponding to a certain level of oxygen availability in the bottom environment. No example is known, however, of a complete array of these major facies grading laterally one into the other (JAMES, 1966), but they are arranged in hypothetical sequences from shore to increasing depths by BORCHERT (1964), GOTTESMANN (1966) and others.

In Recent sediments of the open-marine environment, the depth boundaries and other physical limits of formation have been investigated only for the iron silicate glauconite (CLOUD, 1955; and others): abundant primary glauconite has been found at depths between 30 and 2,000 m. Its interrelationship with chamosite, the most abundant primary iron silicate of post-Precambrian age, could not be established because chamosite had never been recognised in Recent environments (HALLAM, 1966). When glauconite has been found in ancient rocks it has been inferred that this mineral formed both at shallower depths (BORCHERT, 1964), and at greater depths than chamosite (R. E. Hunter, 1960, unpublished, see: JAMES, 1966).

An investigation of Recent marine sediments from three tropical areas—the Niger delta, the greater Orinoco shelf and the shelf off Sarawak—has shown that authigenic chamosite is widely distributed in relatively warm (> 20°C) and shallow environments, while authigenic glauconite develops in relatively cool (13°C) and deep environments (PORRENGA, 1965, 1966). The aim of this paper is to show the depth distribution of these minerals and to compare the results with published data.

Mainly grab samples, collected during various expeditions, were used for analysis. The samples from the Orinoco shelf and adjacent shelf areas were collected during expeditions organised by the N.V. Bataafsche Petroleum Maatschappij in 1952 and 1953. Sea-bed sampling on the shelf off Sarawak was carried out in 1955 and 1956 by The Brunei Shell Petroleum Company, Ltd., while in 1959, in connection with a study of delta formation, samples of the Niger delta were collected during the Recent Sediment Survey jointly organised by the Shell Internationale Research Maatschappij N.V. and the British Petroleum Company, Ltd.

RESULTS AND DISCUSSION

The Niger delta, the Orinoco shelf and the shelf off Sarawak

X-ray diffraction and chemical analysis of mineralised green to blackish-green faecal pellets and fillings of Foraminifera and other organisms, present in the Recent marine sediments of the Niger delta in quantities of less than 1 to more than 60% of the sediment (ALLEN, 1965), showed chamosite to be the main constituent down to a depth of 50–60 m, and showed glauconite to be the main constituent at depths ranging from about 125 to 250 m (Fig.1).

The chamosite is poorly ordered, has a first-order basal reflection of 7 Å indicating a kaolin-type structure and contains about 17% FeO and 8% MgO. The glauconite is also poorly ordered and contains at least 70% expandable layers which, on heating, collapse to 10 Å, indicating a montmorillonite-type structure; it contains about 2.7% K_2O, 3% FeO, 18% Fe_2O_3 and 2–2.5% MgO. Both compositions differ strongly from that of the clay matrix and the grey pellets, which visually do not show mineralisation and which may occur at all depths; they contain not more than 10% iron oxides and less than 1.5% K_2O and MgO.

Close to the shore at depths shallower than about 10 m brown pellets and fillings are predominant, which consist of goethite and occasionally small amounts of chamosite.

The mode of occurrence of the greenish grains leaves no doubt about the authigenic, primary character of the chamosite and the glauconite. Except for a much lower ferrous and higher ferric iron content, the chemical composition of the brown goethite grains is so similar to that of chamosite, that they may well represent the oxidation product of reworked chamosite grains.

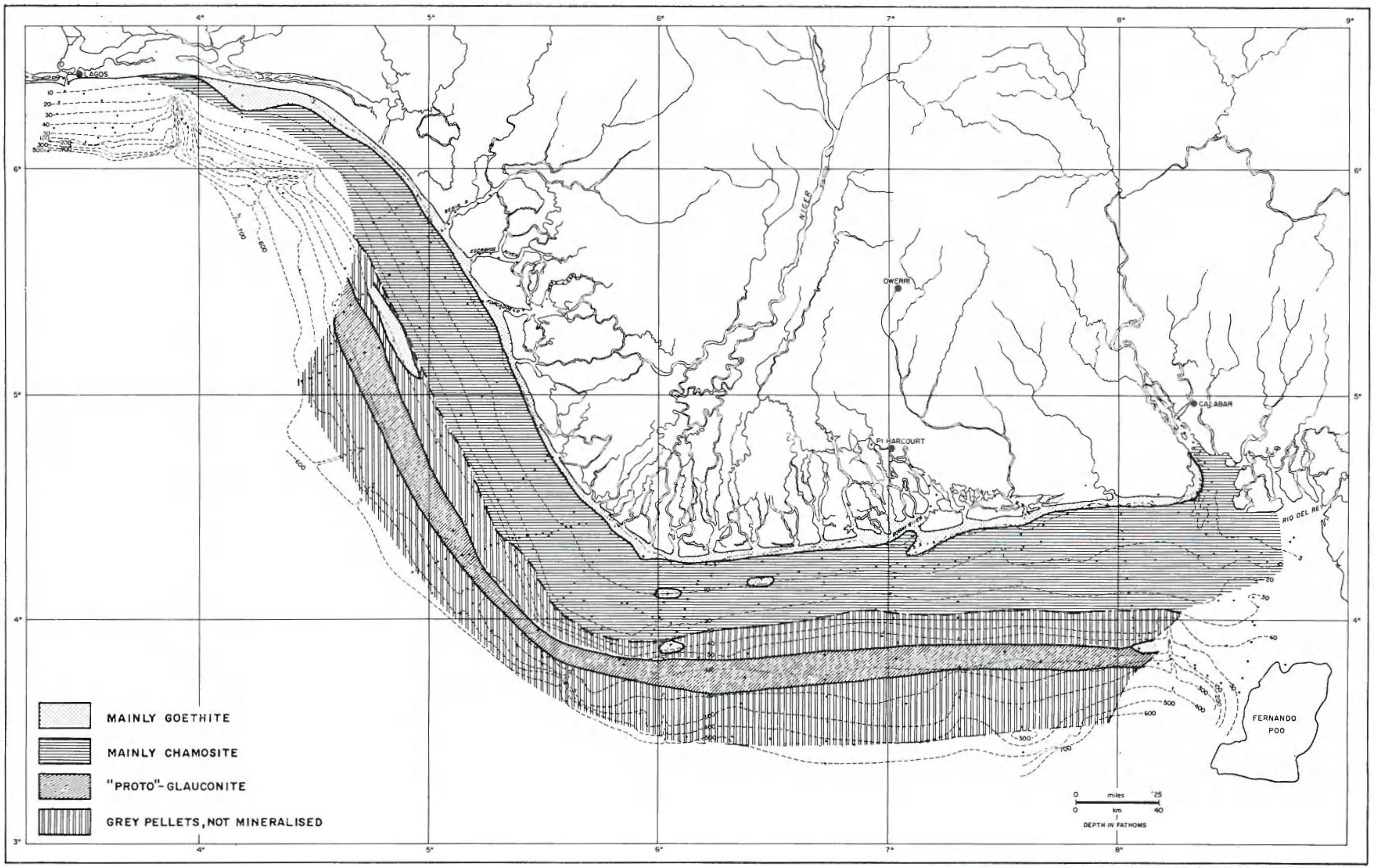

Fig.1. Mineral composition of pellets in the Niger delta.

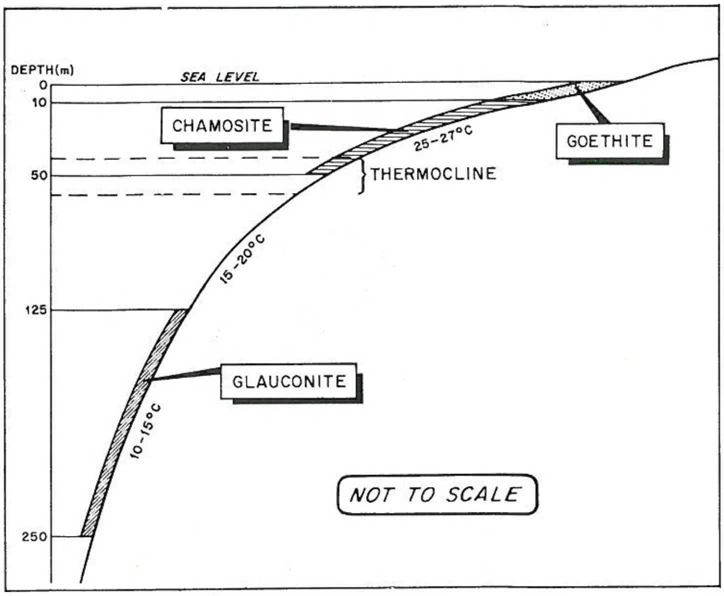

Fig.2. Generalised picture showing for the Niger delta the depth of the sea-floor, the occurrence of goethite, chamosite and glauconite, and the bottom-water temperature as measured in January–February 1959.

Fig.2 shows schematically the relation between the depth of occurrence of these iron minerals and the bottom-water temperature. The zone in which the thermocline is in contact with the sea bottom coincides with the outer boundary of chamosite occurrence.

Chamosite has also been found in the other two tropical areas. In the Orinoco delta down to about 150 m, at which depth in the region north of Paria it gives way to rare glauconite, and down to about 60 m in the Recent sediments of the shelf off Sarawak, where it occurs in fairly large quantities as fillings of organisms. In addition, at a depth of 50 m locally on the Sarawak shelf, many transitions from chlorite to chamosite have been noticed. These are analogous to the transition from biotite to glauconite described by GALLIHER (1935). No glauconite has been found, even in some samples derived from the deeper parts of the South China Sea.

That chamosite occurs down to greater depths in the Orinoco–Paria area than in the Niger delta, may be connected with the marked difference in bottom-water temperature. North of Paria, at 150 m depth, the temperature is about 17°C (VAN ANDEL and POSTMA, 1954), whereas in the Niger delta the temperature drops below this value at depths as shallow as 50–80 m.

Other areas

Brown goethite pellets have been found by LENEUF (1962) along the Ivory

Coast, by VON GAERTNER and SCHELLMANN (1965) near the coast of Guinea and by GIRESSE (1965a, b) near the coast of Gabon. In the two latter areas, chamosite as well as goethite occurs in pellets in shallow-marine sedimentary environments. Von Gaertner and Schellmann are of the opinion that the chamosite is not primary, but secondary after goethite, while Giresse considered his material as an early-stage glauconite. Finally, chamosite has been detected in sediments of Malacca Strait between Malaysia and Sumatra (G. H. Keller, 1966, personal communication). Fig.3 shows the distribution of all so far known chamosite occurrences in Recent sediments. This distribution, which is widespread but probably restricted to the tropics, may well be related to the warm bottom waters occurring in these areas.

The foregoing data demonstrate that glauconite can no longer be considered as the only iron silicate formed in reasonable quantities in modern seas and oceans (TRIPLEHORN, 1966).

Many literature data are available on the distribution of glauconite in Recent marine sediments, but only few (BURST, 1958; EHLMANN et al., 1963; PRATT, 1963) contain X-ray diffraction and chemical data. The following picture is obtained, if records of others, who may sometimes have confused chamosite with glauconite, owing to the striking similarity in appearance and modes of occurrence, are also included. Apart from a few exceptions demonstrating that it possibly also forms in non-marine environments, glauconite may be considered, on the whole, as a marine clay mineral. It is widely distributed (Fig.4) and occurs in regions of little or no detrital

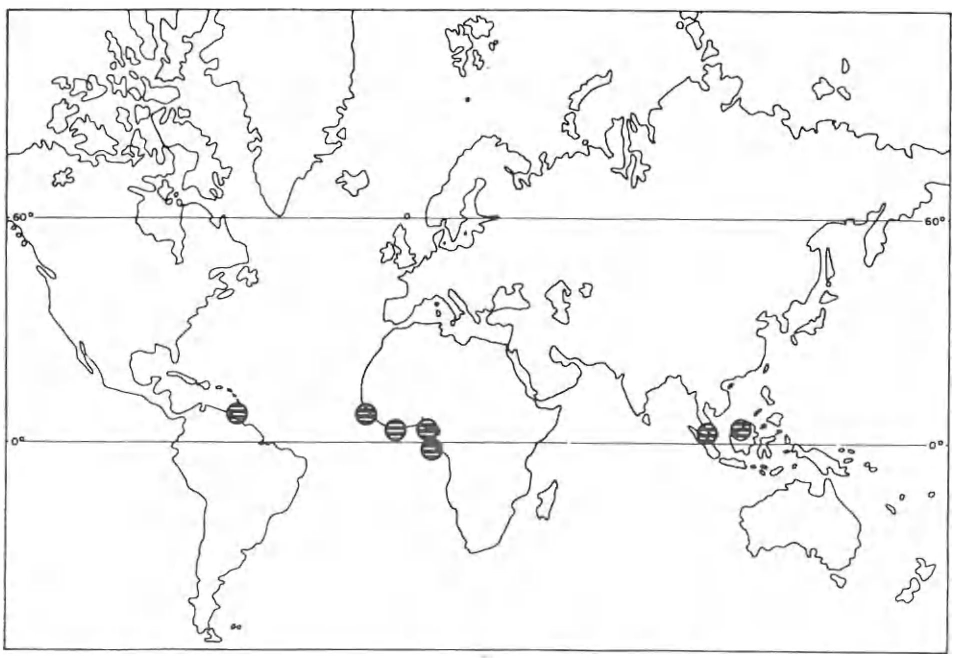

Fig.3. Known chamosite occurrences in Recent sediments.

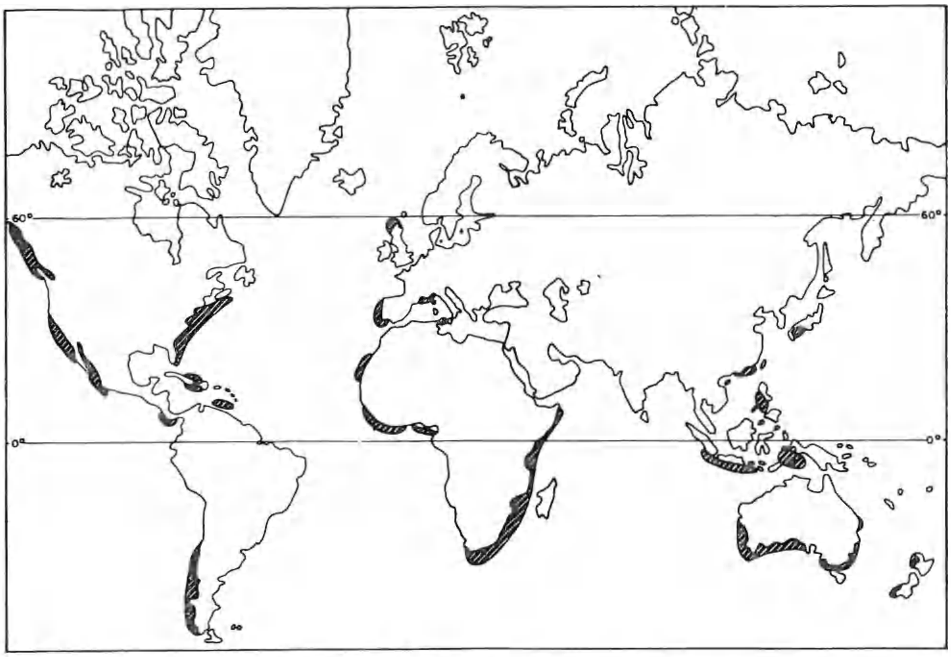

Fig.4. Glauconite occurrences in Recent sediments. (After GALLIHER, 1935.)

sedimentation under a fairly wide but nevertheless limited range of temperatures and depths.

According to a review given by CLOUD (1955) and new data of EHLMANN et al. (1963), PRATT (1963) and LECLAIRE (1964) glauconite is rare above 10 and below 2,000 m and is commonest at depths ranging from 30 to 700 m. In the tropical seas of Indonesia, however, glauconite does not occur shallower than 50 m and becomes reasonably abundant at about 250 m (NEEB, 1943), which largely agrees with the observations from the Niger and Orinoco deltas. It is not unlikely that temperatures lower than about 15°C would favour the generation of glauconite. To explain the rather scarce occurrence of glauconite in the Palaeozoic and Mesozoic iron-rich sedimentary rocks, BRAUN (1962) also assumed that the formation of glauconite needs lower temperatures than that of chamosite.

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