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CLAY MINERALS IN MODERN DELTAIC SEDIMENTS OF THE KRISHNA RIVER, EAST COAST OF INDIA*

A. S. R. SWAMY, N. V. N. D. PRASADA RAO AND M. P. RAO
Marine Geology Laboratory, Andhra University, Waltair

ABSTRACT

Sediment samples from fresh water, estuarine and tidal creek environments of Krishna Delta and core samples off Krishna River Confluence collected during the 18th cruise of "INS Kistna" are analysed for the clay minerals by X-ray diffraction technique. The predominant clay mineral is montmorillonite. Minor amount of Kaolinite is present in Krishna River channel and deltaic sediments. Traces of illite are found in marine sediments off Krishna River in addition to the above clay minerals. The montmorillonite is subjected to a minor chemical change in the estuarine environment from Ca^{2+} montmorillonite to Na^{+} montmorillonite with no marked structural alteration. Such a transformation of montmorillonite towards progressively saline water is attributed to the increasing concentration of Na^{+} ions in the overlying waters. The chemical composition of the source rocks and the climatic conditions seem to be the important factors controlling the type of the clay minerals in the Krishna deltaic and marine sediments. The above observations indicate that diagenesis is not an effective process in determining the type of clay minerals in these sediments.

INTRODUCTION

A REVIEW of literature shows tremendous expansion of the investigations on clay minerals within the last three decades, beignning chiefly with the work of Pauling (1930) and Bragg (1937). The multifold interest in clays has greatly stimulated many research workers, who dealt the subject from different disciplines. Of the two schools of thought, the importance of the source area in controlling the types of clay minerals in any environment has been emphasized by Murray and Harrison (1956), Weaver (1958, 1960) and Taggart and Keiser (1960). On the other hand Grim *et al.* (1941), Grim and Johns (1954) and Nelson (1959) have emphasized the process of environmental diagenesis in clays. Keeping in view that the clay minerals may provide useful information in weathering, provenance, environment of deposition, diagenesis and petroleum occurrence, an investigation has been undertaken by the authors to study the clay minerals of the modern deltaic sediments of Krishna River. Studies have been carried out by Sastry *et al.* (1958), Subba Rao (1963) on the clay mineral distribution in the continental shelf sediments off the east coast of India and by Siddiquie (1967) in deep marine sediments of the Bay of Bengal. Venkatarathnam (1965) and Naidu (1968) have investigated the clay minerals in the lacustrine sediments of Chilka and the modern deltaic sediments of Godavari River respectively.

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GEOLOGY AND CLIMATE OF THE DRAINAGE BASIN

The Krishna River, one of the largest rivers in India, stretching about 1280 km drains through different geological formations (Fig. 2) namely the Deccan Traps (Cretaceous-Eocene), Unclassified Crystallines comprising mostly Dharwars, and sedimentary formations of Cuddapah Basin (Puranas). In the last phase the Krishna River flows through the Pre-cambrian Archean complex. However, the Krishna Delta appears to be receiving a major portion of the sediments from the Deccan Traps consisting of ferro-magnesium minerals (Seetaramaswamy, 1970).

The drainage basin of the Krishna River covering an area of 2,52,500 sq. km, experiences mostly semi-arid climate as per Thornthwaite's (1955) scheme of climatic classification (Subramanyam, 1968). A special feature of the climate is the unambiguous existence of absolutely arid (E) climate in the central Deccan right in the middle Krishna Basin (Fig. 3).

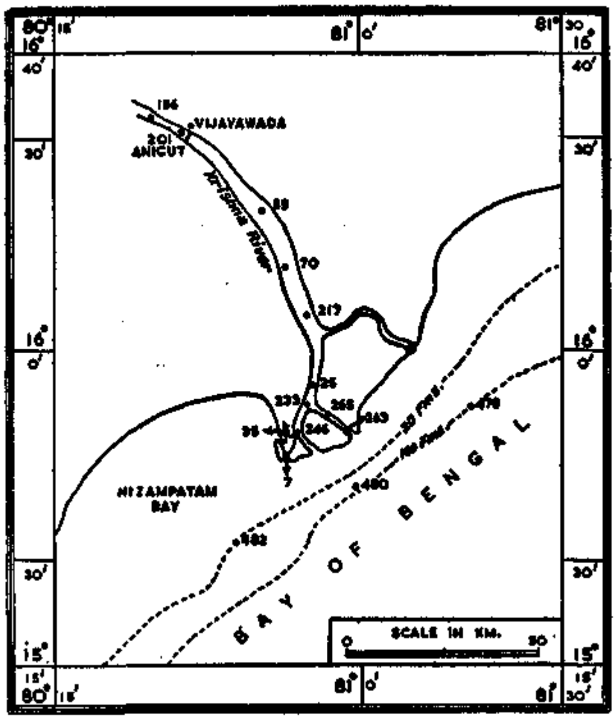

Fig. 1. Sample locations in different environments of the Krishna delta.

METHODS OF STUDY

The sediments studied were grab samples collected by a light weight La Fond-Dietz snapper in different environments of the Krishna Delta and the core samples of the marine environment of the Krishna Delta collected during the 18th cruise of INS Kistna as part of IIOE programme in 1965. Fifteen sediment samples representing various environments of the Krishna Delta (Fig. 1) are selected for X-ray analysis. The sediments were dispersed in distilled-deionized water, fractionated by sedimentation method, mounted on glass slides and air dried. Less than 2μ fractions were analysed by X-ray diffraction technique untreated and treatment with ethylene glycol and heated upto 550°C for one hour. By measuring the depth of the valley (V) and height of the peak above background (P) on the low angle side of the peak in the X-ray diffractometer patterns, the V/P ratios were calculated as described by Biscay (1964).

RESULTS

X-ray diffraction analysis of modern clay sized deltaic sediments of the Krishna River revealed the predominant occurrence of montmorillonite with percentages ranging from 80-85. Kaolinite (5-8%) is next in abundance to montmorillonite. Traces of illite and chlorite are noticed in some samples. Table 1 presents the clay mineral composition and V/P ratios in sediment samples of different environments of the Krishna Delta.

TABLE 1. Clay mineral distribution in the Krishna deltaic sediments

sample No.	Environment	Clay minerals in order of decreasing abundance	V/P ratio
156	River channel (fresh water)	Ca^{2+} Mont. Kao. Chlo.	0.82
201	"	Ca^{2+} Mont. Kao.	0.89
55	"	Ca^{2+} Mont. Kao.	0.70
70	"	Ca^{2+} Mont. Kao.	0.69
217	Estuarine	Ca^{2+} Na^{+} Mont. Kao.	0.75
25	"	Ca^{2+} Na^{+} Mont. Kao. Chlo. Illi.	0.64
233	"	Na^{+} Mont. Kao	0.84
246	"	Na^{+} Mont. Kao.	0.79
7	"	Na^{+} Ca^{2+} Mont. Kao. Chlo.	0.64
265	"	Na^{+} Mont. Kao. Illi.	0.81
263		Na^{+} Mont. Kao.	0.82
35	Brackish (Tidal Creek)	Na^{+} Ca^{2+} Mont. Kao. Chlo.	0.52
478	Marine	Na^{+} Mont. Kao. Illi.	0.82
480	"	Na^{+} Mont. Kao.	0.82
482	"	Na^{+} Mont. Kao.	0.79

(Mont = Montmorillonite, Kao = Kaolinite, Chlo = Chlorite, Illi = Illite)

A decrease in V/P ratios indicating poor crystallinity of montmorillonite downstream is noted, Ca^{2+} montmorillonite occurring in the upstream sediments progressively changed to Na^{+} montmorillonite with increasing salinities.

DISCUSSION

Even though the sediment samples represented the environmental extremities, the clay mineral composition is almost homogeneous. Thus, a noteworthy and conclusive observation from the present study is that the environmental conditions of deposition failed to leave their characteristic impressions on the clay mineralogy of deltaic sediments. However, this does not mean that the clay minerals cannot partially adjust geochemically to the depositional environments. But this adjustment is only on a small scale accompanied by no marked structural or chemical changes in the clay minerals. Such a small scale adjustment in clay minerals is noticed in the Krishna deltaic sediments by the replacement of calcium in montmorillonite by sodium in the marine and estuarine environments. The subject of marine diagenesis of clays, however, has becone quite controversial. Grim and Johns (1954) from their work on sediments of San Antonio Bay, off the Texas Coast, concluded that the montmorillonite alters to chlorite and illite in saline waters. Powers (1954) and Nelson (1959) have offered explanation for clay mineral origin which depends upon partial to complete chemical transformation of source clay material by marine environment. These investigators have considered the source influence as subordinate. If in a marine environment montmorillonite alters to chlorite and illite, the sediments of estuarine and the marine facies of the Krishna Delta influenced by saline water must contain appreciably less montmorillonite than the upstream sediments, which are strictly non-marine.

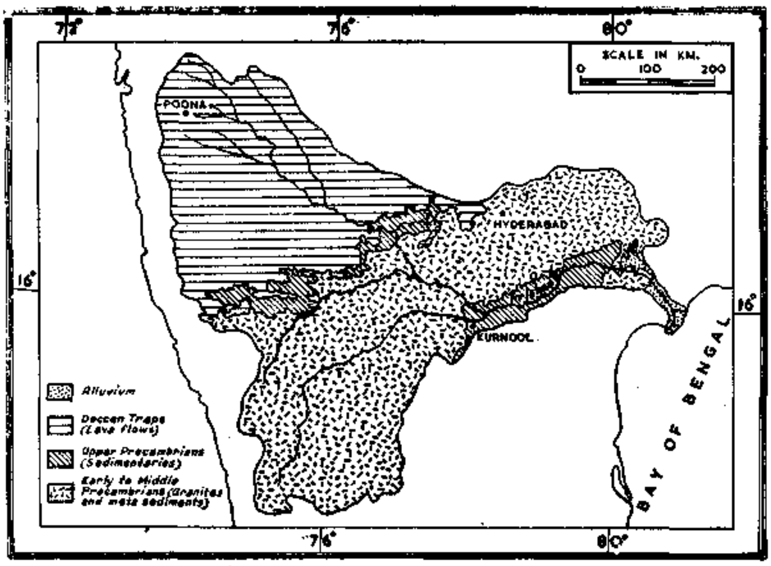

Fig. 2. Geology of the drainage basin of Krishna River.

But the results of this investigation indicate no difference in the montmorillonite content attributable to environmental diagenesis. Moreover, illite and chlorite are present only in traces. The possibility of Kaolinite development from montmorillonite during diagenesis is also cited in literature. Although the kinetics of this diagenesis is generally slow, significant chemical changes can be expected over geological periods of time. The high rate of sedimentation gives no time for the clay minerals for adjustment to the prevailing chemical environment. The sedimentary discharge of the Krishna River is estimated by Anonymous (1957) as averaging 4,221 million cu. ft per year at Vijayawada. Further, there is no significant variation of the pH conditions, which to some extent controls the fate of the parent material and the type of the clay mineral that will ultimately develop (Degens, 1965), in the Krishna Delta. From the foregoing discussion it is clear that the environmental diagenesis in the Krishna deltaic sediments is not so effective.

Considering the source of the clay minerals, Deccan Traps, representing a considerable portion of the drainage basin, contain significant amounts of Mg, Na and a low content of K (Karkare, 1965). The weathering under conditions of moderate rainfall and poor drainage permits the magnesium to remain in the weathering zone, after it is released by the breakdown leading to the formation of montmorillonite. The other alkalies and alkaline earths appear to play a relatively minor role, except that there is a suggestion that calcium favours the formation of montmorillonite and prevents the formation of Kaolinite (Grim, 1953). Noll (1937) reported the formation of montmorillonite as an alteration product of the constituents of the basic igneous rocks and that montmorillonite was formed on account of the presence of magnesium. Sherman (1952) studied the influence of climatic changes responsible for the formation of different types of a clay minerals from the same source (Basalts) and concluded that at moderate precipitation montmorillonite is the principal mineral. The occurrence of alkali rich clays, formed during the alteration of the underlying rocks in parts of the drainage basin of Thungabhadra, a tributary of Krishna River, is pointed out by various workers of Mysore geological survey. The underlying rocks in all these places are highly fissile foliated schists

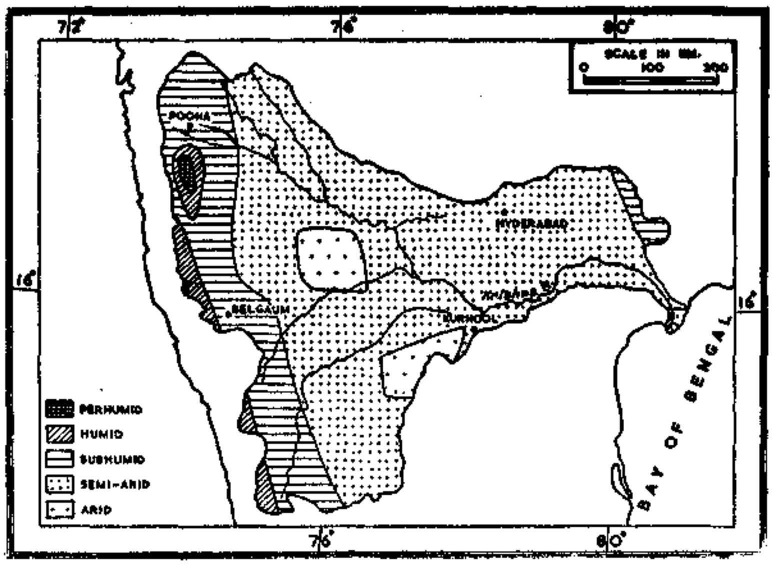

Fig. 3. Climatic zones in the drainage basin of Krishna River (after Subramanyam, 1968).

showing glistening specks of sericite on fresh surfaces. Panduranga Rao (1941) observed the Kaolin deposits of Narasimharajapura and stated that the waters of the region are drained by the streams Tunga and Bhadra which flow along the borders of the region and join at Kudli to form Tungabhadra, which later joins the main river Krishna. It can be considered from the above data, that the Kaolinite occurring in the deltaic sediments might have been derived from the Tungabhadra drainage area, which is mainly constituted of Dharwar schists.

A minor part of the kaolinite present in the deltaic sediments may be attributed to red soils derived mainly from the Khondalite suite of rocks (Nagelschmidt *et al.*, 1940). It may be supposed that montmorillonite and Kaolinite have not undergone change during continental runoff as there is no significant variation in the clay mineral composition of the sediments. Grim (1953) and Jackson (1959) have described the circumstances favourable for the formation of montmorillonite in soils indicating its stability under a wide range of climatic conditions.

Finally, the origin of montmorillonite occurring in the modern deltaic sediments of Krishna River may be attributed to the high Mg and Ca contents of the source rocks and to the semi-arid climatic conditions of the drainage basin. Griffin and Goldberg (1963), and Biscay (1964) have considered that clay mineral assemblages in Pacific and Atlantic Oceans are largely influenced by source material. Subba Rao (1963) attributed source as the dominant factor in causing the differences in clay mineral assemblages observed in the shelf sediments off the east coast of India.

From the point of view of occurrence of oil, this study affords an interesting and useful information. There appears to be a peculiar relationship in so far as basins high in montmorillonite contain more crude oil on an average than basins where non-expandable clay minerals (kaolinite, Illite and Chlorite) predominate. Basing on the 20,000 clay mineral analysis, Weaver (1960) has obtained the correlation between oil production and montmorillonite contents and also water-hydrocarbon relationship. He explains this coincidence between montmorillonite content and the amount of oil as due to structural reasons. Montmorillonite can hold more water, which is necessary to flush the hydrocarbons, down to greater depths of burial than the non-expandable clays. Perhaps, montmorillonites due to their 'organophilic character have great affinity for hydrocarbons or their organic precursors than the non-expandable clay minerals (Degens, 1965). Even thouh the number of sediment samples investigated were considerably less, the uniform distribution and the abundance of Montmorillonite in the sediments under study point out the possibility of carrying out oil prospecting in the deltaic region of the Krishna River.

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