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First record of gravity flows from Cretaceous exposures, Ariyalur – Pondicherry area, Cauvery Basin, India

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Abstract

The present communication is the first record of gravity flows from Cretaceous exposures in the Cauvery Basin, Tamil Nadu. These gravity deposits are mainly sand prone and occur at several stratigraphic intervals in the passive margin sequence of the Cauvery Basin. Two major phases of gravity flows recorded are within upper Turonian- Coniacian and Santonian- lower Maastrichtian sequences representing Trichinopoly Group and lower part of Ariyalur Group respectively. Based on field studies they are categorised into two types, viz. tabular and channelized deposits. The deposits are mainly sandy debris flows, deposited in sub-aqueous conditions exhibiting erosional bases. Most deposits have sandy debris flows at the base followed by high and low density turbidites respectively. The proximity of a high relief provenance and the position of the Indian sub-continent in the southern tropics, with high seasonal river discharges, during these times are interpreted to be the main cause for the gravity flows. The study of these gravity flows assumes importance as in the subsurface of the basin they are the principal reservoirs for hydrocarbons.

Introduction

The Cauvery basin, an oblique rift basin (1) in the southern part of the Eastern Continental Margin of India (ECMI), was formed during its separation from Antarctica in the Late Jurassic-Early Cretaceous period (2). Its economic importance was established in the seventies with the establishment of commercial reserves of hydrocarbons hosted in gravity deposits.

The rifting phase of the basin which continued till the lower Aptian records deposition of initial coarse and later finer fluvial to deltaic clastic deposits. The post break-up, passive margin sequences were deposited in the basin from upper Aptian onwards. Shelf deposits representing the early part of the passive margin stage occur in a narrow area of exposures in the Ariyalur-Pondicherry sub basin (Fig. 1a). These deposits are lithostratigraphically classified into Uttatur, Trichinopoly and Ariyalur Groups (3) (Fig. 1b).

The thickness of the passive margin Cretaceous deposits in these proximal exposures is less than one km. However, more than 4 km thick pile of sediments is accumulated in the distal subsurface, reportedly transported and deposited mainly by gravity processes (4, 5). The hydrocarbons discovered in the basin are hosted in reservoirs, which are products of these gravity flows. Studies on these gravity deposits, specifically reservoir prone deposits, have been undertaken mainly by Oil & Natural Gas Corp. Ltd., based on data recorded from the subsurface (seismic, logs & cores). These have resulted in a few publications in the public domain. However, reports of the presence of gravity deposits in surface exposures were absent.

Initial field studies undertaken in this area indicate the presence of gravity flows, mainly sand prone at several stratigraphic intervals in the passive margin sequence of the Cauvery Basin. The present study records gravity flows deposited in two major phases, viz. upper Turonian- Coniacian and Santonian-lower Maastrichtian in the Trichinopoly Group and lower part of Ariyalur Group, respectively.

Methodology

Field mapping was carried out to trace the surface extent of the gravity flow deposits and to understand the lithological and rheological variation occurring in them. Digital elevation profiles were analysed, to understand the origin of gravity flows and their association with other shallow water deposits. The lithologic and stratigraphic contacts were marked on these profiles along with their dips to obtain 2D geological cross sections. Age presently assigned to these commonly unfossiliferous deposits is based on the stratigraphic relations observed in the field.

Location

The present studies were done in the Ariyalur-Pondicherry sub-basin. The area of interest falls between latitudes 10°54’ and 11°53’ and longitudes 78°50’ and 79°15’; in Trichinopoly, Ariyalur and Perambalur Districts of Tamil Nadu (Fig. 1a).

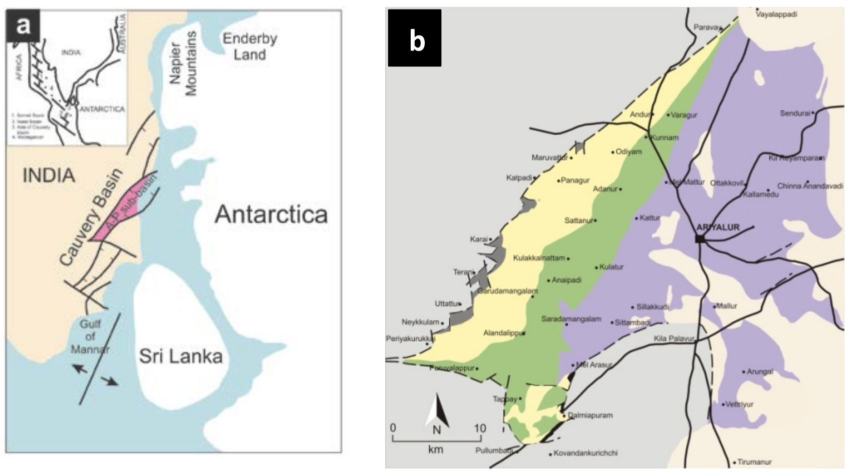

Fig. 1: Ariyalur–Pondicherry sub basin: a) Location map (modified after Lal *et al.* 2009, 6) and b) Geological Map (modified after Sundaram *et al.* 2001, 7).

Observations

On the basis of the field dimensions, the gravity flow deposits found are categorised into two types, viz. tabular and channelized deposits. Tabular deposits are mainly restricted to and are in association with the coquinid calcareous sandstones, the basal beds of the Kulakkalnattam Formation, Trichinopoly Group; informally known as the Trichinopoly /Garudamangalam Shell Limestone. Whereas, channelized deposition is present in younger parts of Trichinopoly Group and early part of the Ariyalur Group. Initial field studies indicate that while sand prone gravity flows are well exposed, their shaly/ clayey counterparts are not discernable, either due to poor exposure or probable erosion.

Tabular deposits: These flows commonly occur above the sequence boundary, at the base of Trichinopoly Group. They occur as massive, well cemented conglomerates associated with coquina. The clasts in these conglomerates range in size from pebbles to boulders (Fig. 2a). They are ill-sorted, sub-angular to sub-rounded, consisting mainly of basement gneissic rocks and occasionally of older reworked limestones, commonly mixed with large mollusc shells and silicified wood logs; rare carbonized twigs and leaf impressions are also recorded. The matrix binding these clasts is composed of medium to fine quartzose sand and calcareous mud. Lack of distinct imbrication and random orientation of the clasts is common. Individual flow units with erosional bases occur over intervening cross bedded units (Fig. 2b).

Channelized deposits: Stacked sequences of channelized coarse, gritty sandstones occur elsewhere in the Trichinopoly and Ariyalur Groups around Alunthalipur, Melarasur and Saradamangalam. While the stacked thicknesses vary from 4m to 15m, individual beds vary in thickness from 20cm to 100cm (Fig.

3a). Both the lower and upper bedding surfaces show scoured nature (sc. s.). Internally they exhibit normal graded (ng) coarse pebbly sandstone in the lower parts, followed by thick, massive (m) coarse sand interval, without internal bedding but with floating clasts. These are overlain by a cross bedded unit (cs) followed by a unit with fine laminations towards the top, which is occasionally preserved (Fig. 3a). The upper laminated portion commonly shows high bioturbation indices. At a few places large rip-up clasts are seen towards the top of flow units. Clasts of coarse laminated sandstones are present in a host of finer massive sandstones (Fig. 3b). Small distinct sinuous channels are present with a general flow direction of WSW to ENE (Fig. 3c)

Fig. 2: Conglomeritic debris flows at the base of Trichinopoly Group. a) Ill-sorted gneissic basement boulders in sandy limestone near Garudmangalam. b) Conglomeratic debris flow with erosional base over cross-bedded calcareous sandstone. (Scale: 15cm)

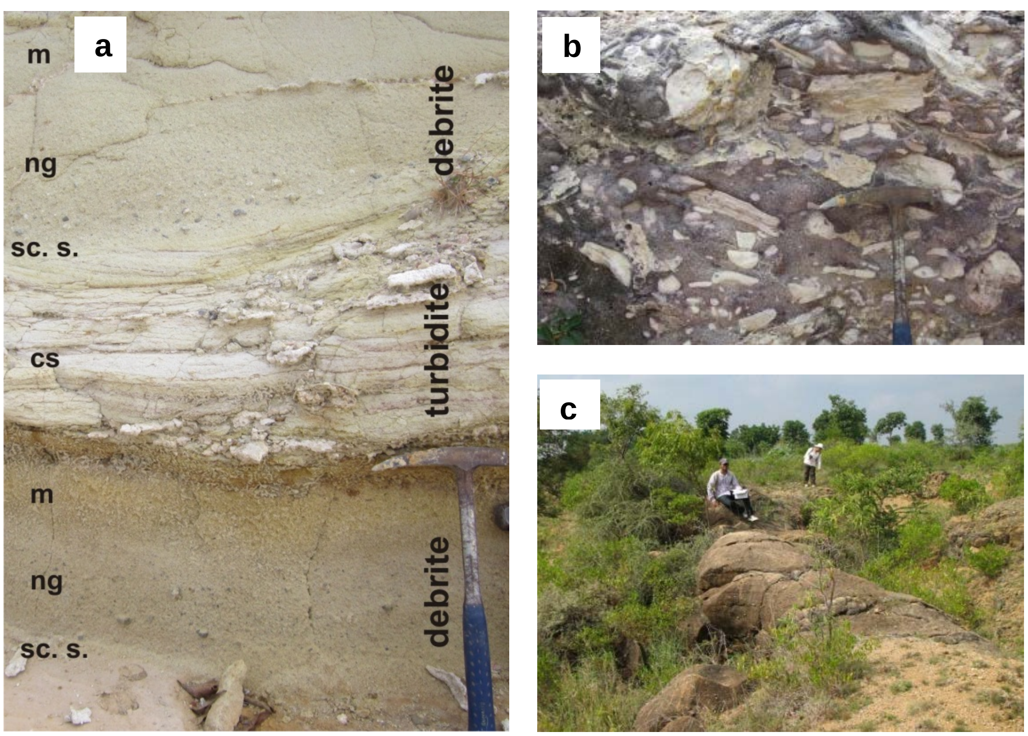

Fig. 3: a) Stacked sequences of coarse gritty sandstone densities showing an ill-sorted fining upward debrite at the bottom followed by turbidites. b) Sinuous channelized sandy debris flows. c) White laminated sandstone rip-up clasts embedded in upper portion of reddish sandy debrites.

At Palavur, top portion of one such channelized gravity flow is comprised of about 2.5m thick ill-sorted, friable, pebbly sandstone. No gradation could be observed in them. They are highly bioturbated (BI 5-6) with a monogeneric opportunistic ichnoassemblage of *Thalassinoides* surrounded by halos, resulting from substantial diagenesis and leaching, indicating period of quiescence and or abandonment of these channel bars.

The sinuous channelized gravity flows exposed near Saradamangalam show a variety of depositional features and elements. The bed thicknesses vary from 1m to 2m. The beds towards the base are commonly scoured and their tops either eroded or highly bioturbated. The channel fills are predominantly massive, comparatively well cemented, ill-sorted sandstone with floating outsized pebbles (Fig. 4a). Lateral accretion and migration of these channels is distinct in the field. The migrating bars of the channelized system, consist of massive pebbly sandstone, followed by thick and parallel, finely laminated, highly bioturbated unit at the top (Fig. 4b). In the upper part, most beds show development of climbing ripple lamination (Fig. 4d), large scale planar and trough cross stratification (Fig. 4c). The levee part of these deposits, which dips away from the channel axis, shows development of tabular facies.

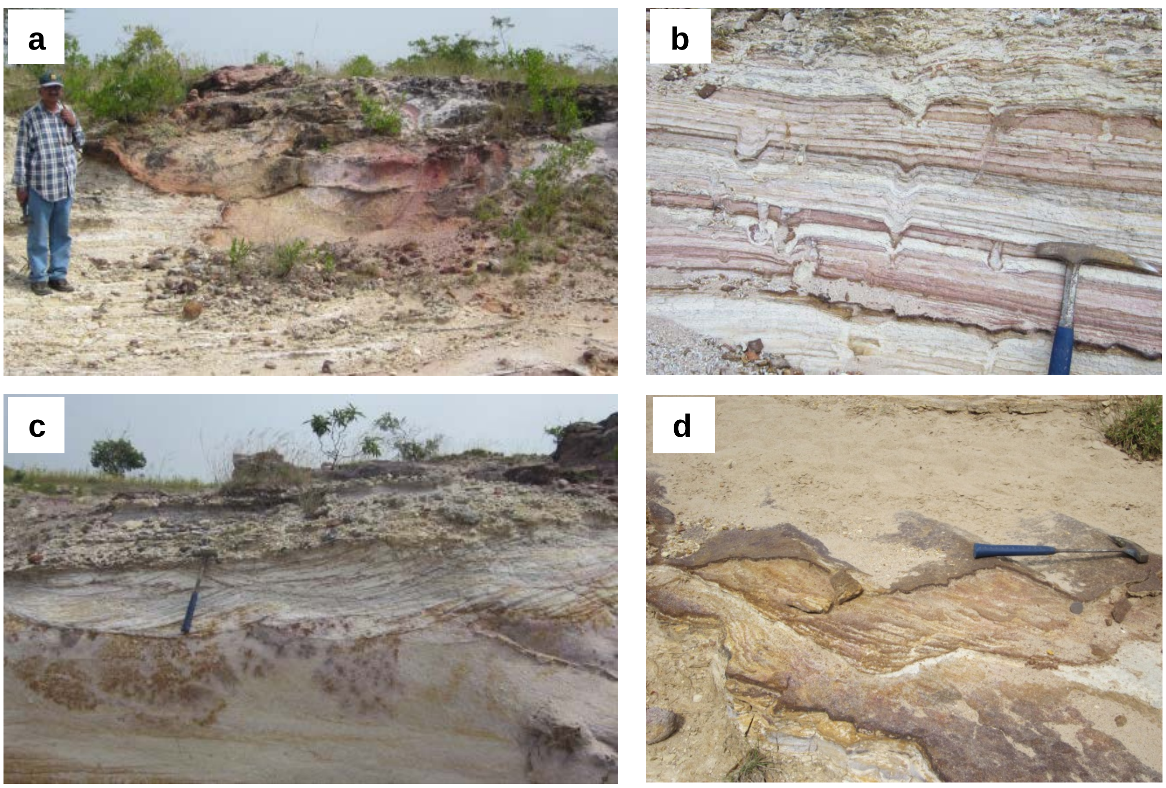

Fig. 4: a) Channel filled coarse grained illsorted sandstones with floating pebbles. The channel is cutting though thinly laminated portion of migrating bars. b) Biogenic escape structures in the laminated portion. c) Large scale planar and trough cross stratification in the uppermost part of the channelized system. d) Climbing ripples and ripples marks.

Discussion

Flow rheology: It can be observed that both Newtonian and non-Newtonian fluid rheologies were acting during the deposition of these sediments. The dominant sediment support mechanism includes dispersive grain pressure, fluid turbulence as well as matrix strength (8).

The tabular deposits show characters of debrites in the lower portion; whereas, in the upper portion they exhibit normal grading and fine lamellar structure assignable to turbidites, indicating waxing and waning phases with a mixed rheology, initially non-cohesive high density flows alternating with a cohesive Newtonian plastic flow. Some amount of reworking by long shore currents may be present as indicated by rare imbrication, their extension along the strike of the beds and association of near shore cross bedded and laminated coquinid calcareous sandstones.

The channel deposits either show normally graded or massive non-graded character and can be classified as debrites. Due to presence of both cohesive and non-cohesive character in a single flow unit further classification of the debrites is difficult (8). However, these may represent the association of an initial cohesive flow and its waning phase. Matrix strength is the main sediment support mechanism for these debrites. The laminated and cross bedded units are obvious products of the associated fluidized Newtonian flows. Rip-up clasts indicate underlying bed erosion and deposition in surges (9).

Architecture of flows and facies association: Various classification schemes can be appropriately utilized for these deposits. We have followed the scheme of Lowe, 1982 (10). The tabular deposits are interpreted to represent S_1 and S_2 units whereas the channel deposits represents unit R_2 and R_3. The bedded and laminated units represent T_t and T_d facies of the low-density flows.

Origin and depositional mechanism: Presence of gravity flows within shelfal deposits is unusual. The common causes for the generation of sandy mass transport deposits/ sandy gravity flows are earthquakes, meteorite impacts, volcanic activities, tsunamis, tropical cyclones and monsoon flooding events (11). In the present case, their presence can be attributed to the dispersal system flowing out of a high relief provenance on the basin margin (Fig. 5). Across the Cauvery Basin margin, the Precambrian South Indian craton has a high relief; drainage from which directly debouched into the nascent Cretaceous shelf. As the Indian subcontinent drifted from the high southern latitudes to the southern tropics during this time period, the climatic conditions were favourable for high seasonal discharges from the inflowing rivers. The loss of gradient across the basin margin results in the loss of strength in the gravity flows, trapping sediments on the low relief shelf. In part these flows may also represent deltaic hyperpycnal deposits.

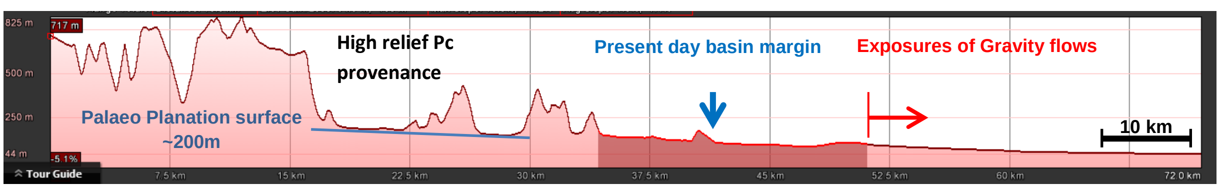

Fig. 5: Present day elevation profile of the basin along NW-SE direction. Red arrow marks the location of the gravity flows along the section. Note the proximity of the gravity flows to the high relief provenance even at this date.

The deposition of Cretaceous sediments in the Cauvery Basin is principally controlled by the earlier developed unfilled grabens, with a high relief on the basin margin (12). From the present study it can be noticed that the major flow direction of the inflowing discharge of these deposits is from the SW/WSW. While the strike of tabular deposits is parallel to the overall strike of the sediments, the channelized deposits flow along the axis of the Ariyalur-Pondicherry sub-basin.

Implications: Hydrocarbon reservoirs of Cretaceous and Paleogene age in the basin are products of gravity flows (4, 5). Diagenetic alteration of these reservoirs has posed challenges in the development of the discovered reserves. The exposures of gravity flows discussed here can provide key inputs for the understanding of the distribution, reservoir characterization and diagenetic alteration of these reservoirs. Our future studies will delve upon these aspects of the reservoir prone gravity deposits.

Conclusions

Gravity deposits constitute an important facies in the depositional history of the Cauvery Basin. The present record of gravity deposits and facies within them imply short distance transport by hyperpycnal plumes through drainage originating from the high relief provenance and deposition due to loss of gradient on entering the basin. The recorded sand dominated debrites and turbidites constitute important reservoir facies in the basin.

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