

Ooid Turbidites from the Central Western Continental Margin of India

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Abstract

Gravity displaced debris flows/turbidites have been observed in five box cores collected between water depths of 649 and 3,627 m from the central western continental margin of India. Studies on grain size, carbonate content, and coarse fraction revealed that the turbidites are mainly composed of ooids, shell fragments, and shallow water benthic foraminifera. Bioclastic sediments of the outer shelf and upper slope regions are considered the source of the debris flows/turbidity deposits. It appears that the flows were initiated by failure on the outer shelf and upper slope during late Pleistocene low stands of sea level.

Introduction

The term turbidite should denote a bed deposited by a turbidity current. However, it has also been used by many workers in a much broader sense to include all the mass flow deposits and the resulting turbidite facies (Mutti and Ricci-Lucchi 1972). Though studies on the extent of single turbidites and their correlation are relatively easy in modern basins, the earliest attempts of correlation of individual turbidites come from ancient rocks. Recent turbidites, however, have been correlated by various authors for varying distances, mostly from Atlantic continental margins and European seas. Elmore and others (1979) mapped a large single turbidite, "The Black Shell Turbidite" of the Hatteras Abyssal Plain.

Mass transport and deposition of turbidites in the deep seas have been studied most often in the context of submarine canyon and fan systems (Shanmugam and Moila 1988). Relatively little research has been done on the slope and base-of-slope mass deposition in areas far removed from the influence of channel-

ized flow through canyons (Nardin and others 1982).

Ooids have been reported from the deep western continental margin of India (Hussain and Gupta 1985, Rao and others 1988, Shetty 1972). The unusual occurrence of ooids at such large depths is of particular interest and it was thought worthwhile to examine the mechanism responsible. The purpose of this article is to report on the presence of ooid turbidites covering a large area on the western continental margin of India not related to submarine canyons nor to seismicity.

The cores considered for this study from the western continental margin of India (Fig. 1) were collected as part of the ongoing geological programs of the National Institute of Oceanography. Though randomly placed, they record the presence of turbidites at various intervals. The coarse fraction is dominated by ooids and, for ease of identification and future discussions, they have been informally termed "Ooid Turbidites." The detailed description of some of the cores have been given elsewhere (Rc-17-119: Hussain and Gupta 1985, SK-T-7/1: Rao and others 1988, Cores 29, 43; Shetty 1972) and will not be repeated here.

Geographic Location

The study area is situated along the western continental margin of India, which is a passive margin. The width of the shelf is greater in the northern part (about 220 km off Bombay) and becomes narrow towards the south (about 100 km off Ratnagiri). The shelf break is of the gentle type (Wear and others 1974) and is located between water depths of 95 and 130

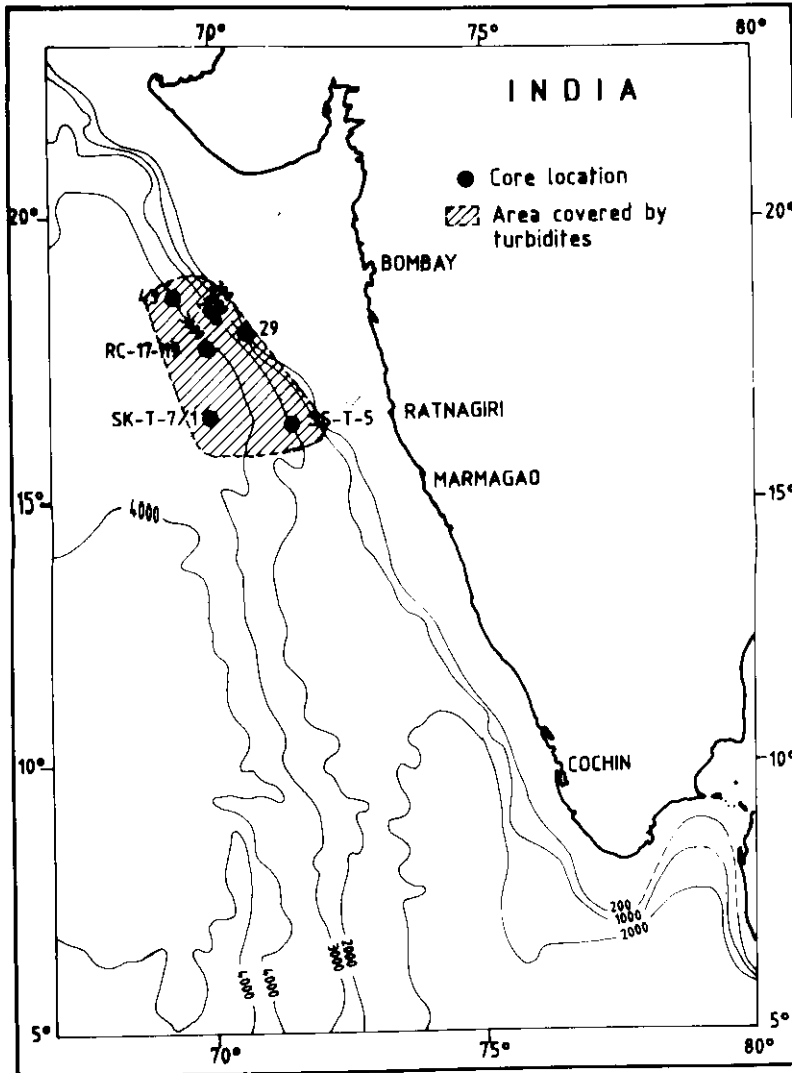


Figure 1. Map showing the core locations and area covered by turbidites, western continental margin of India.

m. The shelf platform is nearly flat, having extremely low gradients, from the shoreline to the break-in-slope. Beyond the shelf break the depth increases sharply. The presence of submerged terraces at depths of 92, 85, 75, and 55 m indicate former low stands of sea level (Nair 1975). Seaward to a depth of 200 m, the bottom becomes irregular by the presence of pinnacles having heights up to 8 m. The continental slope beyond 200 m water depth is smooth and steep in this region. The topography of the continental rise is influenced by the Indus Fan.

The sediments on the inner shelf (<50 m) consist of silty clays and clayey silts discharged by small rivers that drain the western ghats. The outer shelf is a zone of nonsedimentation and/or erosion (Rao 1989) and is composed of relict carbonate sand, and algal and oolitic limestones of Holocene age (Nair 1975). A mixture of terrigenous and biogenic sediments are

present in the slope region. The continental rise receives Indus borne sediments.

Turbidites

The turbidites exhibit pale olive (10Y 6/2) to yellowish grey (5Y 7/2), olive grey (5Y 6/2), and greenish grey (5Y 6/1) color. Downcore variations in lithology, size fractions, calcium carbonate, and organic carbon content for core SK-T-7/1 are shown in Figure 2. The turbidites are mainly bioclastic. The coarse fraction of the sediments consists of ooids, shell fragments, shallow water benthic foraminifera, bivalves, pteropods, gastropods, pyritized shells, fish scales, and detrital material (Fig. 3). The occurrence of ooids along with the coarser sandy fraction at various levels (Fig. 4) suggest that a series of turbidite layers is present.

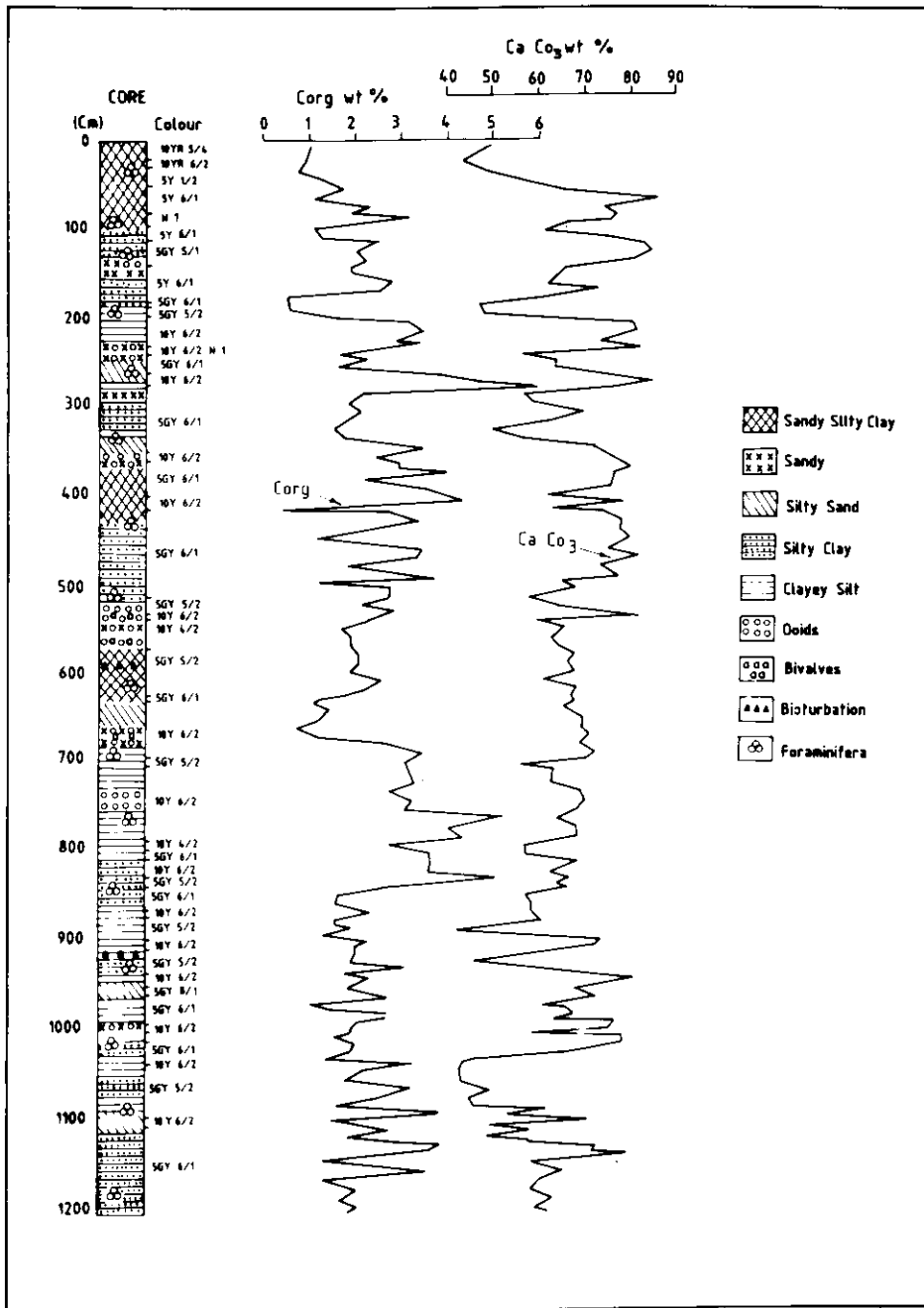


Figure 2. Down core variations of lithology, calcium carbonate and organic carbon contents of core SK-T-7/1.

Provenance

Ooids form in warm, shallow, agitated waters. The prerequisites for ooid formation are (1) exposure of nuclei to waters that are saturated with calcium carbonate, (2) episodic but persistent agitation of the nuclei in order to form smooth uniform carbonate coatings, and (3) continuous replenishment of calcium carbonate at the site of formation (Lloyd and others 1987). The cores are from deep waters; supersaturation of calcium carbonate and prevailing of high en-

ergy conditions are not possible, even under extreme conditions, at that depth. The ooids, therefore have been transported from shallow water.

Studies on the sediments of the western shelf of India revealed the presence of ooids and their formation during the late Pleistocene (11,000 years B.P.) lowered sea levels (Nair and Hashimi 1980). The majority of turbidites on the continental rise were deposited during glacial times and particularly at the beginning of the post glacial period, when relict material was supplied from the outer shelf (Stackelberg 1972).

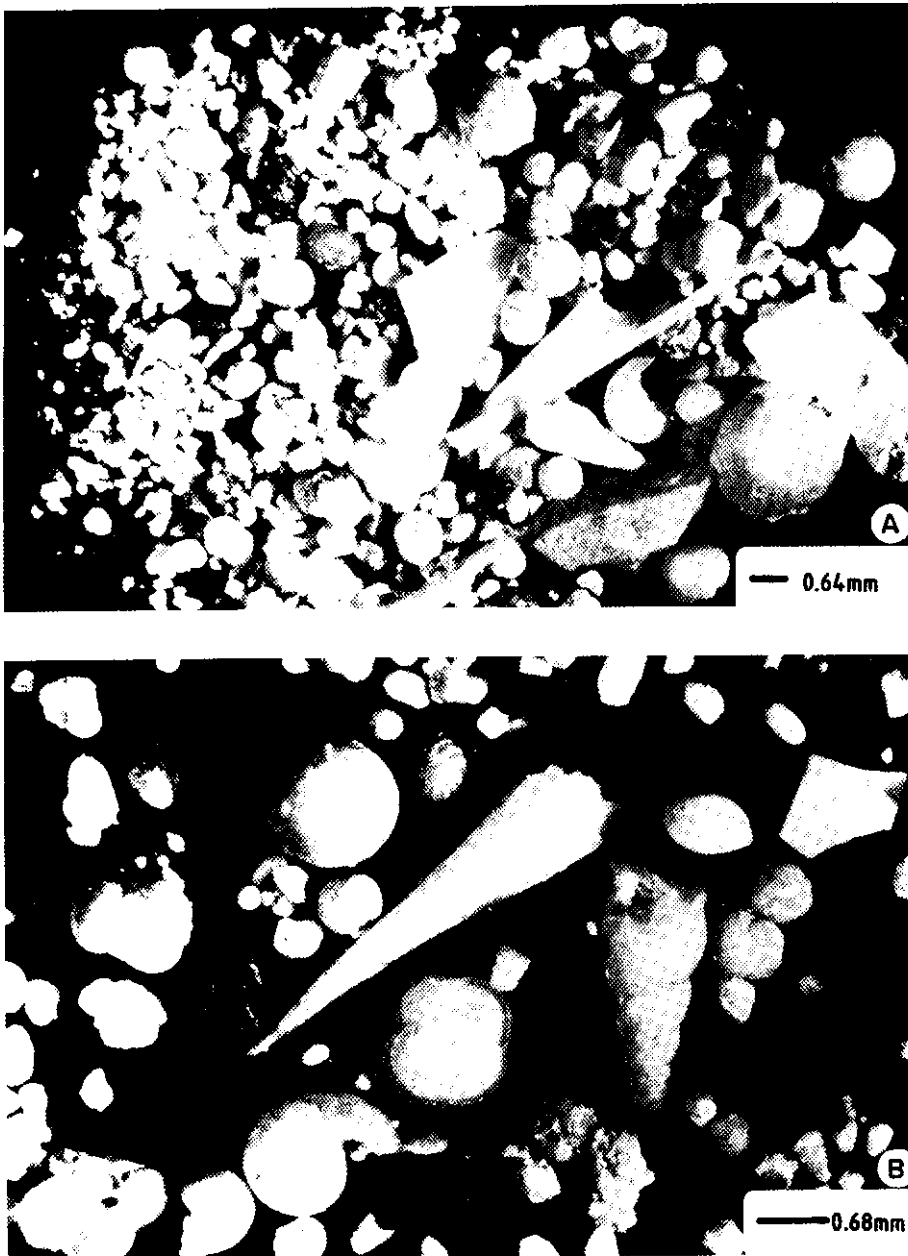


Figure 3. Photographs showing (A) abundance of bioclastic constituents of the coarse fraction of core SK-T-7/1 (130–140 cm), and (B) occurrence of pteropods, bivalves gastropods, shallow water benthic foraminifera, and ooids.

The turbidites are consistently rich in carbonates. The calcium carbonate content ranges from 42 to 86 percent (core SK-T-7/5, Fig. 2) emphasizing the bioclastic origin of the turbidites. The high carbonate content in this region is attributed to the presence of sediments slumped from the outer shelf and slope. Organic carbon in the surficial sediments of the Arabian Sea generally is <1 percent, with the exception of the deep Indian continental margin (Kolla and others 1981). The high organic carbon values (up to 6 percent Fig. 2) from sediments of this region may have resulted from slumping of sediments from the continental slope which contain 10 to 20 percent of organic

matter (Paropkari and others 1987). Higher sand percentages in the deep areas along the Indian margin mainly reflect local derivation by slumping (Kolla and Coumes 1987).

Triggering and Flow Mechanisms

The presence of discrete ooid layers in the cores suggests that each one represents a single gravity flow event. The occurrence of ooids at many intervals (Fig. 4) indicates that such events were frequent and must have played an important role in the depositional his-

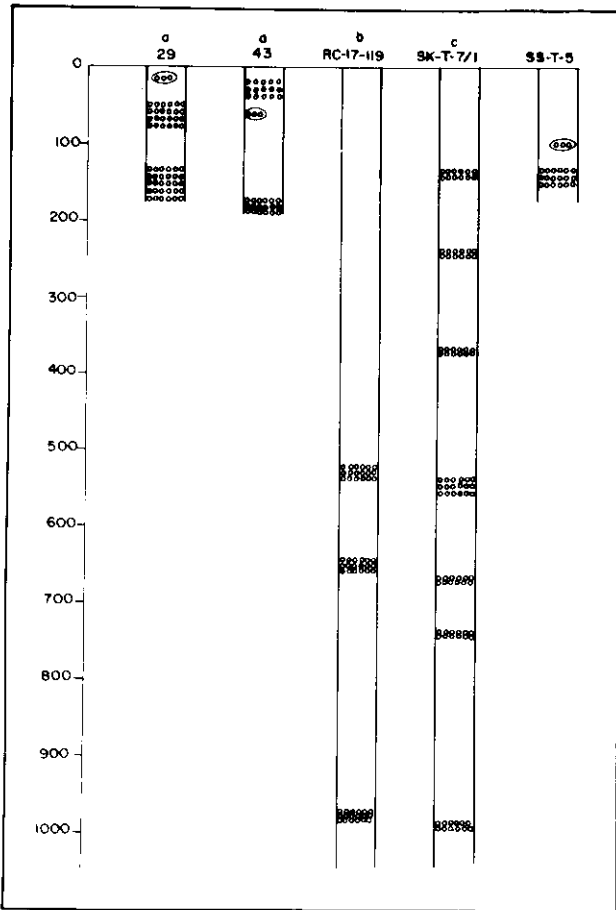


Figure 4. Occurrence of lenses of ooids and ooid layers at various levels in the cores: ((a) Shetty 1972; (b) Hussain and Gupta 1985; (c) Rao and others 1988).

tory of the Arabian Sea. The ooids of the present study were formed almost at the same time as those of the shelf oolites (Shetty 1972). Rao and others (1988) pointed out that the ooids were transported by slumping from the outer shelf and upper slope region of the western continental margin of India during the late Pleistocene lowered sea levels. Therefore, the age of the turbidites would appear to be about 11,000 years B.P. The Arabian Sea was not glaciated, but glacio-eustacy lowered the sea level by about 90 m (Nair 1975). During this period a large part of the western Indian continental shelf was subareally exposed and subjected to erosion and bioclastic accumulation. If the angle of repose is lower in air than in water, such bioclastic accumulations might lose equilibrium and trigger a mass flow (Cita and others 1984). The changes in hydrodynamic pressure due to propagation of severe waves, such as storm waves, may cause shear failure in unconsolidated sediments and lead to submarine slides (Rahman and Layas 1986). The presence of gas and gas hydrates (Siddiquie and others 1981) may also have contributed to sliding (Carpenter 1981). Eustatic lowering of sea level is therefore considered conducive for the triggering of submarine slides, perhaps in association with other factors such as periodic storm waves and the presence of gas hydrates. The slumped materials were largely transformed into suspensions that flowed down slope in the form of debris flows (Almagor and Wiseman 1982).

It is difficult to estimate the exact lateral extent and volume of the ooid turbidites at this point. In the slope setting, sediment input occurs along linear sources;

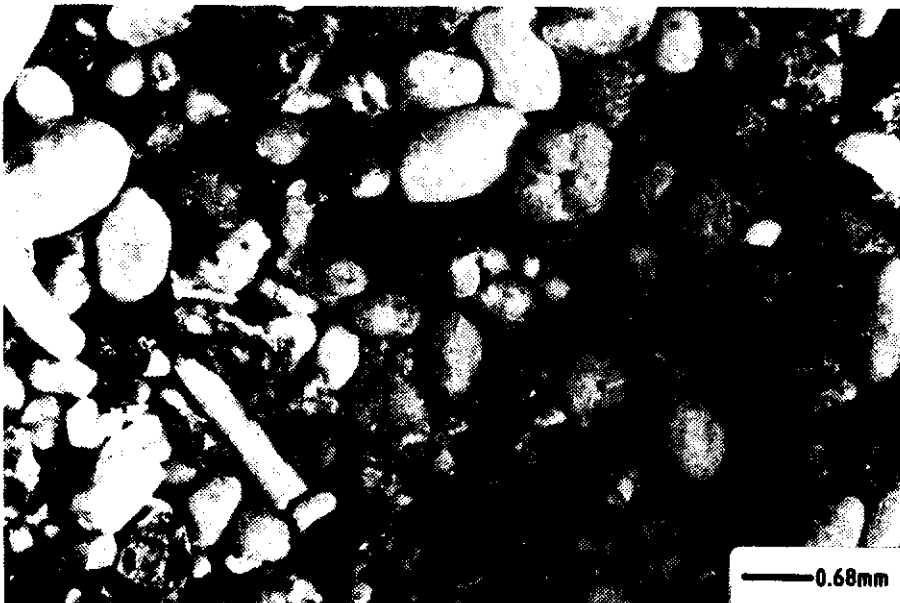


Figure 5. Photograph showing the abundance of ooids in core SK-T-7/1 (535–540 cm).

slumping has been reported all along the central western continental margin of India (Stackelberg 1972). Ooids were transported to deeper areas more than 200 km away from the shelf edge. The abundance of the ooids decreases with increasing distance of transport from the source (Bornhold and Pilkey 1971). Ooids constitute more than 60 percent of the bulk sediment samples (by weight) at 235, 535, and 990 cm depth in core SK-T-7/1 (Fig. 5) and at 640 cm in core RC-17-119 (Hussain and Gupta 1985), which indicate that the ooid layers spread far beyond these locations. Debris and turbidity flows generated by slumping reached the eastern part of the Indus Fan (Kolla and Coumes 1987). Hence it appears that the turbidites occur in an area more than 250 km in length and 200 km in width (Fig. 1). The bottommost layer of the turbidites could not be traced, although a coarser sandy layer containing ooids was encountered at 990 cm in core SK-T-7/1, suggesting that the turbidites are more than 10 m thick at certain places. Considering the area affected by slumping and debris flows (at least 40,000 km²) and thickness of the turbidites, it is possible that one or more megaturbidites (Bouma 1987) might be present. However, systematic sampling and subbottom profiling are necessary to correlate the individual turbidites, map the lateral extent, and estimate their volume.

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