

Ooids in Deep Sea Core from the Western Continental Margin of India

N HUSSAIN*

Physical Research Laboratory, Ahmedabad 380 009

and

M V S GUPTHA

National Institute of Oceanography, Dona Paula, Goa 403 004

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Ooids occur at 520 and 640 cm sediment depths in a deep sea core taken from a water depth of 3085 m from Arabian Sea. CaCO_3 content of the bulk sediments in these oolitic sections at c. 520 and 640 cm is 58 and 72% respectively. Ooids show an excess of 50% Sr compared to marine aragonitic deposits. U-Th series radionuclide data on the separated ooids from $>63 \mu\text{m}$ fraction appear to suggest that they are younger than 25,000 y. They also show $1.2 \pm 0.2 \text{ dpm g}^{-1}$ excess of ^{226}Ra over that of ^{230}Th . Transportation of these ooids from relatively shallower depths to the present location due to slumping of the sediments is envisaged.

Extensive work has been carried out on the sedimentological aspects of the western continental shelf of India¹⁻⁵ and relict carbonate sediments in the shelf regions, exceeding 60 m water depth off Bombay have been reported. These sediments show an increasing trend in their carbonate content towards the shelf edge^{6,7}. Ooids and pelletoids constitute a bulk of these relict sediments. Ooids range from 50 to 90% in the coarse fraction at 80 to 90 m water depth on the northwestern shelf and the radio-carbon ages of these ooids indicate⁸ a range of 10,000 to 11,000 y.

During the course of study on the Arabian Sea cores, core RC-17-119 (17°46.68'N, 69°57.65'E), collected from the water depth of 3085 m has shown the occurrence of oolitic sands at 2 distinct levels. This unusual occurrence of oolites at such large water depth and their origin is discussed here.

Methods

The $>63 \mu\text{m}$ fraction of the sediments from 520 and 640 cm core sections was separated by wet sieving. Some of the most representative ooids were picked up from these fractions and mounted on epoxy, at different orientations. The epoxy was polished to obtain the required horizontal and vertical cross-sections for texture studies using stereo-microscope and SEM.

Abundance of elements like Ca, Mg, Sr, Fe, Cu and Mn was determined on atomic absorption spectrometer (Perkin-Elmer 305A). For the determinations of

the radionuclide concentrations, 2-3 g dry separated ooids were dissolved completely in dil. HCl and 2-3 drops of H_2O_2 . Solution was spiked with ^{234}Th and ^{232}U tracers and ^{226}Ra was first measured through the ingrown ^{222}Rn following Bhat *et al.*⁹. Standard radiochemical and counting procedures¹⁰ were followed to isolate and measure the uranium and thorium isotopes.

Results and Discussion

Lithology—Core RC-17-119 (1223 cm) shows interbedded foraminiferal marl ooze. The faunal and floral components include radiolaria, planktonic and benthic foraminifera, pteropods, corals, echinoidal spines and diatoms. Around 520, 640 and 970 cm (last section was not available but the information is taken from core-log), the foraminiferal ooze grades into an oolitic foraminiferal ooze and at these levels the coarse fraction is composed of ooids and planktonic foraminifera. The abundance of $>63 \mu\text{m}$ ooids at 640 cm (by weight of the bulk sediments) is 64%.

Vertical and horizontal sections of most ooids showed dark nucleus at the centre with surrounding annular rings of lighter intensity (Fig.1). Scanning electron microscope studies of the nucleus and the rings showed that they chiefly consist of Fe and S, the darker the ring, the higher the amount of Fe and S and lesser Ca (Fig.2). X-ray diffractogram showed that more than 99% of their total CaCO_3 is in aragonite form. Results of major and trace elemental analyses on the separated ooids from $>63 \mu\text{m}$ fraction are presented in Table 1. An almost 1.5 times higher Sr content observed in this study compared to its normal

*Present address: School of Chemistry, University of Bath, Bath BA2 7AY, UK

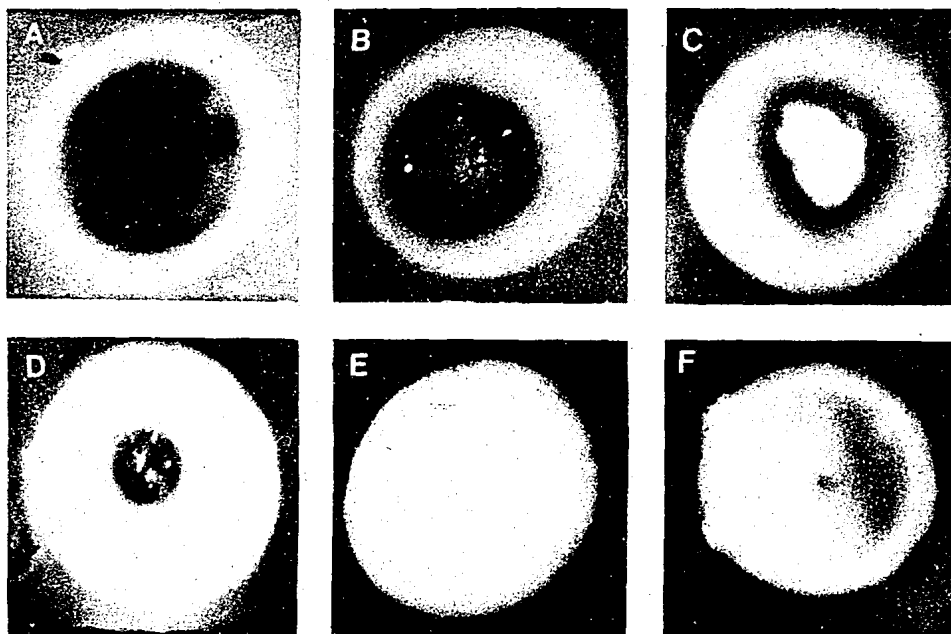


Fig. 1—Cross-sections of different ooids under stereo-microscope, in reflected visible light [During polishing, the central nucleus came out in (F) and thus it is the photograph of the remaining shell fixed in epoxy. Sizes of these ooids varied between 0.5 and 1 mm]

content in marine aragonites¹¹ of c. 8,000 ppm is in agreement with the reported values of about 1% Sr in the ooids from Great Bahama Bank¹².

Sedimentary frame-work on the western continental shelf—Ooids is one of the important tools in sedimentology for deciphering the palaeoenvironmental setting. It is widely accepted that water supersaturated with calcium carbonate, warm climate and agitated shallow waters are favourable conditions for the formation of ooids¹²⁻¹⁴. Formation of ooids cannot take place in regions other than shallow water environments. Suess and Futterer¹⁵ have precipitated well developed aragonitic ooids (10-100 μm) by adding humic acids to artificially super-saturated seawater. Although there are indications that anaerobic conditions did prevail in Arabian Sea in the recent past¹⁶, it is difficult even to speculate the super saturation of seawaters with respect to CaCO_3 at 3085 m depth, from which the core was extracted. Thus their presence in such deep waters suggests that there must have been processes like slumping or turbidity currents, which transported these ooids from relatively shallower regions to the core site.

Ooids in the present core are largely ellipsoidal and discoidal (Fig.3) and are greyish to greyish black. Microscopic observation of these ooids show that they have almost negligible pitting on the surface. This is in contrast with the ooids found on the shelf which are light yellow to black and show prominent pitting caused due to the algal growth⁸. This observation

suggests that immediately after the formation, the oolitic sediments on the shelf must have been transported to the deeper site either due to slumping at the time of lowered sea level or the turbidity currents^{17,18}. As stated earlier, ooids of the shelf region have been dated by ¹⁴C to be about 11,000 y old^{8,19}. This time scale also marks the boundary between Pleistocene and Holocene. With a view to estimating the age of the present ooids, ²³⁴U/²³⁸U, ²³⁰Th/²³⁸U and ²²⁶Ra/²³⁰Th activity ratios²⁰ have been measured following the standard radiochemical procedures^{10,21} (Table 2).

Recent marine corals and oolites^{20,22} incorporate the 15% oceanic excess of ²³⁴U over ²³⁸U. Once formed, this excess ²³⁴U in oolites decays *in situ* with its half-life, 245,000 y. The observed ²³⁴U/²³⁸U activity ratio in present ooids is 1.11 ± 0.02 (Table 2). Hussain *et al.*¹⁶ have carried out detailed geochronological work in Arabian Sea. Their study in Core RC-17-119 shows that ²³⁴U/²³⁸U activity ratio does not show any significant variation throughout the available length of the core (7 m). From 1.13 ± 0.01 in the top, its value decreases to 1.12 ± 0.01 at 7 m core length. ¹⁴C ages of sections up to 29 cm yield c. 10,000 y age¹⁶. It may, therefore, be expected that the ooids are also about that old.

Calcareous deposits like corals and ooids do not scavenge thorium isotopes during their formation (see Ku²³) and so it is possible to date them through their ²³⁰Th/²³⁸U activity ratio^{23,24}. Based on the

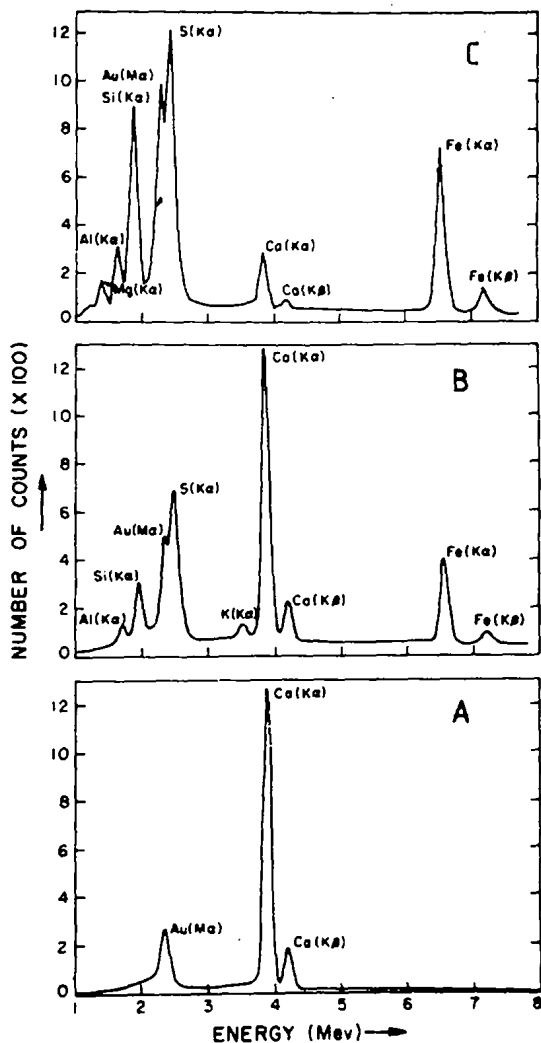


Fig. 2—Relative abundance of Ca, Fe, S and Si in 3 different rings of ooid cross-section shown in Fig. 1A [In the white ring, only Ca is abundant (A). In progressively darker rings, Fe, S and Si increase relative to Ca (B&C). Gold peak is due to gold used in plating]

Table 1—Stable Nuclide Composition of Ooids from the Core RC-17-119

Nuclide	Conc.(ppm)	Nuclide	Conc.(ppm)
Ca	3,64,000	Fe	1,600
Sr	12,100	Cu	215
Mg	1,100	Mn	22

assumption of no ^{230}Th in ooids at the time of their formation and attributing the total observed ^{230}Th to its *in situ* growth from ^{234}U , the observed $^{230}\text{Th}/^{238}\text{U}$ activity ratio of 0.39 ± 0.02 (Table 2) corresponds to $45,000 \pm 2,800$ y. However, this is an upper limit on the age of these ooids since there could be a significant

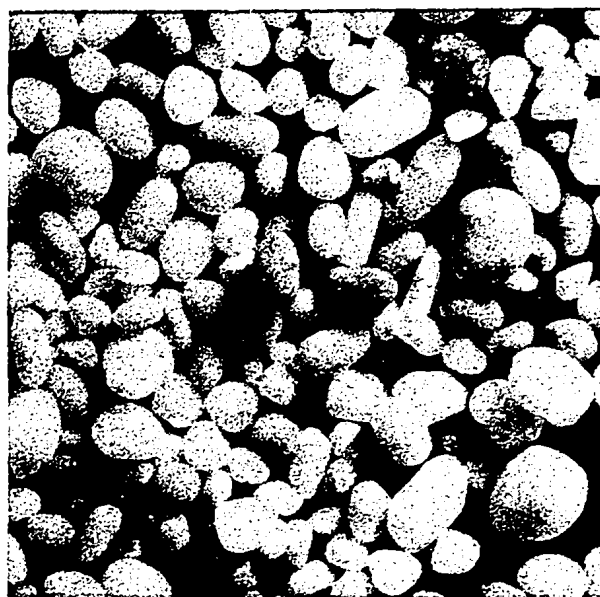


Fig. 3—Stereo-microscopic photograph of $> 63 \mu\text{m}$ fraction of 640 cm section from Core RC-17-119 [The bulk consists of highly polished, grey coloured ooids and pelletoids, besides some planktonic foraminiferal shells and their fragments. Six times magnified]

Table 2—Radionuclide Concentrations of Ooids from the Core RC-17-119

Nuclide	Conc.(dpm g^{-1})
^{238}U	2.81 ± 0.07
^{230}Th	1.11 ± 0.05
^{226}Ra	2.29 ± 0.05
^{232}Th	0.16 ± 0.02
$^{234}\text{U}/^{238}\text{U}$ (AR)	$1.11 \pm 0.02^*$

*The number is the activity ratio of the 2 uranium isotopes and is a dimensionless quantity

contribution to ^{230}Th from the oolitic core which is rich in Fe and S (Fig.2). Presence of 0.16 ± 0.02 dpm g^{-1} of ^{232}Th (Table 2) in these ooids is a proof of Activity ratio of $^{230}\text{Th}/^{232}\text{Th}$ in various sections of the 7 m core, centres at 3 with a 10% standard deviation¹⁶. Correcting for this detrital ^{230}Th component by subtracting 3 times ^{232}Th amount from the observed ^{230}Th , the age of the ooids are calculated to be $23,000 \pm 3,800$ y.

^{226}Ra (half-life=1,600 y), a daughter of ^{230}Th shows an excess of 1.2 ± 0.2 dpm g^{-1} in these ooids (Table 2). Based on the decay laws²⁵, it is expected that in an isolated system, after 9,600 y, the activity of the unsupported ^{226}Ra would be reduced to only 1.6% of its initial excess and after about 16,000 y (i.e. 10 half-lives later), ^{226}Ra and ^{230}Th would be almost in equilibrium state. The excess of ^{226}Ra (Table 2), if incorporated in ooids at the time of their formation,

would suggest that the ooids are not older than about 6-7 half-lives of ^{226}Ra . Based on about 10,000 y as the age of the ooids⁸, their initial ^{226}Ra excess works out to be about 80 dpm g^{-1} . However, this value appears to be too high compared to the ^{226}Ra concentrations in various recent marine carbonate deposits²⁶. Bernat *et al.*²⁷ have attributed the huge excess of ^{228}Th in phillipsites from 600 cm deeper sediments of Pacific Ocean to the migration of ^{228}Ra into the interstitial waters following its production from ^{232}Th in the solid phases and its subsequent uptake by phillipsites. A similar mechanism could have been operative in the oolites giving rise to a steady state ^{226}Ra excess of 1.2 ± 0.2 dpm g^{-1} . This conclusion could not be checked by measuring the excess of ^{228}Ra (half-life = 5.7 y) or its daughter ^{228}Th (half-life = 1.9 y) because the sediment core was extracted 10 y before its analysis and almost 70% of the ^{228}Ra excess would have decayed. The activity ratio of $^{228}\text{Th}/^{232}\text{Th}$ was indeed very close to unity in these ooids. This also precludes the possibility of assigning age limits on these ooids through ^{226}Ra measurements, if the steady state conditions had prevailed between the Ra uptake by the ooids and its subsequent decay.

To conclude, it appears that the oolites of the present study from deeper waters were formed almost at the same time as those of the shelf oolites²⁸, about 11,000 y before present and subsequently a part thereof was transported away to the deeper waters due to sudden change in the sea level at the Pleistocene-Holocene boundary and the increased turbidity currents. Stackelberg³ has reported the occurrence of slumping on the south-western continental margin of India. If slumping were the mechanism of transportation of the oolites, there must have been 3 distinct slumping episodes in a relatively short time to have given rise to 3 distinct layers of oolitic sand in the core RC-17-119. This would also necessitate caution to be taken in interpreting the sedimentation rates and palaeoclimates in this zone due to the shallow water sediments contaminating the deep sea sediments.

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