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Microfossil proxies; an Insight to the Deep in Age, Environment and Petroleum Exploration

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Abstract: Physical, chemical, biological and geogenic living and non-living resources in ancient and modern ocean basins is a part of the measurable blue economy. This synoptic article presents the role of microfossils in decipheringthe process of unaltered organic material into fossil fuel resources.

Introduction

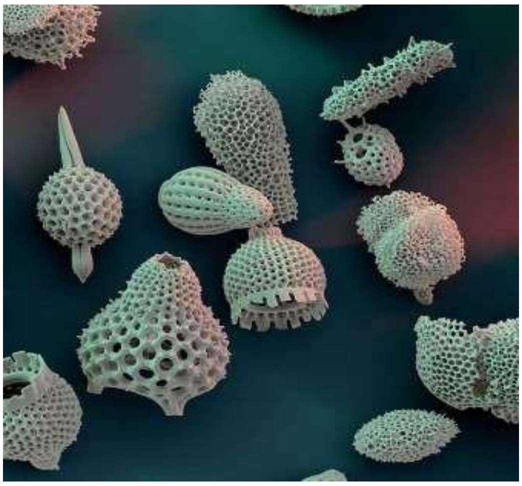
Microfossils are the remains of once-living bacteria, protists, plants and animals. The diatoms, coccolithophores (autotrophic nannoplankton), conodonts (tooth-like fossils of <3mm long), dinoflagellates, nannofossils, ostracods, radiolarians and foraminifera serve as bio-proxies to resolve the past environment, paleoecology, paleo-depth, paleotemperature, paleoclimate, age, the depositional environment of sediments. The foraminifera isvalued in the correlation of marine formations and its abundance through geological periods facilitates the reconstruction of palaeogeography of the continents. Ostracods are useful lfor determining palaeoecological and paleoenvironmen tdue to their wide distributionacross various ecosystems and longer range in geologic time. Spores and pollens are well-preserved because of their hard-resistant parts and distributed over large areas on continents,lagoon sand marinesystems.The niche level studies of these organic and plant remnants offer the potential knowledge required for exploration of various metallic minerals, gas hydrates and hydrocarbons (Petroleum).The sustainable use of these exhaustible offshore natural resources is termed as blue economy. The blue economy activities are related to marine resources such as marine mineral mining and offshore oil and gas exploration. Microfossil bioproxies offer immense utility in comprehending the exploitation and preservation of the marine environment.The Fig.1. shows some of the significant microfossils useful in ecological and geological applications.

Role of Fossil Organisms in Paleoenvironment

The evolution of organisms through time provides the framework for a system of zonation by which discrete units of time represented by the material accumulation of sediments can be recognized. Since it evolves, and stages in their evolution provide a basis for subdividing the rock column into units. Microfauna help visualising the evolution of the environment in which they habitat. The diatoms, sponge spicules are characteristic of lacustrine; the sessile foraminifera and ostracod deduce littoral; the spores and pollens, conodonts, arenaceous and porcelaneous foraminifera affiliate to lagoon environments. Marine microfossils recorded in Precambrian-Recent sediments are used in deducing the biostratigraphy and palaeoecological interpretations (Haq and Broersma, 1978). They lived in all the marine realms ranging from the beach to deep sea and aid as an interpretation tool to record changes in the paleoenvironment. These forms are useful in monitoring past changes in oceanic environments, particularly changes in temperature. Ostracod, bryozoans, foraminifera and diatoms demonstrate the distribution patterns linked to water depth, sediment type and physical and chemical variables in seawater; they are useful in delineating changes in the deep environment. Spores and pollen, although derived from land plants are strongly climate-dependent.

a

b



c

d

Fig.1 Microfossils (a) foraminifera, (b) radiolarian (c) conodonts (d) coccolithophores

Foraminifera is the protozoans, connected chambered with aperture, diversified morphological features in response to the depositional environment. These are abundant in Phanerozoic,Mesozoic and Cenozoic sediments, geographically widely distributed in all marine environments. Planktonic foraminifera provinces in the modern ocean follow sea-surface temperature (SST) gradients, reflecting the strong relationship between SST and species abundances, and therefore serves as indicators of palaeoceanographic conditions (Fig.2). Their shell morphology and coiling directions help comprehend glacial cycles. The Oxygen isotopes (^{18}O and ^{16}O) in the fossil shell reflect the paleoclimate and paleotemperature. The change in coiling of *Neogloboquadrina pachyderma*(Fig 3) used as a proxy for deducing warm and cool periods of paleoclimate. When the earth experiences periods of relatively cold temperature, ocean waters are cooler and *Neogloboquadrina pachyderma* forms its test such that it coils to the left and alternatively, during the period of relatively warm temperatures when ocean waters are warmer, the test with a coiling direction to the right.The agglutinated fossil foraminifera buried deeply in sedimentary basins is used to estimate thermal maturity, a key factor for petroleum generation. The Foraminifera colour index is applied to quantify the colour changes to estimate the burial temperature, particularly in the early stages of petroleum generation (approx... 100ºC).

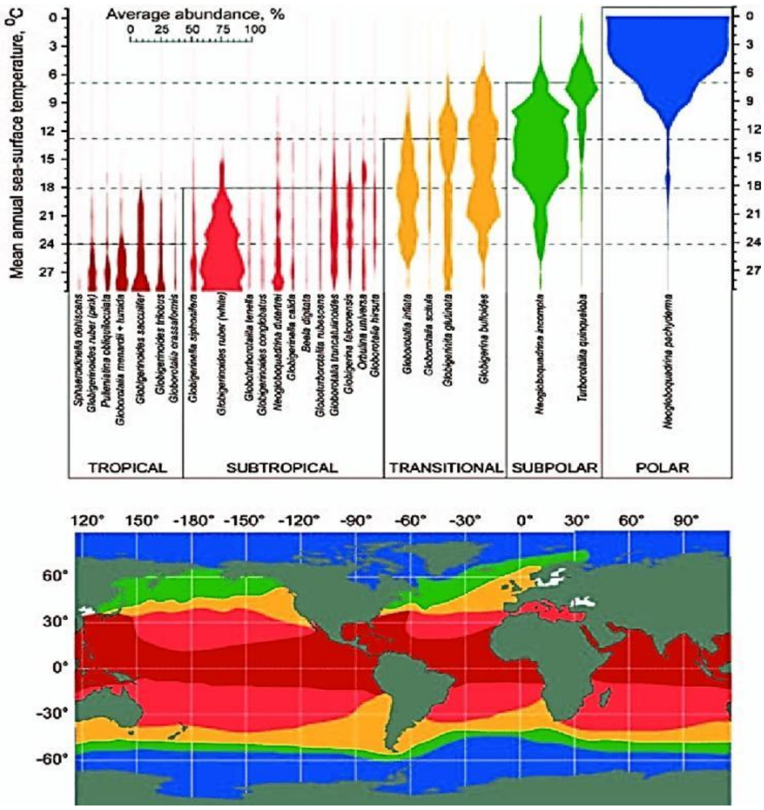


Fig.2. Planktic foraminifer provinces in modern oceans. (Researchgate.in)

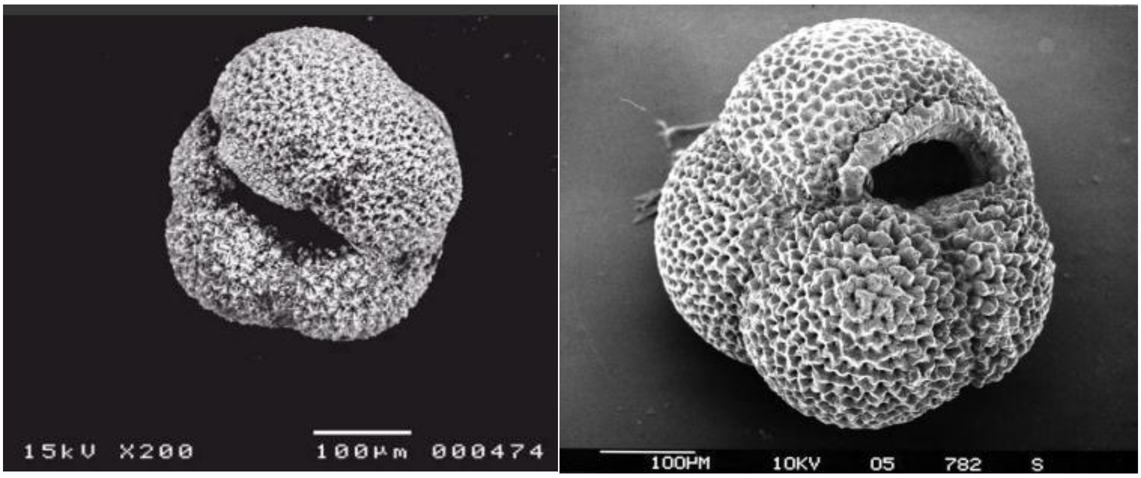


Fig.3.Dextral and sinistral coiling in *Neogloboquadrina pachyderma*

The spores and pollens get darker with increased heat and helpto assess the temperature to which a rock sequence was heated during burial and thus useful in predicting oil or gas occurrence in the region (Davies &Bujak,1987). Classically paleodepth of any site is determined based on its benthic fauna. Mixing of fauna (shallow to deep) reflects the tectonics, sea-level changes, erosion of adjacent landmasses. Paleoecology interpretation is based on present-day patterns of sedimentation, chemical cycling, circulation, and water mass dynamics of the ocean as they relate to the organism.

Bio-proxy in hydrocarbon exploration

Oil and gas are formed by the thermal cracking of organic compounds buried in fine-grained rocks. There are two types; Hydrogen-rich algae are oil-prone whereas hydrogen poor are gas prone.Organic hydrocarbon sources are the plant and animal’s remains were transformed into petroleum by bacterial action, heat and pressure, catalytic reactions and radioactive bombardments. The hydrocarbon generation and accumulation governed by its source material as organic matter, heat and pressure to cook the sediment, a path to allow oil and gas to move upwards, a reservoir rock to contain the oil, and a seal or cap rock and trapping mechanism.The necessitated conditions are that organic-rich sediments to be rapidly buried under anoxic bottom waters, as this prevents the non-decay of organic content, in restricted basins and high organic productivity at oxygen minimum zone. The thermal maturation process for source rocks is the movement to the point before significant thermal transformation where the temperature is less than 50ºC. When the temperature is between 30ºC and 60ºC, source rock produces kerogen, and >60ºC-120ºC the liquid hydrocarbons and >120^0C and 150^0C dry gas (thermogenic methane) is produced. The kerogen producing source rocks are rich organic carbon of altered remains of marine and lacustrine organisms with varying amounts of terrestrial debris. Alginates type of kerogen forms from *Botryococcus braunii* algae, sapropelic and oil-prone in shales with H/C ratio of 1.9. Whereas Liptinitic type of kerogen is the principal source of oil derived from marginal marine, algal tissues, spores and pollens and H/C ratio up to 1.4. Vitrinite type forms from remains of plants and prone to gas generation of H/C ratio is 1(Table 1 &2).

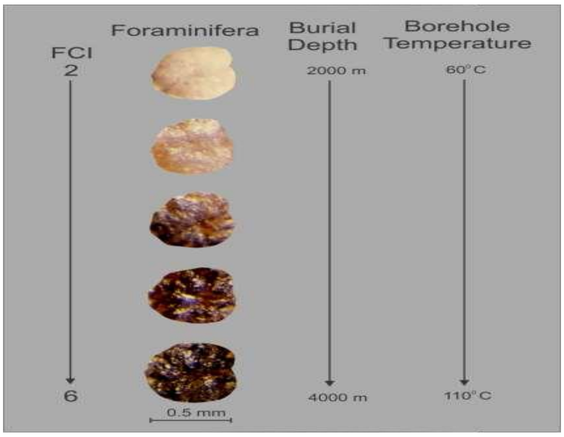


Fig 4 Burial depths vs. color index of Foraminifera (FCI)
(http://en.wikipedia.org.wikiForaminiferal_Colouration_Index)

Source rock materials for hydrocarbons are chiefly organic debris (phytoplankton, marine and terrestrial algae, lipid-rich land plants). The identification of potential hydrocarbon generation sequences accounts by estimating quality, quantity and maturity of organic matter in thesedimentary basin (Table 1). Estimation of quality/quantity and maturity of organic facies by Kerogen typing, total organic matter estimation, palynofacies interpretation, and ThermalAlteration Index (TAI), time and duration of hydrocarbon generation, delineation of facies favorable for hydrocarbon generation (Figs.4&5). The vitrinite reflectance of the particulate organic matter (OM) found to increase with thermal maturity: Vro greater than 1.5% reflects highly matured source rock (SR), which can produce gas, Vro1–1.5signals intermediate maturity; Gas with less oil, it is 0.8 – 1.1; wet gas with oil shows 0.6 – 0.8; Oil-Less than 0.6 indicates Immature source (LeRoy, 1977).

Conclusions

- The foraminifera is precious in the correlation of marine formations and its abundance through geological periods facilitates the reconstruction of palaeogeography of the continents.
- Fossil shell morphology and coiling directions help comprehend glacial cycles.
- The agglutinated fossil foraminifera buried deeply in sedimentary basins is used to estimate thermal maturity, a key factor for petroleum generation.
- The Foraminifera colour index is applied to quantify the colour changes to estimate the burial temperature, particularly in the early stages of petroleum generation.
- Foraminifera advocates the geological age of the formations and useful in determination of paleobathymetry.
- The isotopic investigations on the fossil test attributes paleotemperature and palaeoceanographic conditions.
- The spores and pollens get darker with increased heat and help to assess the temperature to which a rock sequence was heated during burial and thus useful in predicting oil or gas occurrence in the region.
- Alginates type of kerogen forms from *Botryococcus braunii* algae, sapropelic and oil-prone in shale. Whereas Liptinitic type of kerogen is the principal source of oil derived from marginal marine, algal tissues, spores and pollens and Vitrinite type forms from remains of plants and prone to gas generation.

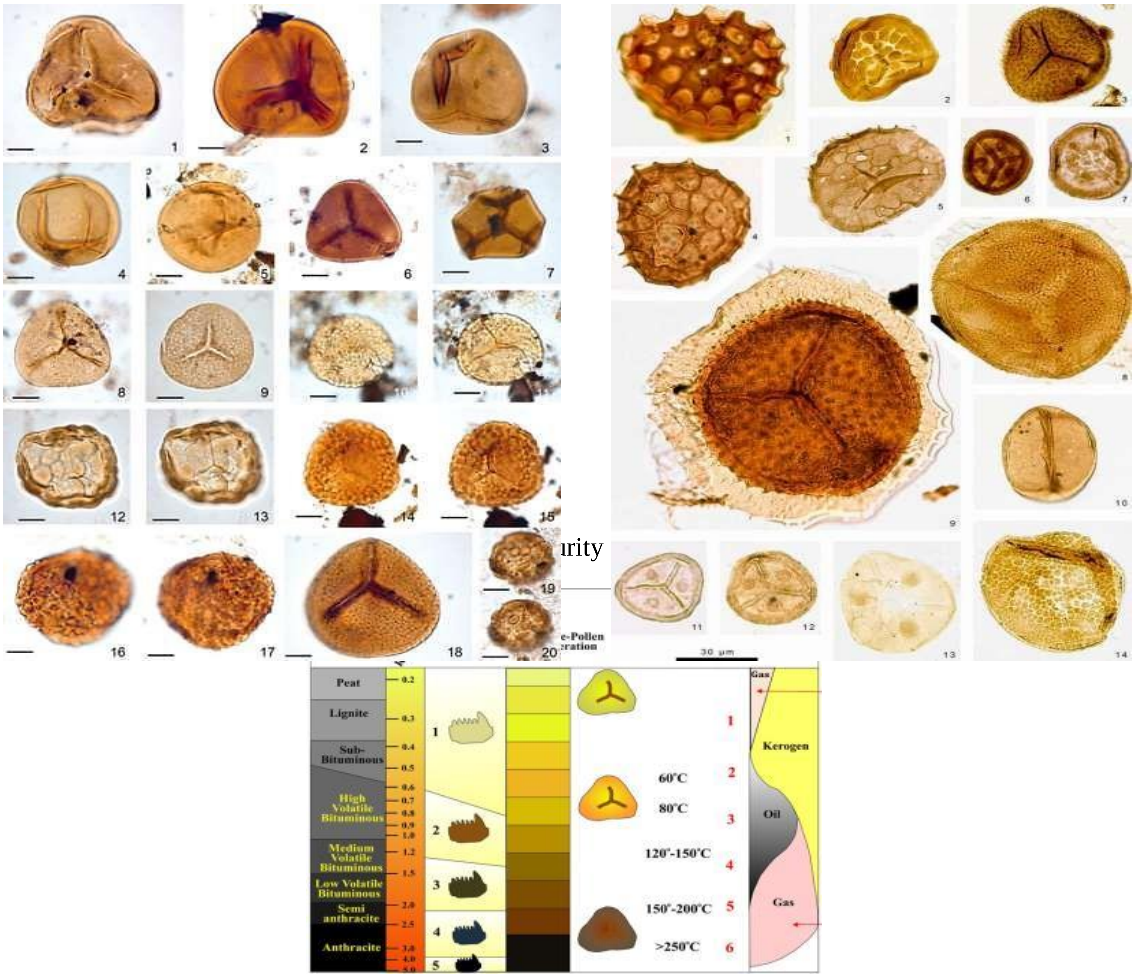


Fig 6. Methods for the maturity of source rocks (www.slideshare.net/joelEdegbai/understanding-source-rocks)

Table1. Kerogen Index in producibility of oil and gas

Bibliography

Type of Kerogen	Environment	Providence	H, O,C content	Producibility
Type I	Lacustrine, Marine	Mainly Algae	Rich in Hydrogen	Oil Prone
Type II	Deep Marine, Reducing	Mainly Plankton	Rich in H, Carbon low	Produces oil at lower
Type III	Terrestrial	Terrigenous Plant Debris	Low H Higher Oxygen	Tends to generate gas
Type IV	Varied	Reworked organic matter after erosion	Poor H, High O, High C	Very low potential

OM type	Kerogen type	Maceral	Source	Hi	S2/S3	Atomic H/C	Expelled product
Sapropelic	I	Alginite	Fresh water algae	>600	>1.5	>1.5	Oil
	II	Liptinite	All land plant lipids & marine algae	300-600	10-15	1.2-1.5	Oil
	II	Exinite	Pollen, Spores	200-300	5-10	1.0-1.2	Mixed oil, gas
	II	Cutinite	Land Plant cuticles				
	II	Resinite	Land plant resins				
Humic	III	Vitrinite	Woody &Cellulosic material from land plants	50-200	1-5	0.7-1.0	Gas
	IV	Inertinite	Highly oxidized or reworked OM of any origin	<50	<1.0	<0.7	None

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