water during early Holocene (11.5–5.5 ka) has been observed than at present, which has been interpreted as the wettest period during the last 25 ka as a result of ISM strengthening[22].

The present study suggests that change in sedimentation in the northern Andaman Sea is a function of changing monsoonal activity and the detrital influence, whereas a previous study has shown that the overhead productivity and upwelling events persist as a result of winter monsoon and winds[22]. Further analysis and detailed multiproxy approach will provide a good platform to decipher the effects of summer and winter monsoons on the Andaman Sea basin during the Holocene.

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First record of parrotfish bite mark on larger foraminifera from the Middle Eocene of Kutch, Gujarat, India

Larger foraminifera are excellent recorders of shallow marine sclerobionts (*sensu* Tayler and Wilson[1]) in low sedimentation regimes[2,3]. The range of sclerobionts may include cemented or organically anchored sessile taxa, borers and vagile organisms that live on or habitually visit the live or dead foraminiferal tests. In India, body fossil and ichnofossil (mostly bioerosion) of sclerobionts that subsisted on the larger foraminifera have been systematically recorded from the Paleogene of Kutch, Gujarat[4–10]. These sclerobionts comprise acrothoracican cirriped, worm, bivalve, gastropod, green algae, scleractinian coral, other foraminifera and bryozoa. Here we document a new sclerobiont in the form of bite marks of nectobenthic parrotfish (class Actinopterygii, family Scaridae) preserved in the Middle Eocene larger foraminifera *Assilina exponens* (Sowerby, 1840). It may be noted that the lectotype of *A. exponens* (a microspheric specimen) illustrated by Samanta[11] (plate 26, figure 1) also bears the characteristic parrotfish bite mark, but the same was overlooked by the past workers. To the best of our knowledge, there have been no previous studies regarding parrotfish bioerosion on the Tertiary larger foraminifera of India.

Palaeocene–Pliocene sediments are well preserved in the Tertiary basin of Kutch[12]. The examined specimens of *A. exponens* were collected from Jhadwa, Guvar and Lakhpat areas of Kutch basin (Figure 1). This foraminiferal species, characterized by feebly involute planispiral chambers and involute spiral wall[13], occurs in rock forming abundance in the lower part of Fulra Limestone (Middle Eocene)[12]. The protist is represented by dimorphic forms; diameter of microspheric and megalospheric test ranges from 20 to 28 mm and 6.5 to 9.5 mm respectively. The parrotfish bite marks are predominant on the large microspheric specimens of *A. exponens*. The present study is based on examination of 51 microspheric and 4 megalospheric bioeroded specimens of *A. exponens* under a light microscope. Seven parrotfish bite mark-bearing microspheric specimens of *A. exponens* were examined under a scanning electron microscope (SEM).

The parrotfish bite mark occurs as millimetre-sized paired, rectangular grooves of equal length on one or both sides of the foraminiferal test (Figure 2 *a–f*). The occurrence of multiple bite marks in a single foraminiferal test is common. Grooves of a pair may be mutually parallel or they may subtend an angle of 20°–25°. The grooves are short and narrow with sharp margin, smooth vertical wall and shallow rectangular base. Length and width of the individual grooves range from 0.9 to 4.3 mm and 0.14 to 0.6 mm respectively.

The extant parrotfish are restricted to the low-latitude coral reef environment, where they constitute conspicuous part of the herbivorous fish community[14]. According to Hoey and Bellwood[15], extant parrotfish possess cement-coated, fused, beak-like frontal jaws (dental plates) laced with numerous caniniform or thickened teeth of various dimensions that allow them to remove portions of the carbonate substrate while feeding on algae (both epiphytic and endolithic algae present in the coral reef[16]). The classification of present-day parrotfish on the basis of their feeding patterns includes three categories, viz. scrapers, browsers and excavators[14,17]. Parrotfish of the first two categories remove epiphytic algae from above, whereas excavators remove pieces of the substratum along with the algae, leaving behind the distinctive paired bite marks. The substrate-excavating parrotfish can cause deep (0.1–3.0 mm) grooves. The relative scar size may vary greatly; large scars (twice as long as wide) are often broken midway along the length giving the appearance of two short scars. The above scheme of feeding modes and their bioerosional aspects were revised by Hoey and Bellwood[15], and the feeding taxa were described as croppers, scrapers and excavators. Croppers remove only the epiphytic algae from above, while scrapers and excavators remove pieces of the calcareous substrate along with the epi- and endophytic algae to form the paired bite marks. The scrapers cause relatively shallow bite scars (two parallel <1 mm long feeding marks on the substrate with scar length being approximately ten times the width), whereas excavators leave similar but deeper bite scars and remove greater quantities of substrate in each bite. The presently observed bioerosion in *A. exponens* is closely comparable with that of extant parrotfish belonging to the excavator category of Bellwood[14], and Bellwood and Choat[17], or the scraper–excavator categories of Hoey and Bellwood[15].

Examination of parrotfish-bioeroded *A. exponens* under SEM has revealed extensive development of micron-sized bioerosion in the form of long, narrow channels along the test surface (Figure 2 *g–j*). The bioeroded channels maintain uniform width of 4–5 μm along their straight course with repeated high-angle branching. These channels may continue within the test as tubular cavities. This microboring is identified as cf. *Ichnoreticulina* Radtke and Golubic[18] and is similar to the one recorded in the larger foraminifera *Nummulites obtusus* (Sowerby) from the Middle Eocene Harudi Formation of Kutch[6]. *Ichnoreticulina* has also been reported from the Middle Eocene–Middle Miocene foraminiferal bioclasts of Jamica[19]. The present-day green algae *Ostreobium quekettii* Bornet and Flahault is widely regarded as the bioeroder of *Ichnoreticulina*[18].

The high productivity of *A. exponens* and accumulation of foraminiferal bioclasts at the depositional surface provided hard substrate for algal growth in low sedimentation regime[20]. The herbivorous parrotfish may have fed on the algae and in the process left their bite marks on the algae-infested foraminiferal bioclasts. The bioerosion-escaping live individuals of *N. obtusus* exhibit healing of the injury site[8], but none of the parrotfish bioerosion in the present study showed injury healing. This affirms that parrotfish bioeroded *A. exponens* bioclasts. Few extant carnivorous parrotfish can excavate deep into the coral skeleton to feed on the soft tissues[21]. The bite marks on *A. exponens* do not penetrate deep inside the foraminiferal test to reach the protoplasm-bearing chambers to suggest carnivory.

The present ichnological evidence of herbivorous parrotfish is a new addition to the past 50 years' documentation of fossil pisces from the Palaeogene of Kutch[22–25]. The bioeroding herbivorous fishes rose from the Triassic and became prolific since the Eocene[26]. According to Bellwood and Schultz[27], parrotfish are not older than Middle Miocene. However, Bellwood[28] reported that the labroid lineage, which is believed to have given

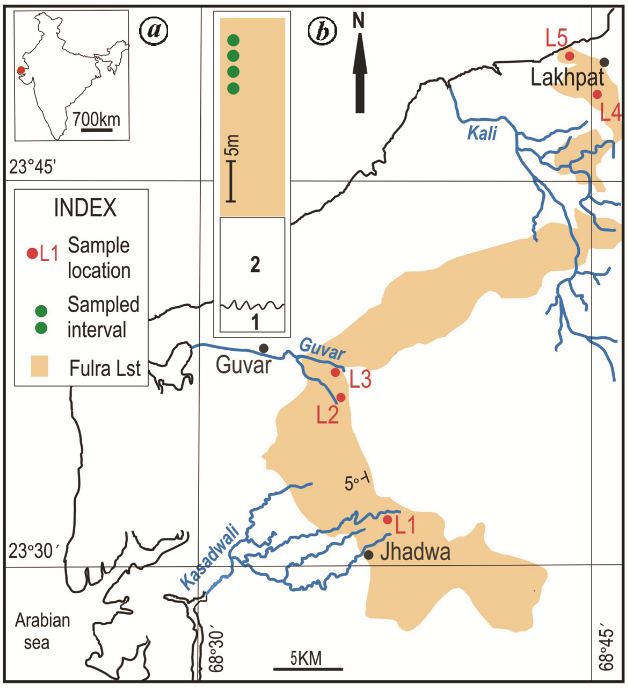

Figure 1. Simplified geological map of the study area showing sample locations in Fulra Limestone (Middle Eocene). ***a***, Map of India showing the study area marked in red. ***b***, Portion of Eocene succession at Jhadwa area showing upper part of Naredi Formation (1), Harudi Formation (2) and lower part of Fulra Limestone (sampled interval marked in green).

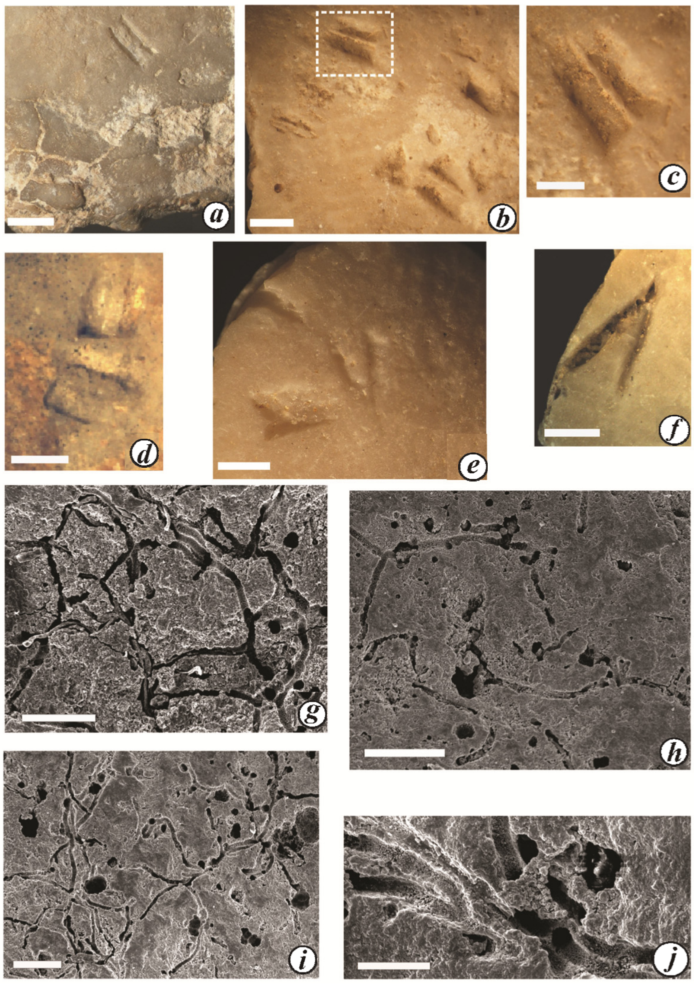

Figure 2. Surface of *Assilina exponens* (Sowerby) from Kutch, western India under light microscope (***a–f***) and SEM (***g–j***). ***a–d*** and ***f–j***, Microspheric test; ***e***, Megalospheric test. ***a–d***, Parrotfish bioerosion forming parallel grooves. ***c***, Magnified view of the bioerosion marked in ***b***. ***e***, ***f***, Parrotfish bioerosion forming grooves that subtend low acute angle. ***b***, ***d***, ***e***, Multiple parrotfish bioerosion in foraminiferal tests. ***g–j***, High angle branching channels of algal bioerosion cf. *Ichnoreticulina* Radtke and Golubic. Bar scales: ***a***, ***b***, ***f*** = 2 mm; ***c***, ***d***, ***e*** = 1 mm; ***g***, ***h***, ***i*** = 60 µm; ***j*** = 20 µm.

rise to the parrotfish, occurs in the early Middle Eocene reef in Italy. The molecular data also favour the pre-Middle Miocene origin of parrotfish[29]. The present documentation from the Middle Eocene of Kutch is useful in understanding the antiquity of parrotfish in the Tethyan realm in general and western India in particular.

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