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Two Indian Ocean Coral Knolls*

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A preliminary assessment of the status of two hitherto unknown coral knolls, one in the Gulf of Mannar and another in the Andaman Sea, representing the respective areas is made. The coral patches together with the shore reef at Kilakarai, the only shore reef now known on the Indian mainland coast, bordering the Gulf of Mannar, are reported. It is suggested that some knolls in the Gulf of Mannar, such as Klinjampaar, may ultimately develop into sand cays by deposition during cyclones. The knoll described from the Andaman sea, the top of which is now exposed in low spring tides, indicates an upgrowth of about 1 fm after it is originally sounded.

THE earliest records of coral knolls are those of Dana[1] from Bahamas, Hartt[2] from Brazil, Darwin[3] from Marshall Isles and Gardiner[4] from Laccadives and Maldives. The more thoroughly known knolls are those from the Pacific. Emery *et al.*[5] reported 2293 knolls from the lagoons of Bikini, Eniwetok and many in the Rongelap, Rongerick and Alinginae atolls in the Marshall Islands. In the Indian Ocean, coral knolls have been first charted by Moresby (1834-36) in the British Admiralty Charts and briefly described by Gardiner[4,6] in the Laccadive and Maldive group of islands. Pillai[7], Spencer *et al.*[8] and Stoddart[9] re-examined the knolls of Minicoy, Addu lagoon and Diego Garcia lagoon respectively. Surgeon Paradise[10] has described them from the Great Barrier Reef of Australia. In this paper a preliminary assessment of the status of these knolls, hitherto unknown, found in the Gulf of Mannar and the Andaman Sea is made. Sizes of knolls given are by approximation only.

Definition

Emery *et al.*[5] have mentioned that coral knolls are variously termed as patches, coral heads and big hats, and coral heads are often used by sailors. The most frequently used terms are shoals[11], coral patches and coral pinnacles[12] to those occurring in the Indian Ocean. Following Emery *et al.*[5] Darwin's[3] term 'Coral knoll' is adopted here.

Coral knolls are isolated mounds of corals rising from the lagoon bottom to different depths to the low tide level. In the Pacific and Indian Ocean atolls, these arise from a maximum depth of about 35 fm. These are nearly always circular ($\frac{1}{4}$th to 1 mile diam.), and out of 2293 knolls observed only one emerged in low water[5]. Emery *et al.*[5] infer that these occur in thickness of staghorn *Acropora* in shallower water and sporadically over the entire bottom; new growths appear on the old, raising the patch above the floor and growing upwards towards the zone of more light and freer currents. They further state that the age, origin and internal constitution of knolls are not known because no structure of this kind has ever been drilled. Gardiner[6] considers that these arise perpendicularly from the lagoon floor with the upper surfaces flat plateaus at about the low tide level with edges often overhanging. Geologically, these are considered to be circular topographic highs of the lagoon floor but biologically these are large circular mounds growing upward towards the sea level. These grow in shallow protected waters and are not to be confused with patch reefs which are small equidimensional or irregular shaped reefs and form parts of reef complexes. These may probably be comparable to table reefs which are flat-topped, isolated, small reef mounds of the open ocean[13,14]. Nelson *et al.*[15] consider that patch reefs grow on the lee side of larger reefs or behind the main reef trend, and no evidence of wave action is formed until it grows above the wave base. These are thus excluded from their general definition of reef which states that a reef is a skeletal limestone deposit formed by organisms possessing the ecological potential to erect a rigid wave resistant topographic structure in the zone of wave action. Coral knolls are invariably submerged and exposed usually in the lowest of the low water spring tides. Stoddart[10] considers that knolls in atoll lagoons may owe to either contemporary growth features or kart-eroded limestone hillocks formed during periods of low sea level.

Gulf of Mannar

All along the stretch of over 150 km parallel to the coast in the Gulf of Mannar, regarded as barrier[16], there are a series of 20 islands, some containing fringing reefs[17]. These are located about 8 km from the mainland shore with lagoon-like formation between the two trends with a depth of 10 m. Reefs along the coast of the Indian mainland are uncommon, but a shore reef along the mainland coast appeared at Kilakarai in the Ramnad district, Tamil Nadu (Fig. 1a). This reef is usually visible at the tide height of less than 0·2 m and covers a length of 2 km and width of 0·4 km approximately. This reef is unreported, while Foote[18] and Reddiah[17] mentioned the occurrence of beach sandstones in

*Paper forms part of authors' coral reef studies in the Gulf of Mannar from 1967 to 1971.

the area. The reef generally runs parallel to the mainland shore but joins the mainland shore about 1·5 km west and 0·5 km east of the harbour. Mainly flat-topped *Porites* and *Montipora* among corals and *Lithothamnion* and *Lithophyllum* among the calcareous algae appear to be the chief frame builders. From the reef to the shore are various kinds of shoal not greater than 2 m deep in which grow the live boulders of *Porites* and *Montipora* and with numerous green algal growths. A number of coral patches (5 to 10 m diam.) occur (Fig. 1b). The top layers are generally flat and dead and covered by settling sand, detritus and green algae. Since these have already reached the low tide sea level and are subjected to sub-aerial exposure, upwards growth is limited or almost arrested. Upward growth is compensated by lateral growth as shown by Reddiah[17] for *Montipora foliosa*. However, this species is also known to be a deep water form. These may form the small patch reefs.

As the 8 km width of the channel that separates the mainland reef is crossed to reach the stretch of 20 islands, on calm weather and bright sunlight, a series of low and high level mounds are visible while approaching the islands. The configuration of these patches show as if the islands have been built by the upward growth of the mounds and by subsequent deposition. The dugouts by Gravely[19] and the emerged reef blocks of Appa Island[1] are cases in point. But deep boring only could determine whether the islands are based on coral mounds. The only large coral knoll found in the Gulf of Mannar is an island popularly called Kilinjampaar (unmapped) located between Appa Island and Puvarasanhalli Island about 1 km SW of Appa Island. The island (Fig. 2a) is not visible in high tide but at low tide, a 50 m length of the island, covered with a thin layer of sand, is exposed. There is an extensive growth of green algae all round. There is a relief of probably 10 m, gently sloping on the relief side and steep slope from the circumference of the knoll. The exposed sandy part is veneered by the growth of green algae and up to a depth of 2 m or more, it was encircled with various growth forms of Acroporid corals, *A. hyacinthus* and *A. humilis* (Fig. 2b). The breaker zone is located about 1 km away from the island and not so close as in the case of Appa Island. The knoll is located in a moderately agitated water and has grown above the wave base and thus wave resistant, even if the waves are ever to break on the knoll. It is concievable that some islands in which dead coral is found under the sand cays, these could well have been formed by knoll-like coral growths originally and by sand spitting in shallower areas adjoining the knoll.

Andaman and Nicobar Islands

Apart from the soundings marked in the Admiralty Charts, practically nothing is known of these knolls from the Andaman and Nicobar Islands. A more closely examined and photographed knoll is the one located in the Tadmajaru Channel between Havelock Island and Peel Island. Its position as marked in the chart is 12°3′, 92°59′ and 2·25 fm depth over it[12]. The knoll is located ½ km west of Havelock jetty and closer to a mangrove area before the Havelock Island. It is exposed at the predicted tide height of 0·26 m and has about 8 fm depth all round it. The knoll measures about 30 m diam. (Fig. 3a and b) and has two elevated rims. An outer rim contains a growing veneer of *Porites*, *Acropora* and *Pocillopora* with a relief of 2 or 3 m and a vertical slope on all its circumference. The arborescent *Acropora* surrounds the outer rim and its growth is visible up to a depth of 3 m. The outer rim is separated from an inner rim by a shallow channel of ¼ to ½ m depth. The bottom of this groove between the outer rim and the inner rim is covered mostly with living flat-topped *Porites*. The inner rim (20 m diam.) is also similarly raised as the outer rim and encloses a similar lagoon, thus presenting the appearance of a micro atoll within a micro atoll. The bottom of the lagoon of the inner rim, in some places exposed, is made mostly of *Favia* boulders grown *in situ* and glued by calcareous algae as a compact unit containing numerous growths of *Tridacna* (Fig. 4b). Even though the knoll is located close to the shore, there is very little deposition, but where deposition is present it has been mostly detrital. A good part of the area of the inner rim is covered with the alcyonarian corals, *Sarcophytum*, *Lobophytum* and *Sclerophytum*, and in varying stages of growth encrusting the dead *Porites* and *Favia*. Growths of *Porites* encrusts the dead boulders (Fig. 4a). An occasional sea urchin and a meter long fish, *Gymnotherax* sp., appear among the alcyonarian mats.

A marked feature of the knoll is the absence of solitary fungiids, *Heliopora* and *Montipora*, even though these are quite common in the channel reefs close by. The wave resisting *Acropora* such as *A. humilis* and *Pocillopora* abound, while the arborescent coral is found around the circumference and up to bottom. Cementing calcareous algae are present but the green algae are sparse. The vertical slope of the knoll is probably 10 m. There is a huge cup-like sponge (Phyllospongid) of 1 m diam. at the base of the knoll with a purple inner coating.

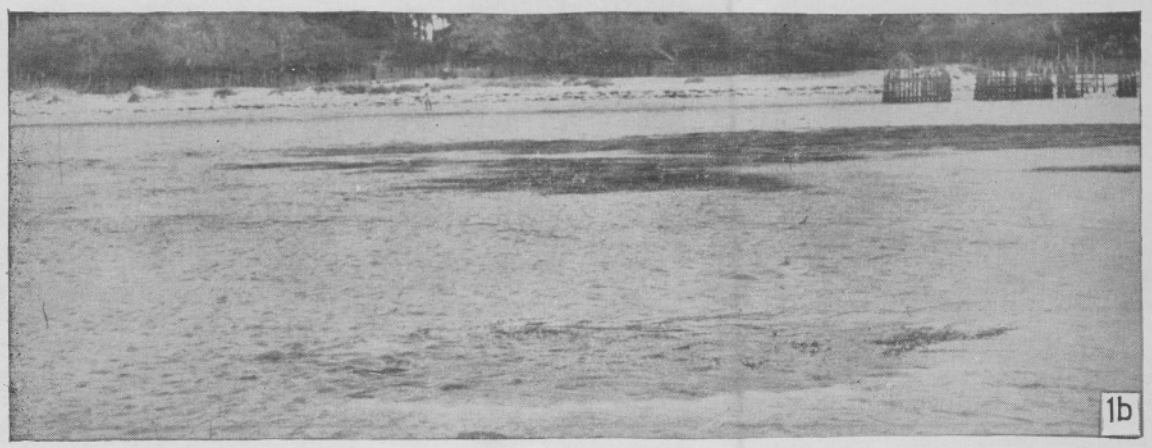
The knoll is probably similar to that described off Eninman Island in the Bikini lagoon by Emery *et al.*[5] in the shape and size but differs in the surface topography and the coral fauna.

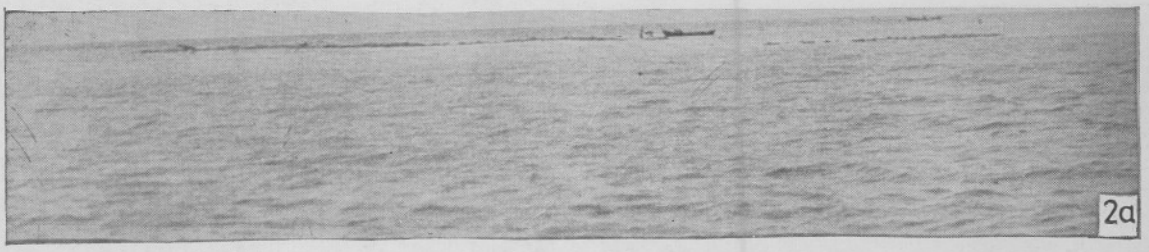
Laccadives and Maldives

Coral knolls in the Laccadives and Maldives have been referred as shoals by Gardiner[4] and are incompletely known. In two atolls, viz. Kolumandulu and Suvadiva, the knolls are dead and exist as mounds well below the low tide level. Pillai[7] reported a rich live growth at Minicoy. Spencer Davies *et al.*[8] recorded 23 knolls in Addu lagoon, none exposed. They too considered that knolls, in general, are dead.

Navigational Hazards and Utility

The knolls located almost in the middle of the channels are dangerous to navigation. These are nearly always submerged and are within the cruising range of ships and smaller craft. It is suggested that uncharted or little charted reefs in the Andamans and Nicobars, Laccadives and Maldives could be resurveyed and the extent of growth, if any, after a lapse of 140 yr, of these live knolls could be estimated.





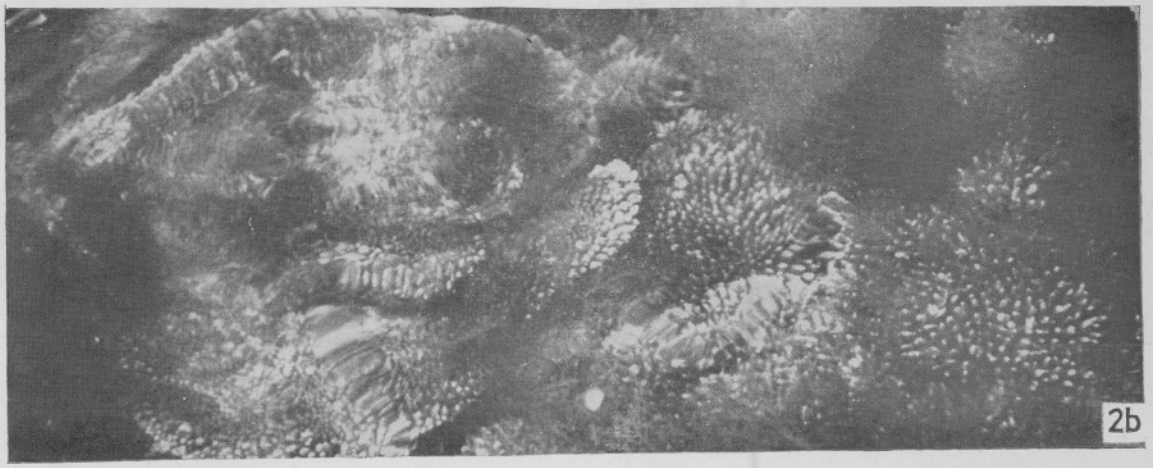


Fig. 1 — a: Shore reef on the mainland coast at Kilakarai [White patch represents a surf zone on reef front and dark patch, the emerging back reef in low tide]. b: Coral mound (patch) covered with green algae, in the back reef shoal of the shore reef at Kilakarai [Dark veneer behind is the green algal growth]

Fig. 2 — a: Coral knoll of Klinjam paar island [Dark area is the sand veneer of the island fringed with dead green algae. Light patch near the anchored boat is the relief of the knoll on which live corals flourish. (photo by S. V.)]. b: Plate like *A. hyacinthus* and *A. humilis*

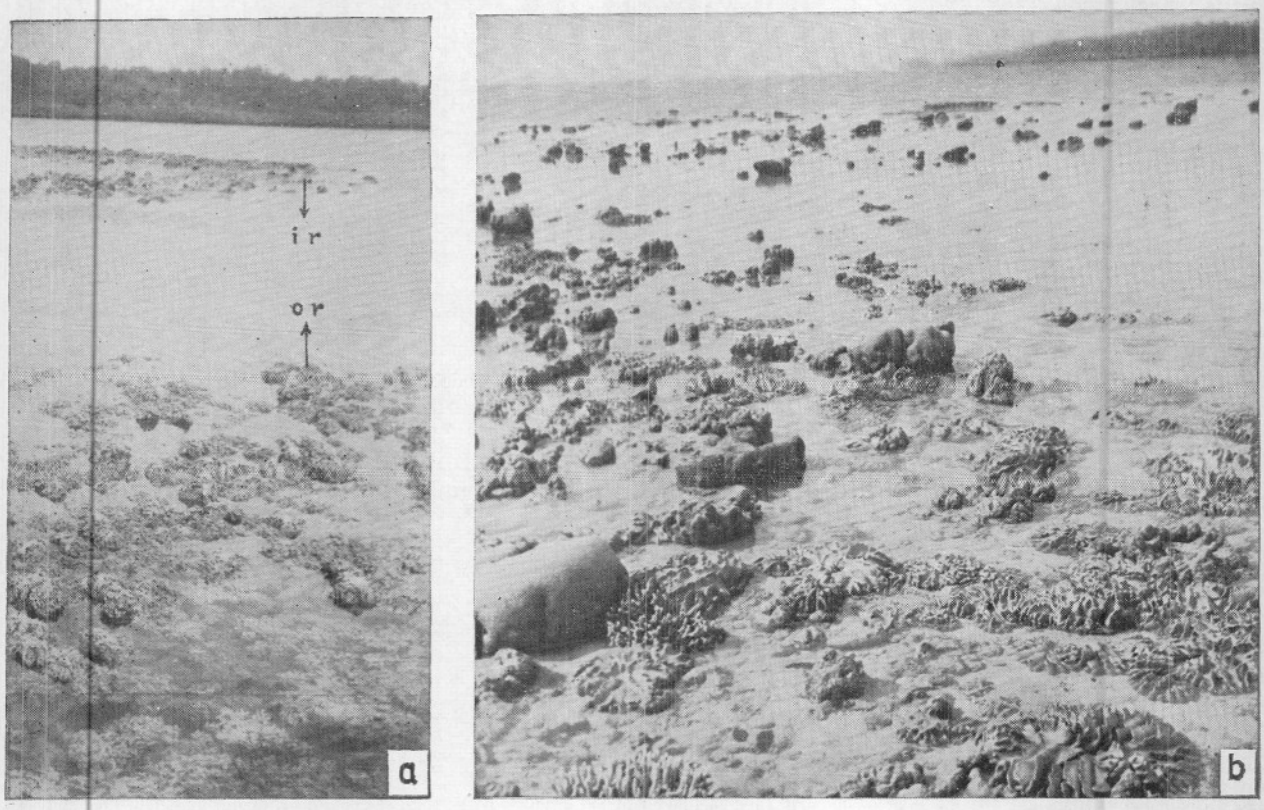


Fig. 3 — a: Coral knoll off Havelock island in the Rechie's Archepelago [ir, inner rim; or, outer rim]. b: The knoll viewed from across the inner rim through the channel and the Peel Island behind [Note the abundance of alcyonarian growths over the cemented dead boulders mostly of *Favia* and *Porites*]

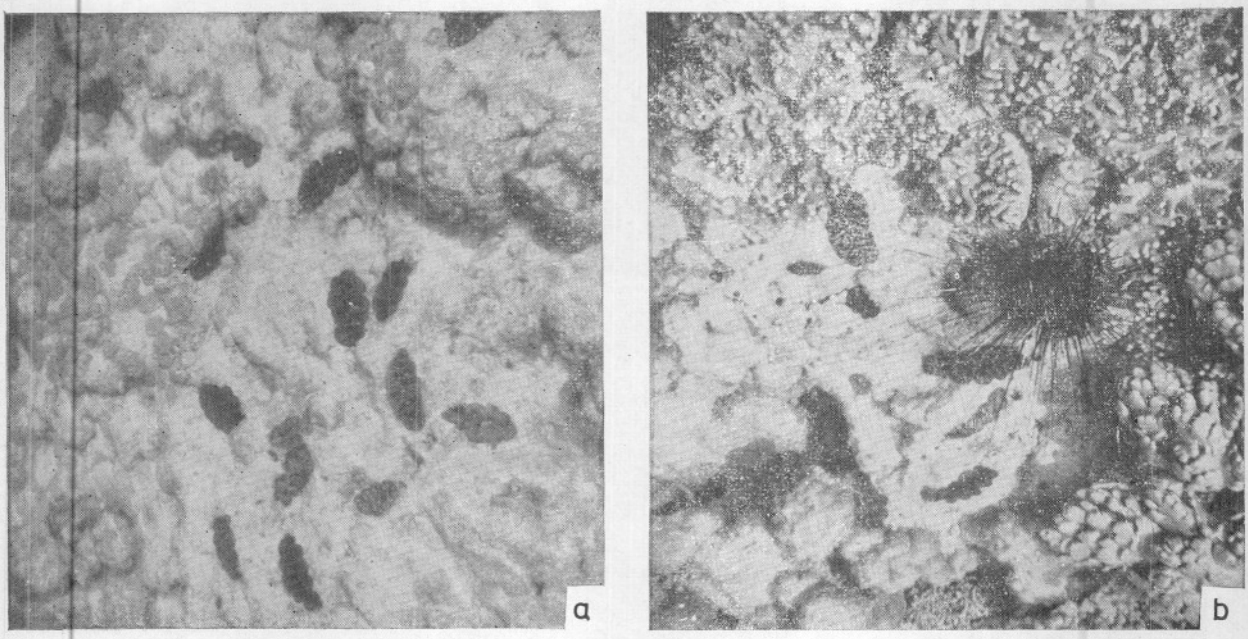


Fig. 4 — a: Dead *Porites* boulder on top of which is a new bud [Specimens (15) of *Tridacna* are embedded in it. Note the detrital filling on dead boulders]. b: Another old boulder with alcyonarian cover [In the centre a sea urchin and 8 specimens of *Tridacna crocea* inside it are seen. Note the new *Porites* growth below]

It is not known how the knolls are of any direct use to petroleum geologists except that their appearance is an indication of shallow, lagoonal environment and that these occur in the vicinity of a lagoon reef or a channel reef. If the dead knolls are found in lagoons, it would probably be an indication of more of organic deposition.

Discussion

The coral knolls in the Indian Ocean are incompletely known. Their occurrence in the Gulf of Mannar as topographic highs, ultimately developing into sand cays, is a feature worthy of attention. It could be possible as suggested by Stoddart and

Fosberg[16], that inadequate sand size sediments are transported by waves which when deposited, form irregular, scattered sand bars or islands. It could be because of this inadequacy that the mounds are growing but when it is excessive as it does during cyclones, abrupt burial should occur producing wider sand spits on the knolls and subsequent emergence as islands or islets. Stoddart and Fosberg[16] also considered that Shingle Island stood on a small reef patch supporting the above conclusion that at least same islands in the Gulf of Mannar may have been formed on knolls. MacNeil[20] too considered the possibility of conversion of some knolls in the Marshal Islands into islets. Sheppard[21] regards that some of the former table reefs have been elevated and constituted flat-topped islands like the Washington Island near Hawaii.

Occurrence of coral knolls in the Andaman Islands, as presently known, is limited to channels in calm shallow water and lagoonal type of environment. The Admiralty Charts show their occurrence in greater number, some in the off reef areas. In the Diego Garcia lagoon, Gardiner[6] describes shoals covered with a few feet of water studded with small corals with barren sand and rock in between, never presenting that appearance of crowded or luxuriant life. He considers them to be holding on their own but not growing upwards or outwards. Comparing the soundings in the Cocos lagoon made again after half a century, it has been considered that the growth of coral patches in some places has been rapid and may rise up considerably in a period of half a century but Gardiner[6], comparing the surveys of Diego Garcia lagoon by Morseby in 1837 and Vereker in 1885, which showed some increased growth, concluded that such comparisons are distinctly dangerous. He concedes, however, that to prove that there is no upward growth of shoals in lagoons would require the comparison of accurate charts at considerable intervals of time which do not exist. But, surely, 140 yr is a reasonable time to look for this variation in soundings in the Laccadive-Maldive groups, Andaman and Nicobar Islands and several reefs in the Indian and Pacific Oceans. The knoll in question described by the authors in the Andaman Sea was shown in the original soundings as 2·25 fm depth over it in the charts. Considering that there is 1·4 fm lowering in low water spring tide heights (vide Chart No. 1419), there must be about 1 fm still left over the knoll described in this paper, whereas its top is exposed with the rims emerging 1 ft above low spring tide level. Assuming that the original soundings were correct, the knoll must have grown by 1 fm upwards or the sea level must have fallen relatively by this depth after it was sounded which is very unlikely.

Gardiner[6] describing the knoll of Minicoy, considers that these knolls are usually flat on top, bare or hollowed out in the centre with perpendicular and overhanging sides. The knoll described from the Andaman Sea is having a double hollow, one in the centre and another encircling it but it is not clear whether this hollowing owed to coral growth or inherent in the topography itself. The outer hollow is completely covered with flat-topped *Porites* and *Favia* suggesting it to be a growth phenomenon by flattening of coral boulders, while the inner hollow with dead boulders may be acted upon by solution after the flat coral was bound by calcareous algae and followed by detrital deposition.

The dead knolls of Laccadive and Maldive groups are of interest though these arise from about the same depth as in the Pacific atolls. Gardiner[4,6] and Sewell[11] consider that the major cause of their incomplete growth is deposition, largely by precipitation of lime.

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