A Late Oligocene drowned pinnacle reef in deepwater Makassar Straits

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ABSTRACT

A steep seamount with 320-350m of relief was recently discovered in about 2050m deep water of the South Makassar Straits. It was informally named Snorkel by ExxonMobil interpreters, but remains unnamed. Drop core samples collected from different levels of the buildup by ExxonMobil in 2008 show the Snorkel feature to be an Oligocene pinnacle reef, which drowned in latest Oligocene time.

The carbonate buildup is covered in a thin coating of ferro-manganese cement, representing over 20 Million years of exposure and non-deposition in a deep water environment.

The Snorkel feature is one of the many carbonate buildups that formed on Sundaland and around its margins after a Middle-Late Eocene regional rifting/subsidence event (e.g. 'Berai Limestone' of East Kalimantan), but until now is the only known example of an Oligocene reefal buildup that was never buried under younger sediments.

LOCATION AND GEOLOGIC SETTING OF SOUTH MAKASSAR STRAITS

The seamount described here was first identified on a 3D seismic survey acquired by ExxonMobil Oil Indonesia in the Mandar PSC Block in 2008, and was provisionally named Snorkel (De Man et al. 2011). It is located about 5-10 km east of the NE corner of the large Paternoster Platform, near the base of its slope (Figure 1). This location is in the southern part of the 'Labani Channel', a 45 km wide constriction and sill between the deep water North Makassar Strait and South Makassar Straits Basins (Gordon et al., 1990). It is in the main path of the 'Indonesian Throughflow', which carries large volumes of West Pacific Ocean water to the Indian Ocean.

The Snorkel feature is well imaged on seafloor bathymetry derived from the 3D seismic survey (Figure 2). It has a triangular, irregular 3-rayed star-shaped shape, with greatest elongation in NE-SW direction (about 3.2 km long), width in WNW-ESE direction of 1.9 km and a surface area of about 1.9 km^2.

Vertical relief above the surrounding seafloor is about 340m, from crest at 1718m to basin floor at about 2060m water depth. Typical slope angles are

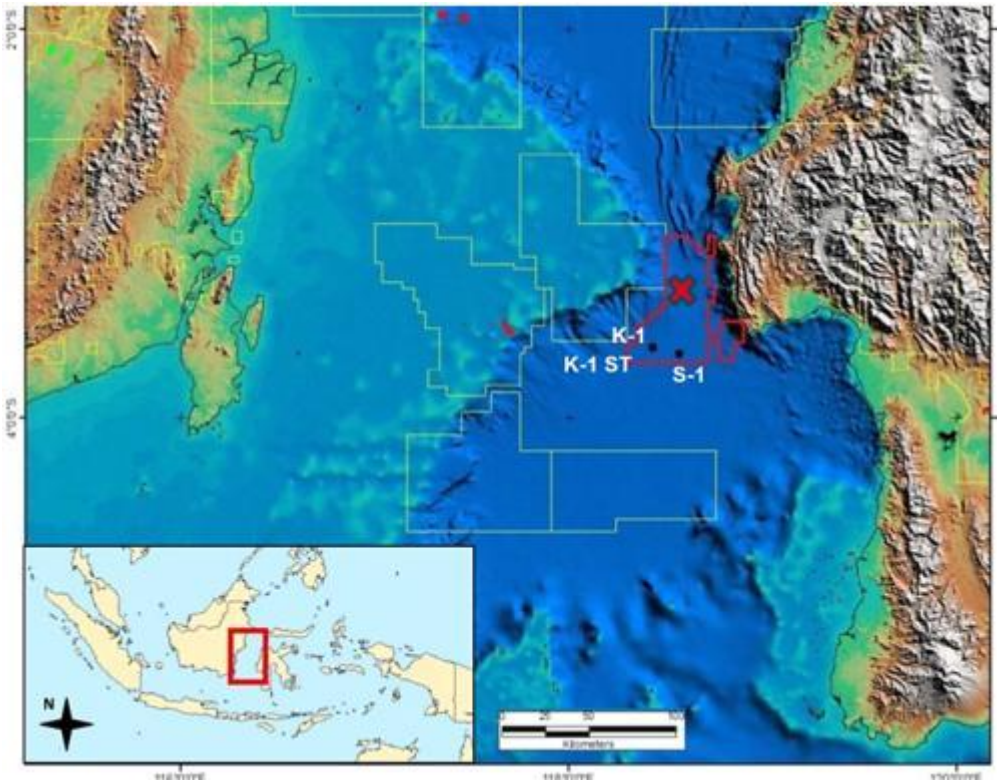


***Figure 1**. Map of South Makassar Straits with location of Snorkel seamount (X), East of the NE tip of the Paternoster Platform. The red outline in the larger figure is the ExxonMobil Mandar PSC Block.*

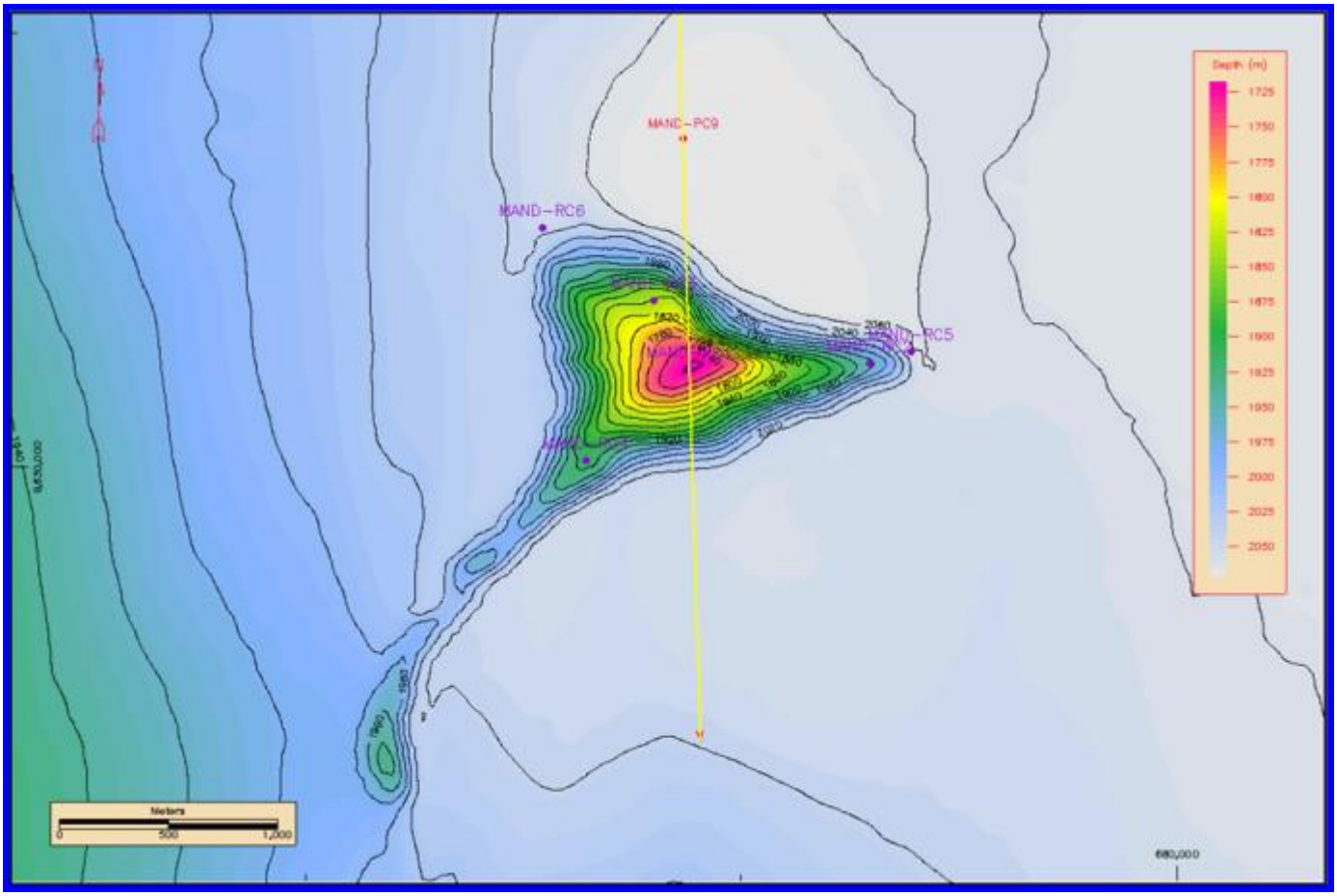


***Figure 2**. Seafloor topography showing triangular shape of 'Snorkel' reef and RC drop core locations. Crest of buildup is at 1718m, surrounding seafloor is 2040-2060m (contour intervals 20m)*

10-15°. Seismic profiles show the seamount is only the top part of a much taller structure, with possible vertical relief of 2.5 times the exposed part (~800m or more?; Figure 3). However, it may also be similar to the section in the nearby 'S-1' well which was drilled by ExxonMobil in 2009, about 38km South of Snorkel, also in the Mandar Block (Bacheller et al. 2011). This well penetrated a 389m thick Late Eocene- Late Oligocene carbonate section. Total relief/closure on the 'S-1' structure was 930m, but it is not all limestone. The basal core of that structure is composed of (Upper Cretaceous?) volcanic rocks, either in a rotated fault block or remnants of a volcanic edifice.

DROP CORES AND FERROMANGANESE CRUST

The Snorkel seamount was sampled by ExxonMobil with six drop cores in 2008, labeled RC1-RC6, and collected in water depths between 1718 and 2058m. Three of the shallower cores (RC1-RC3) sampled Oligocene reefal limestones (Figures 4, 6, 7 & 8). RC4 (Figure 5) mainly returned some ferromanganese crust. The deepest cores (RC5-RC6) from around the base of the reef only returned Recent planktonic foram oozes.

An interesting feature of the drop cores is the presence of a surface coating of up to several inches of black material. It was not analyzed by us, but such material is common on seamounts in deep water environments, where rocky surfaces are exposed to deep sea water for a very long time and where manganese and iron oxides precipitated from cold ocean water. Similar black encrustations were described by De Lange et al. (1989) from sea floor dredge samples from ~1000m water depth W of Misool, and chemical analyses confirmed these to be ferromanganese crust. Numerous other examples have been described from Pacific Ocean seamounts, where they form between 600-7000m water depth, most common between 1500-2500m.

Carbonates facies and ages of samples

Thin sections from drop cores at three levels on the Snorkel feature contain succession of Late Oligocene larger foraminifera assemblages. A brief description of drop core locations, rock types and faunal content is given below, arranged by increasing water depth:

RC1 (crest of reef; 1718m)

Packstones-grainstones dominated by red algal fragments and foraminifera. Foraminifera are a very shallow, reef flat/ platform interior assemblage with common soritids, rosalinids, miliolids and encrusting foraminifera (Figures 6, 7). Age-diagnostic larger foraminifera include *Miogypsinoides* cf *bantamensis*

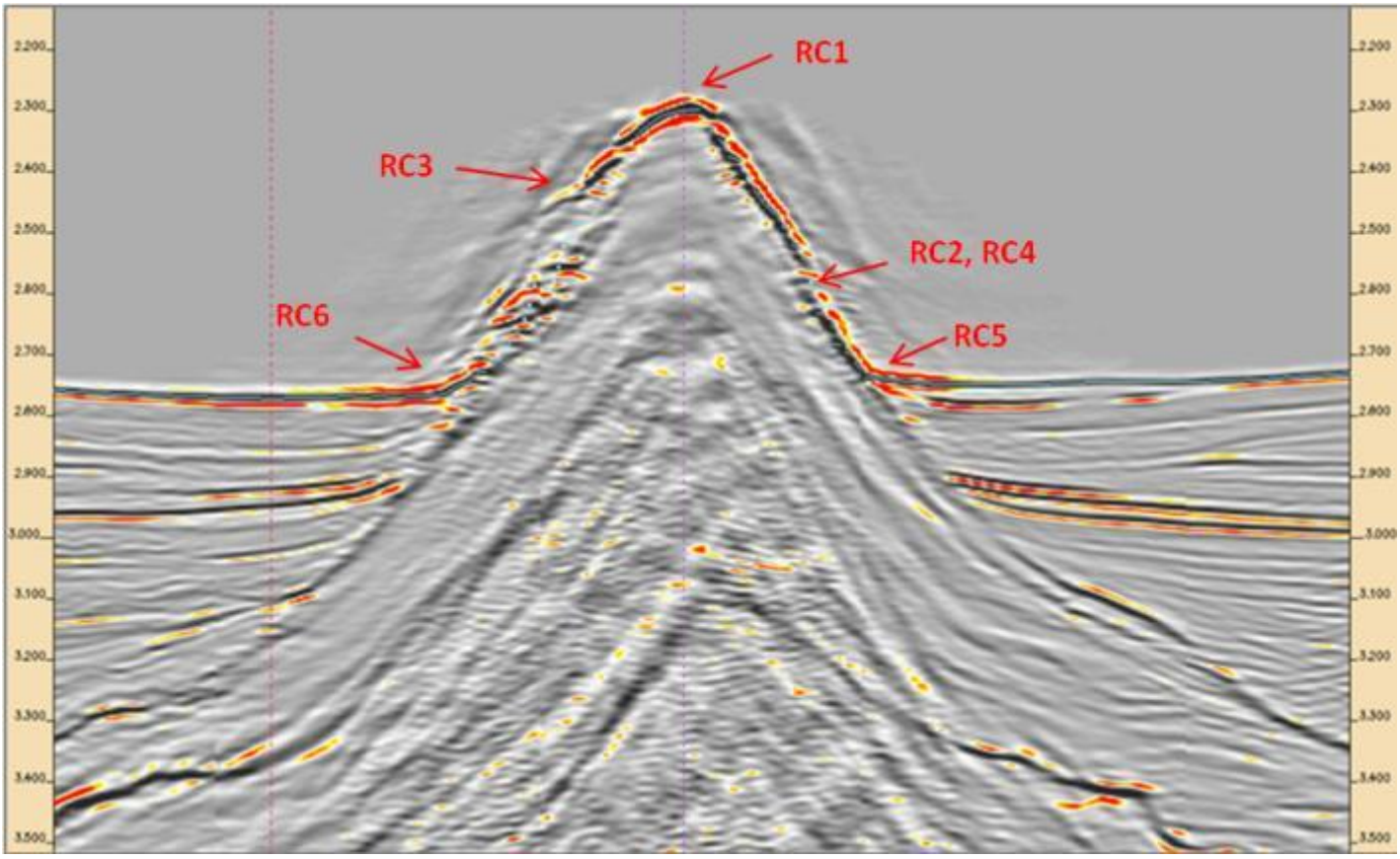


***Figure 3**. N-S seismic section of 'Snorkel' reef and projected locations of RC drop cores. Also shows the seamount is the exposed part of a larger feature.*

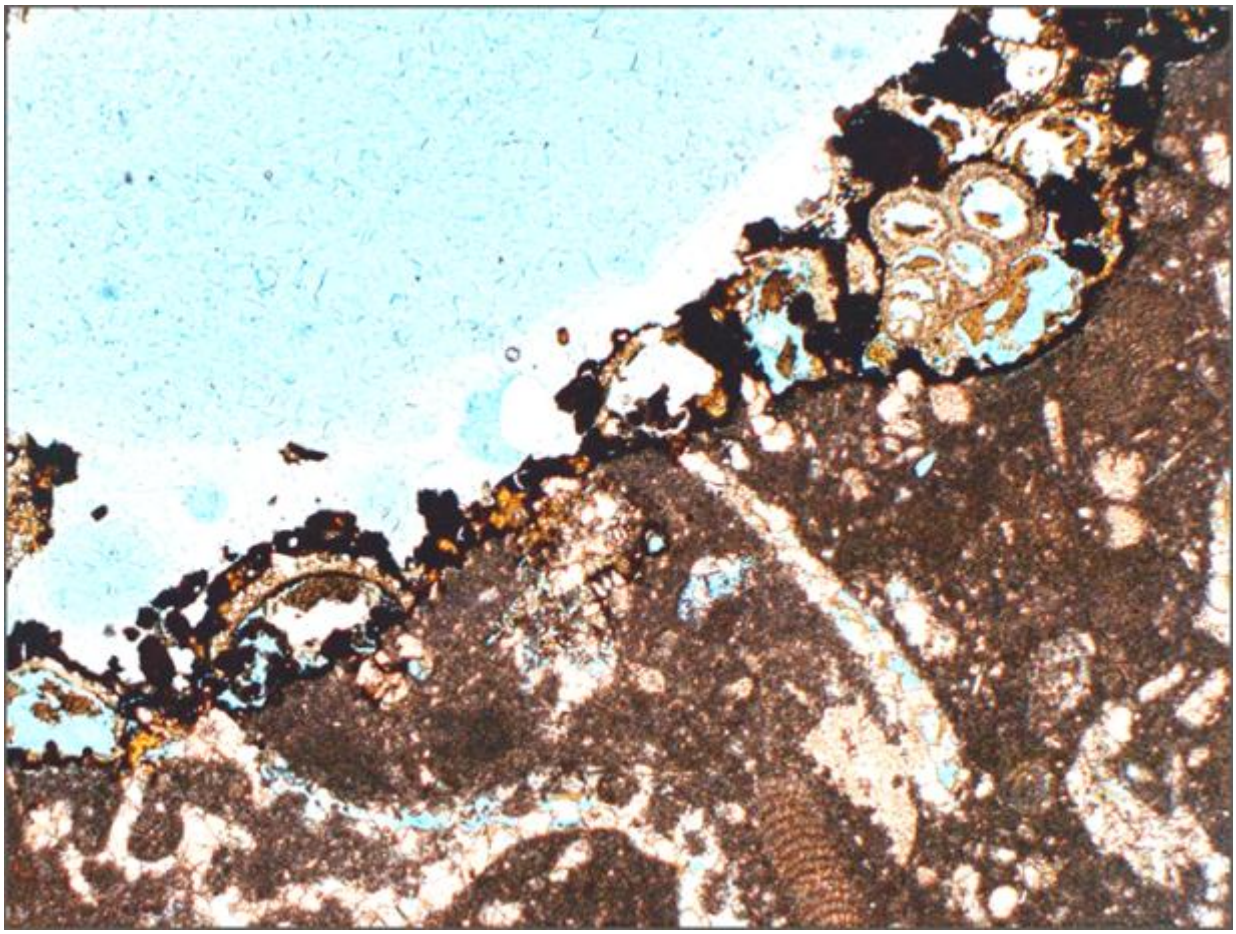


***Figure 4**. Core RC3: carbonate (algal-mollusk packstone) encrusted by ferromanganese mineralization with planktonic foraminifera*

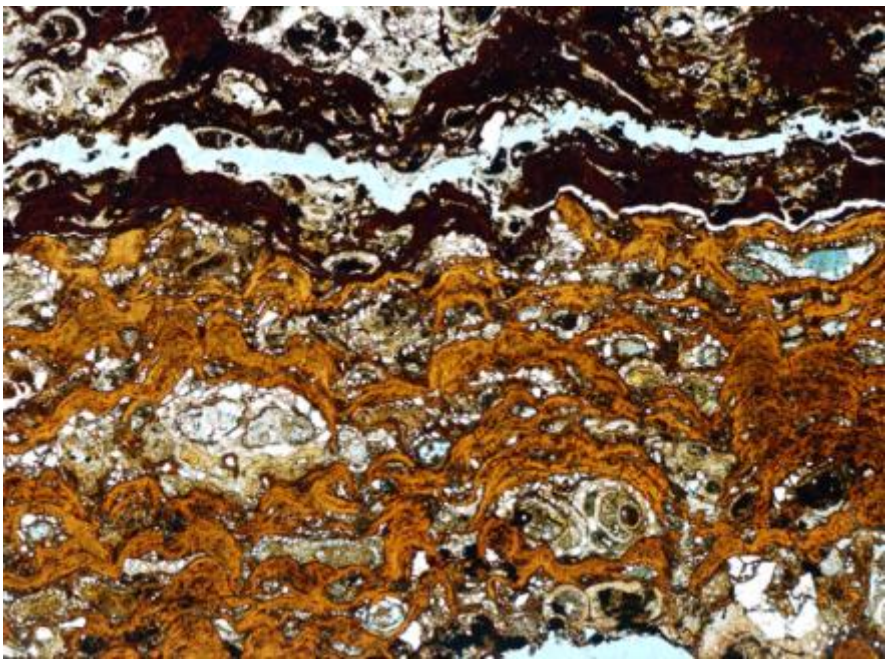


***Figure 5**. RC 4: Ferromanganese crust, showing layers of different composition and texture*



***Figure 6**. RC 1: Red algal-foraminiferal packstone with Miogypsinoides bantamensis and Lepidocyclina.*

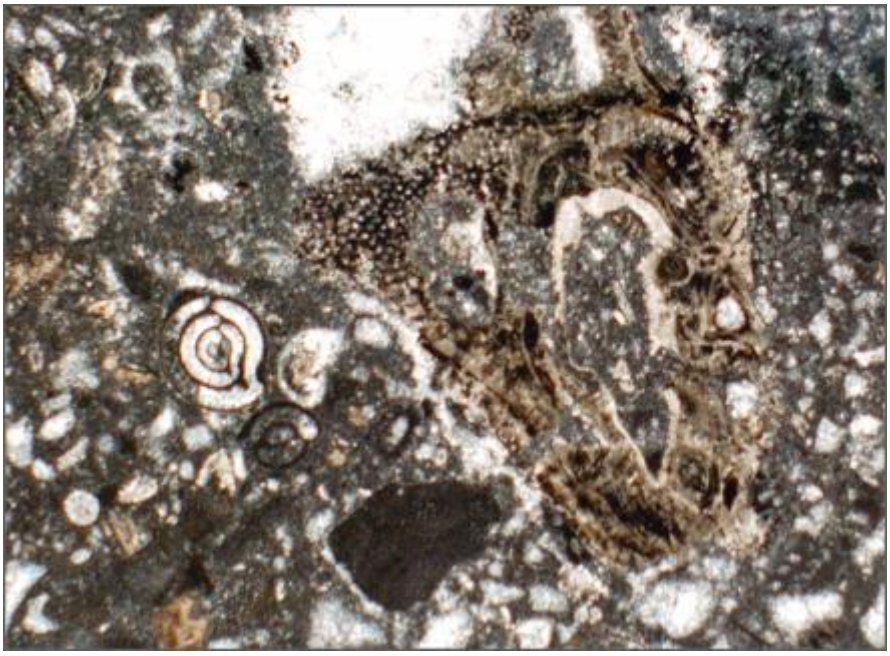
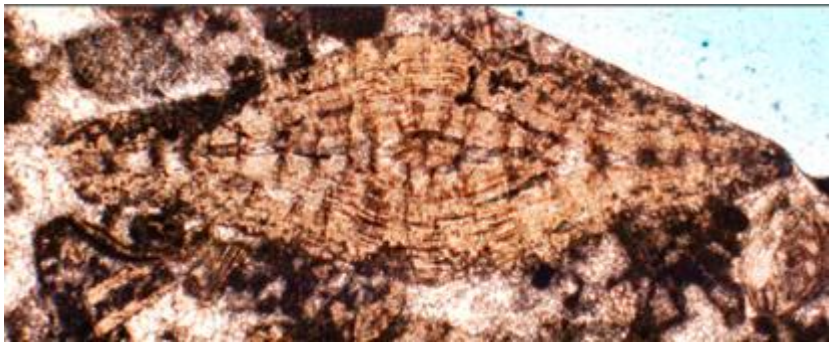
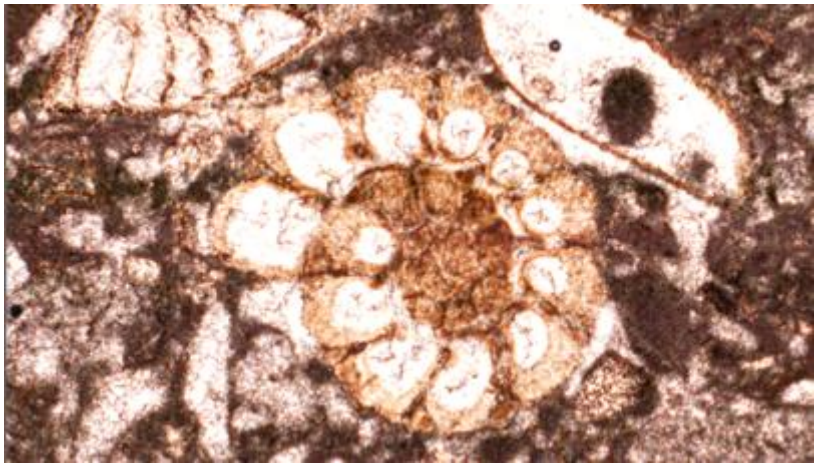


***Figure 7**. RC 1: Typical reef flat/ platform interior assemblage of non-age diagnostic miliolid and encrusting foraminifera*

a



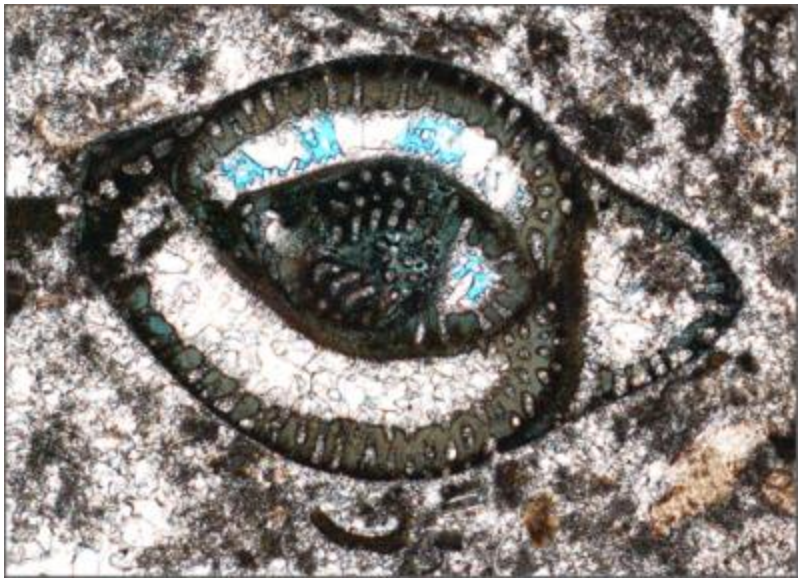
b



c



d



***Figures 8 a-d**. RC 2: Platform assemblage of Spiroclypeus (Tansinhokella), Neorotalia mecatepecensis, Borelis pygmaeus, Austrotrillina striata (not all at same scale)*

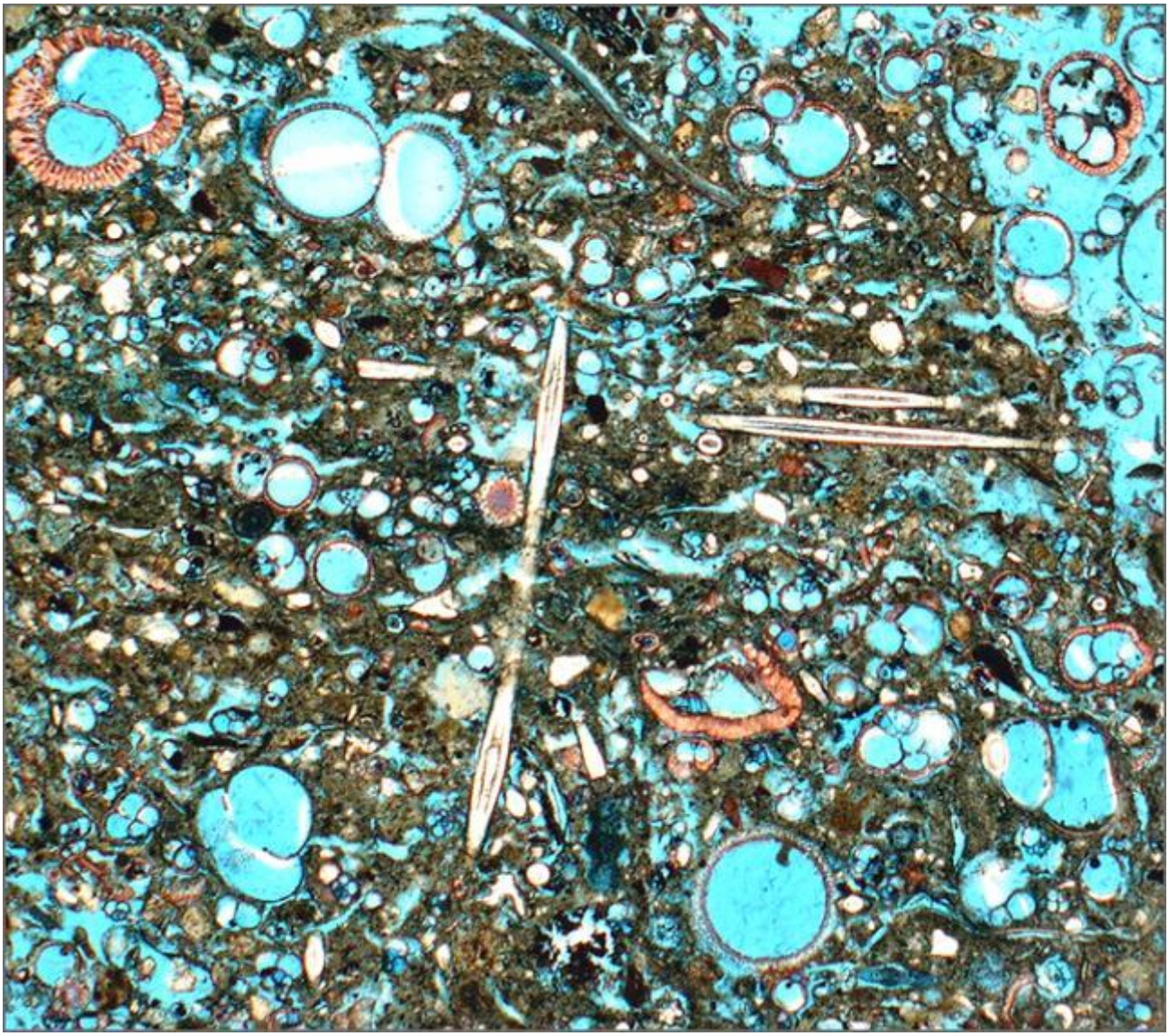


Figure 9. RC 5: Recent pelagic ooze with planktonic foraminifera and sponge needles

(13 chambers in initial spiral), *Lepidocyclina* sp. and *Austrotrillina*. This assemblage, with the absence of *Miogypsina* is diagnostic of larger foram zone Te4 (late Chattian, latest Oligocene).

RC3 (North slope of reef; 1839 m)

Carbonate in this core is a packstone rich in fragments of coral, red algae, echinoids and foraminifera. Larger foraminifera include *Lepidocyclina* and relatively advanced *Spiroclypeus*. This assemblage is relatively poor, and only indicative of an age within larger foram zones Te2-Te5 (Chattian- Aquitanian).

RC2 (near Eastern base of reef; 1954 m)

RC2 cored packstones-grainstones with fragments of coral, red algae and foraminifera (Figs. 8 a-d). Smaller foraminifera include common miliolids, *Amphistegina* and *Neorotalia mecatepecensis*. Larger foraminifera include primitive *Spiroclypeus (Tansinhokella), Borelis pygmaeus* and *Austrotrillina striata*. This rich assemblage, without *Miogypsinoides,* is diagnostic of larger foram zone Te2-3 (mid-Chattian, Late Oligocene)

RC4 (SW flank of reef; 1914 m)

Sample RC4 mainly recovered dark brown- black ferromanganese crust (Figure 5). One small carbonate fragment is present, which shows mainly crystalline calcite with a few indeterminate fragments of larger foraminifera.

RC5 (off Eastern base of reef; 2058 m)

Sample RC5 only recovered young pelagic sediments, dominated by planktonic foraminifera and sponge needles (Figure 9).

RC6 (off NW base of reef; 2046 m)

Sample RC6 is very similar to RC5 and also only recovered young pelagic ooze, composed mainly of planktonic foraminifera (Figure 10).

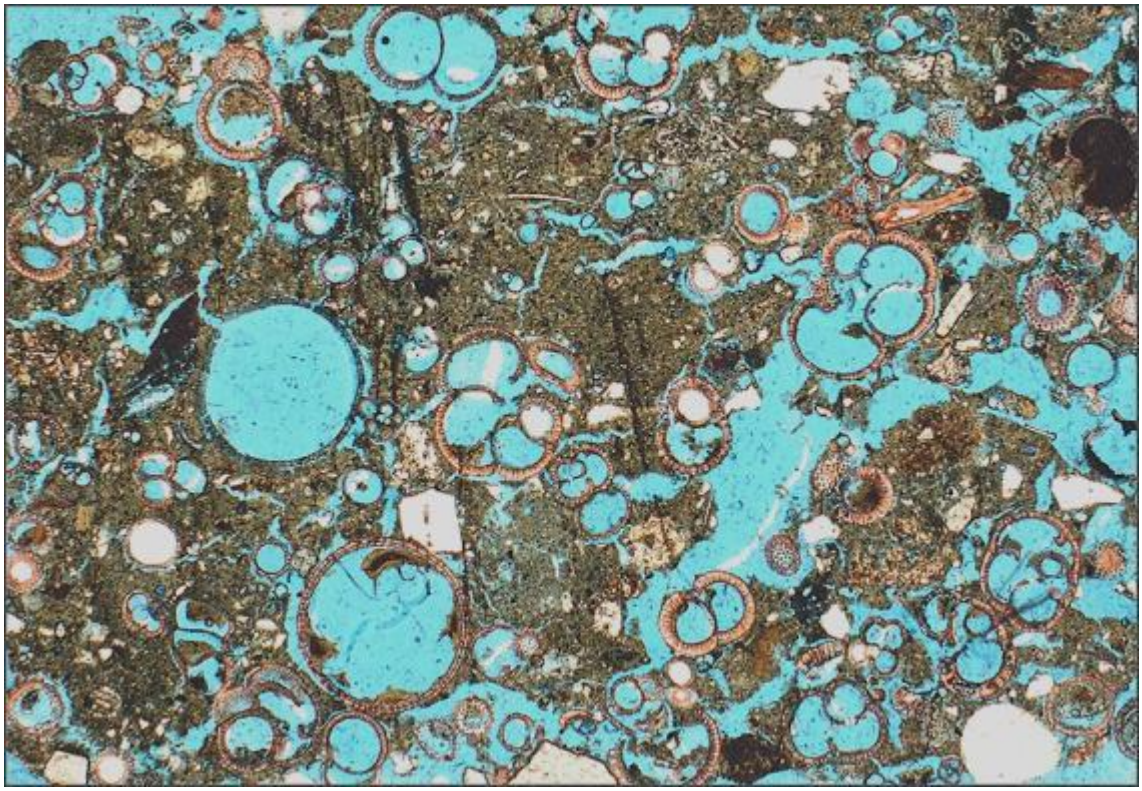


Figure 10. RC 6: Pelagic ooze with planktonic foraminifera

CONCLUSIONS

The 'Snorkel' seamount in deep water of South Makassar Straits is the top 340m part of a shallow marine Oligocene pinnacle reef, which drowned and stopped growth at the end of Oligocene time. This time of drowning of Snorkel and is identical to that of the nearby 'S-1' well ((see below). Both wells had the latest Oligocene zone Te4 index species *Miogypsinoides bantamensis* in the topmost carbonate samples.

The age of the basal part of the Snorkel carbonate buildup is uncertain. Seismic lines suggest a significant part of the Snorkel buildup is buried by onlapping sediment and therefore not sampled. Total relief of the buildup could be ~800m. However, we expect it to be more similar to the section in the nearby 'S-1' well, which penetrated a 389m thick Late Eocene- Late Oligocene carbonate section on a series of volcanic rocks.

Only a few 100m meters of Oligocene- Recent sediment were deposited around the base of the Snorkel seamount, never burying the buildup to where it might have become a petroleum exploration target. This was probably due to the combination of (1) long distance from the major sediment sources along Makassar Straits, and (2) possible ongoing seafloor erosion in the Labani Channel due to confinement of the deep water current path of the 'Indonesian Throughflow' in this narrowest part of the deep water Makassar Straits basin.

ACKNOWLEDGEMENTS

We like to thank management of ExxonMobil E&P Indonesia and Direktorat Jenderal MIGAS for permission to publish this paper, Jim Corthay for the map and seismic displays, Aram Derewetzky for collecting the core samples and CoreLab Indonesia for preparation of thin sections.

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