Playford P.E. and Lowry D.C. 1966: Devonian reef complexes of the Canning Basin, Western Australia. *Geol. Survey W.A. Bull 118*, 150 p.

SUMMARY

A series of Middle and Upper Devonian reef complexes is well exposed in rough limestone ranges extending for about 180 miles along the northern margin of the Canning Basin in the Kimberley District of Western Australia. They occur in a structural subdivision of the basin named the Lennard Shelf.

Four basic facies are recognized in the reef complexes - the reef, back-reef, fore-reef, and inter-reef facies. The reef and back-reef facies together make up limestone platforms which, in Devonian times, stood some tens to hundreds of feet above the floor of the surrounding inter-reef basins. They can be compared with the present-day platforms of the Bahama Banks and associated limestone bank areas of Florida, Cuba, and the Gulf of Mexico.

The reef facies occurs as a narrow rim (which may be discontinuous) around each platform. The platforms are flanked by fore-reef talus deposits having steep depositional dips, and these interfinger with the surrounding inter-reef deposits. The reefs are described as atolls, fringing reefs, and barrier reefs, and the platforms cover areas ranging from a few acres to hundreds of square miles. The maximum thickness of the reef complexes may exceed 3,000 feet.

The reef complexes grew on a basement of Precambrian granitic and metamorphic rocks, except the Emanuel Range reef complex, which grew partly at least on Ordovician sediments. The reef complexes developed around islands and promontories in the basement rocks and along the Devonian mainland shore. They are generally elongated in a northwesterly direction, parallel to the regional structural trend of the Precambrian rocks.0000

The reef facies is named the Windjana Limestone. It is composed of massive limestone, dolomitic limestone, and dolomite. The reef limestones were built up by colonial organisms, mainly blue-green algae and stromatoporoids. These form the framework of the rock and occur in their approximate positions of growth. Minute algae belonging to the genera *Renalcis* and *Chabakovia (?)* occur in great abundance in many of the reefs. They grew only in the reef facies and in the immediately adjoining parts of the fore-reef and back-reef facies. Other reef-building organisms include corals, brachiopods, and sponges. *"Stromatactis"* structures are important in the reef facies in certain areas. They are interpreted as cavity fillings enlarged by replacement of the limestone walls by fibrous calcite.

The reef rim exposed around the edge of each limestone platform is generally 100 to 500 feet wide, but in some areas it is absent or only a few feet wide, and in others the exposed width may be more than a mile. Such very wide expanses of near-horizontal reef are explained by basinward tilting of the reef complex since deposition. The reef normally grew upwards and outwards, advancing over the fore-reef talus deposits, but in certain areas it grew nearly vertically or horizontally, or it retreated over the back-reef facies.

The back-reef facies is named the Pillara Limestone. This facies was deposited in the shelf lagoon behind the reef rim of each platform, and it consists predominantly of well-bedded limestone, which is locally dolomitized. Terrigenous sediments are interbedded with the limestone in some areas. The back-reef deposits were laid down essentially horizontally except in the immediate vicinity of the reef where they may dip away from the reef at low angles. The depth of water in the back-reef shelf lagoons is believed to have been very shallow, probably nowhere more than five fathoms and commonly much less.

The back-reef facies is divided into five sub-facies, which are known as the stromatoporoid, birdseye-limestone, coral, oolite, and oncolite sub-facies. Of these, the stromatoporoid and birdseye-limestone types are the most common. The stromatoporoid sub-facies is characterized by the genera *Amphipora* and *Actinostroma,* which occur in great abundance in biostromal beds. The birdseye limestones are believed to be algal-mat deposits, built up by blue-green algae, and these are particularly characteristic of the Famennian section. The coral sub-facies is dominated by species of *Alveolites, Thamnopora,* and *Hexagonaria,* and it

is developed only in the Givetian and early Frasnian reef complexes. The oolite sub-facies contains little evidence of life other than minor development of algae. The oncolite sub-facies has a more restricted distribution than the other sub-facies. It is characterized by abundant algal balls (oncolites) and thick-shelled molluscs.

The fore-reef facies consists of talus deposits derived from the reef rim and (to a lesser extent) from the shelf lagoon of each reef complex, together with contributions from terrigenous sources and from organisms that grew on the fore-reef slope. The depositional dip of the fore-reef talus is commonly 30 to 35 degrees, flattening gradually down the fore-reef slope. The deposits are made up mainly of calcarenite, calcirudite, andd megabreccia. Large blocks of reef limestone are common in the fore-reef deposits in some areas, and where they are very numerous the rock is termed a megabreccia. Some of the megabreccias also contain blocks of back-reef and fore-reef limestones. Isolated blocks are believed to have been broken from the reefs by wave action, but the megabreccias have probably originated through large-scale submarine sliding caused by the instability of the steeply dipping fore-reef talus deposits. Earthquakes may have initiated such slides.

The inter-reef facies was deposited almost horizontally on the floor of the inter-reef basins between the platforms. The depth of water in which this facies was deposited is believed to have ranged from about 5 fathoms to 100 fathoms or more. The facies consists largely of interbedded terrigenous sediments (shale, siltstone, sandstone, and conglomerate) and thin beds of limestone. It contains little or no material derived from the limestone platforms. The inter-reef facies occupies the valleys between the limestone ranges, where exposures are generally poor. Through most of the area the fore-reef and inter-reef facies have not been differentiated in mapping.

The fore-reef and inter-reef facies of the reef complexes are divided into six formations, five of which are exposed in the eastern part of the Lennard Shelf from the Burramundi Range to the Emanuel Range. The oldest of these are the Gogo Formation (inter-reef facies) and the Sadler Limestone (fore-reef facies). They are overlain by the Virgin Hills Formation (fore-reef and inter-reef facies), and this unit is in turn overlain by the Piker Hills Formation (fore-reef and inter-reef facies). The Bugle Gap Limestone is a fore-reef unit which is laterally equivalent to the upper part of the Virgin Hills Formation and possibly also to the lower part of the Piker Hills Formation. In the Napier Range, Oscar Range, and Geikie Range areas the whole of the fore-reef and inter-reef facies is placed in the Napier Formation, which is laterally equivalent to the other five formations.

The reef complexes have been dated by reference to the standard European succession. They range from late Givetian to late Famennian in age. The only Middle Devonian index fossil known in the reef complexes *is Stringocephalus,* and this has been found only in the back-reef facies of the Home Range, Pillara Range and Emanuel Range. Ammonoids and conodonts are especially important in dating the Upper Devonian sequence relative to the standard German "Stages." These fossils occur most abundantly in the inter-reef facies; they are less common in the fore-reef and reef facies and are very rare in the back-reef facies. They indicate that a continuous sequence is present in the Upper Devonian part of the reef complexes from the early Frasnian "Stage" I to at least Famennian "Stage" IV and probably to Famennian "Stage" V. Brachiopod faunas are also important in the local zonation of the reef complexes.

Large masses of conglomerate, composed of granitic and metamorphic clasts up to boulder size, are associated withh the reef complexes in a number of areas. The Van Emmerick and Behn Conglomerates underlie and intertongue with the base of the Napier Range reef complex, while the Stony Creek and Bobs Bore Conglomerates intertongue with the reef complexes in the southeastern part of the Lennard Shelf. The origin of these conglomerates is uncertain, but it is suggested that they were shed from fault scarps which were active in Devonian times. Evidence of such tectonism is also provided by the presence of local unconformities in the reef complexes at a number of localities. Other masses of similar conglomerate occur in the Burramundi Range-Mount Elma-Sparke Range area, resting with angular unconformity on the Devonian rocks. They may be of Permian age. However it has not been possible to map these younger conglomerates separately from some of the Devonian conglomerates which occur in the same area. It seems likely that the

associated Devonian and ?Permian conglomerates were deposited as a result of separate periods of movement along the same faults.

The reef complexes are overlain with apparent conformity by the Fairfield Formation, an interbedded sequence of limestone, shale, siltstone, and sandstone of Upper Devonian (late Famennian "Stages" V and VI) to Lower Carboniferous (Tournaisian) age. The Lower Carboniferous part was previously named the "Laurel Formation," but this is no longer regarded as a separate rock unit.

The Fairfield Formation was deposited as a shallow-water deposit over the extinct reef complexes. This extinction may have resulted from shallowing of the inter-reef basins by terrigenous sedimentation, which destroyed the conditions of water circulation necessary for reef growth. If this hypothesis is correct, it is unlikely that all the reef complexes ceased growing at precisely the same time throughout the Lennard Shelf, and as a result the base of the Fairfield Formation may be time transgressive.

The Fairfield Formation is overlain in the sub-surface by the Upper Carboniferous Anderson Formation. In outcrop it is overlain unconformably by the Grant Formation, which also extends over the other Devonian units.

The Devonian and Lower Carboniferous rocks have undergone relatively little tectonic disturbance. There has been mild folding and tilting and some normal faulting, but for large areas the rocks are almost undisturbed. The main period of tectonism on the Lennard Shelf may have occurred during the Upper Carboniferous, when strong subsidence began in the adjacent Fitzroy Trough.

The Devonian reef complexes are regarded as primary objectives in the search for oil in the Canning Basin. They are only known to occur on the Lennard Shelf, but may also be present at considerable depth in the Fitzroy Trough and in other parts of the basin. The most prospective area of the Lennard Shelf is believed to be the northwestern part near the boundary with the Fitzroy Trough. The reef complexes are present in this area beneath an adequate capping of Fairfield. Formation which is in turn overlain by Upper Carboniferous, Permian, and Triassic sediments.

Reservoir rocks can be expected in the reef, back-reef, and fore-reef facies of the reef complexes, especially where they are dolomitized. Source rocks may occur in the inter-reef facies, and cap rocks are provided in the overlying Fairfield Formation. The sandstone beds in that formation may also be suitable reservoirs.

Buried reef complexes have been located on the Lennard Shelf using seismic reflection methods. Aeromagnetic and gravity surveys are also useful in locating basement ridges on which the reef complexes could have developed.

Limestone platforms of Devonian reef complexes have been penetrated in four wells drilled on the Lennard Shelf-Meda Nos. 1 and 2, Hawkstone Peak No. 1, and the 67-mile (water) bore. A few gallons of oil were obtained from the Fairfield Formation over the interval 5,110 to 5,133 feet in Meda No. 1, and a moderate flow of gas was obtained from the interval 6,654 to 6,696 feet in the reef fades. Oil and gas showings were also obtained from equivalent horizons in Meda No. 2; other wells drilled on the Lennard Shelf have been dry.