The bathymetry of the Aliwal Shoal, Scottburgh, South Africa

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This paper presents the first accurate geo-referenced bathymetric map of the Aliwal Shoal and illustrates its value as an essential tool for a wide range of applications useful to the broader scientific community. The dense coverage of echo-sounding data in the survey area permitted the construction of a detailed bathymetric contour map and 3-D model. It showed that the Aliwal Shoal forms part of a much larger offshore reef complex than was previously realized. Morphologically, the Aliwal Shoal is dominated by three distinct features, namely, the *Crown, Spur* and *Ridge.* The high-resolution bathymetric map presented here enabled the accurate positioning of the boundaries of the Restricted Zones of the newly proclaimed Aliwal Shoal Marine Protected Area. This geo-referenced GIS-compatible map will form the base map for future studies, ranging from the mapping of biological seafloor habitats to ocean current modelling, thereby also performing the function of an environmental planning and management tool.

Introduction

The Aliwal Shoal (Fig. 1) is one of the best-preserved examples of the many submerged reefs, parallel to the coast, documented on the southeastern continental shelf.[1–6] These reefs consist primarily of aeolianite with subordinate beachrock and are thought to represent Late Pleistocene palaeocoastlines.[3,4] In 1884, the SS *Nebo* sank after striking the reef; in 1974, the MV *Produce* similarly sank, coming to rest on the seafloor northeast of the Aliwal Shoal.[7] In 1963, the *Aimée Lykes* grounded on the reef but made it to Durban harbour. Rock samples removed from the damaged hull confirmed an aeolianite origin[8] and foraminifera provided a Pliocene–Recent age,[9] revised later as Late Pleistocene.[10] Several researchers have included the Aliwal area in regional studies[2,11–13] but none has dealt specifically with this reef and it has remained for the most part unmapped (Fig. 2). In this paper we present the first detailed geo-referenced map of the Aliwal Shoal and illustrate its usefulness as a scientific and environmental management tool.

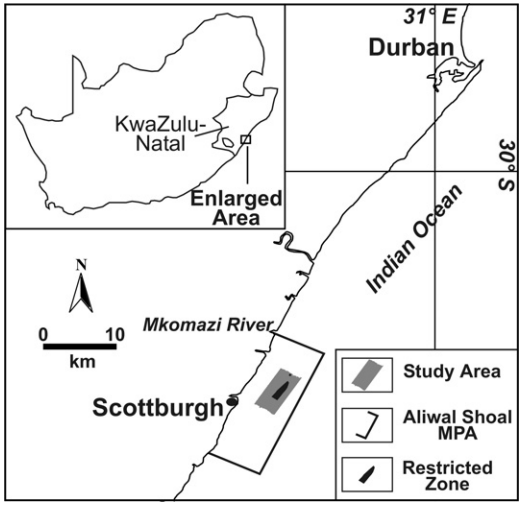

Fig. 1. Locality map of the study area which falls within the 'Controlled Zone' of the newly proclaimed Aliwal Shoal Marine Protected Area (MPA). The Restricted Zones within the Controlled Zone are also shown.

Bathymetric modelling

Echo-sounding data were collected on two separate sea cruises, in March and June 2001. The survey grid comprised northwest–southeast and northeast–southwest tracklines, set 120 m apart (Fig. 3). In all, 266 line-kilometres were surveyed. Depth measurements for the bathymetry map were recorded using an Odom EchoTrac Model 3100 single-beam digital hydrographic echo-sounder and a 200-kHz narrow-beam (10°) Odom transducer. The accuracy of the echo-sounder was 0.01% of total water depth, dependent on the accuracy of the value of the velocity of sound. Navigation and position fixes were provided by a Fugro OmniStar 12-channel differential Global Positioning

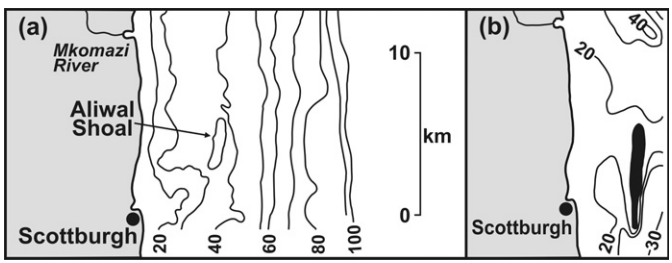

Fig. 2. Maps of the Aliwal Shoal. (**a**) Bathymetry (10-m intervals) and (**b**) geological map showing unconsolidated sediment thickness (isopachs in 10-m intervals) and aeolianite (black area). After Martin and Flemming.[12]

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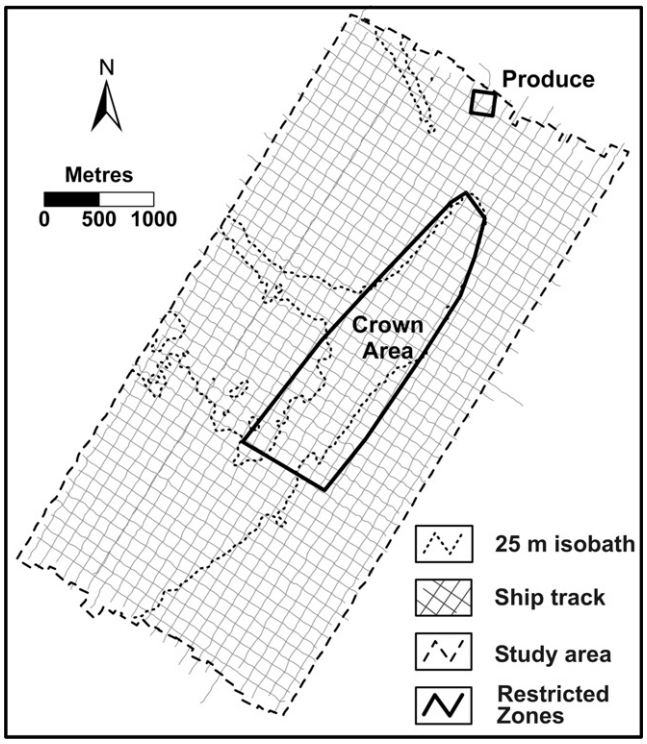

Fig. 3. dGPS tracklines showing data coverage in the survey area. Also shown are the Produce and Crown Restricted Zones of the MPA and the 25-m isobath, which was used to delineated the Crown Area Restricted Zone.

System (dGPS) capable of single-second update rate and sub-metre accuracy. Using an average survey speed of 2.5 knots, this translated into a bathymetric data point every 1.29 m along each trackline.

In total, 101 433 data points were used to create the bathymetric model. All depth values were tidally corrected to the mean sea-level (MSL) datum (local tidal range is 2 m). Data were gridded in *Surfer* version 7 software using point kriging to produce seafloor contours as used in earlier reef surveys on the southeastern continental shelf.[14] Grid sizes and search patterns were optimized to represent the reef most accurately using a 20 m × 20 m grid with an octant search pattern and a search radius of 180 m. Digital terrain models were generated using *ER Mapper 6.4* and *Surfer 8* software to provide three-dimensional (3-D) models of the continental shelf (Fig. 4b) in addition to a 2-D contour plot (Fig. 4a), providing visualization of the reef morphology from any orientation.

Aliwal Shoal morphology

The Aliwal Shoal forms part of a much larger offshore reef complex than was previously realized. The seaward expression of the reef is a narrow ridge with a curvilinear sinusoidal northeast–southwest (coast-parallel) trend (Fig. 4) that has an abrupt northern edge called the *Crown.* The landward expression has a linear margin from which a narrow ridge, just over 1 km long (the *Spur*), projects shoreward. The shallowest part (6 m below MSL) is located in the northern extremity of the *Crown,* with a gradual increase in depth with distance southwards. The steepest gradient recorded, on the northern edge of the *Crown,* is 18°. Other gradients vary from 6.4° on the seaward side to 8° on the landward side.

The Aliwal Shoal averages 380 m in width in the north, narrows slightly in the central region but widens to more than 2 km in the south, where it bends shorewards (Fig. 2). This southern plateau region is called the *Ridge.*[8] Northwest of the shoal is a large

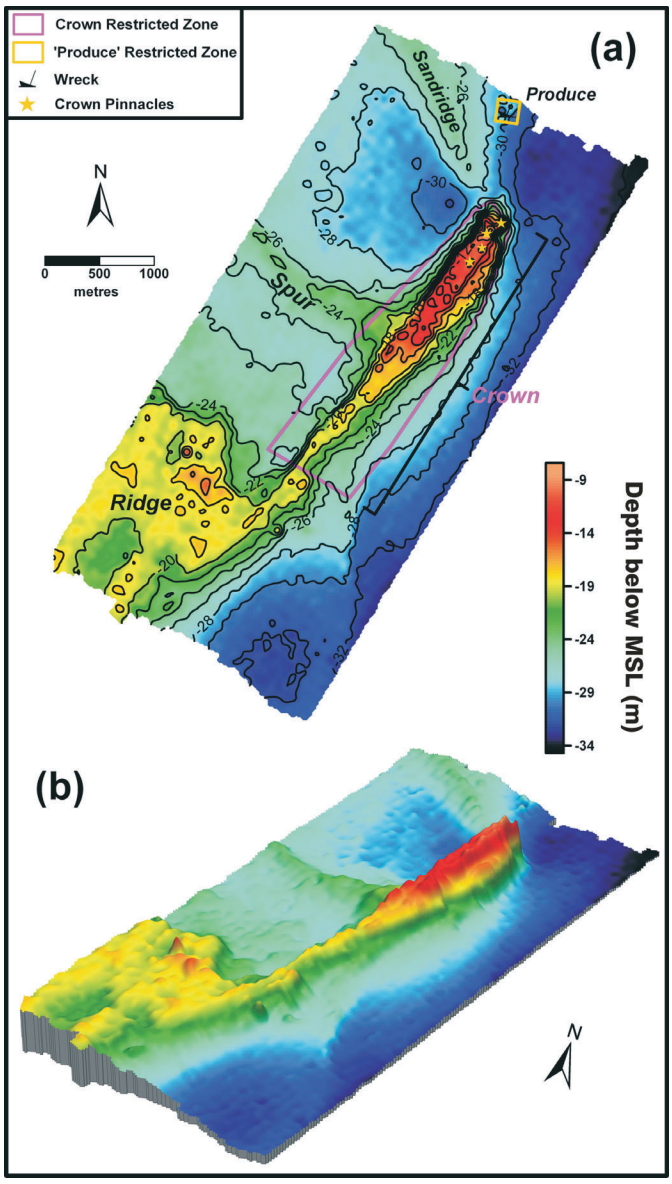

Fig. 4. (**a**) Bathymetric contour map of the study area showing the main morphological features and the boundaries of the Restricted Zones of the MPA. Contour interval is 2 m. (**b**) 3-D bathymetric model of the study area; view is from the south, sunshading from 150° with a 75° azimuth.

bedform, interpreted as submerged spit-bar[12] and reinterpreted as a sandridge[15] (Fig. 2). The landward side of the shoal, between the *Sandridge* and the *Ridge,* is a sand-filled depression, roughly divided into two basins by the *Spur.* The depression slopes towards the *Sandridge* (Fig. 4). The *Spur* consists in part of a northwards-migrating, 2–3-m-high subaqueous dune.

The average depth of the *Crown* is 12.5 m and it contains almost all of the SCUBA-diving locations used by recreational divers, the best known being the *Main Pinnacle Ridge* and *North-Eastern Pinnacles* (Fig. 4). The southern *Ridge* is deeper with an average depth of 19.5 m. This portion and the southern continuation of the *Crown* ridge are characterized by several other isolated pinnacles. The total area covered by the Aliwal Shoal is in excess of 5.56 km^2 and extends westwards to the coast beyond the *Ridge.*

Data application

This dataset provides the first detailed and useful information on the nature of the seafloor in the Aliwal Shoal area and enabled the accurate positioning of the newly proclaimed Restricted

Zone of the Aliwal Shoal Marine Protected Area (MPA).[16] Basic biological inventory studies to determine the status of the reef are required for conservation and management planning of the MPA. This relies on reliable knowledge of the location and distribution of reef habitats. The bathymetry map of the Aliwal Shoal serves as a spatially accurate base map that is easily imported into a GIS database, where it can be used as a multi-surface attribute model for spatially referenced data. The dataset forms a base map for biological surveys to chart changes to habitats and biological zones and provides a means to model effluent discharge and environmental impacts from marine outfall pipelines situated north of the study area.

The new bathymetric map also indicates the presence of other shallow, isolated pinnacles that can be used as alternative dive sites, alleviating pressure on the more popular dive sites situated on the *Crown*. Recreational divers will benefit from the high accuracy of the map by planning the exact location of their dives and minimizing user conflict within the MPA. Furthermore, it is envisaged that these data will form part of an MPA website providing tourists and divers with geological, biological, and oceanographic information and 3-D 'fly-through' visualization.

The bathymetric dataset not only serves as the first accurate and detailed map of the Aliwal Shoal but also serves as a useful 'environmental tool' which will form the baseline for future studies ranging from the mapping of biological seafloor habitats to ocean current modelling. Integration of all the data types will facilitate the development of a comprehensive multidisciplinary environmental management plan, which is vital for the future development, management and conservation of the Aliwal Shoal.

This paper is published with permission of the director of the Council for Geoscience, and benefited from the comments of two anonymous reviewers.

Received 12 September 2004. Accepted 14 May 2005.

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