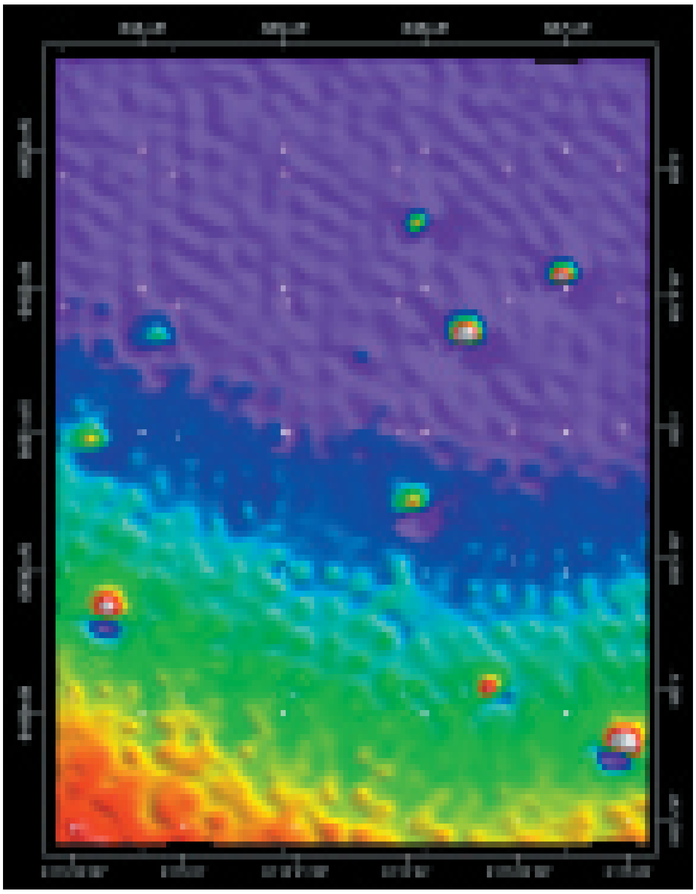
SHALLOW WATER SEARCH OPTIONS FOR HMAS *SYDNEY*/HKS *KORMORAN*

Jeremy Green
Department of Maritime Archaeology
Western Australian Maritime Museum
Cliff Street
FREMANTLE
Western Australia

1 November 2001



Report–Department of Maritime Archaeology
Western Australian Maritime Museum No. 162

Introduction: the problem
The issues relating to the location of HMAS *Sydney* (and by implication HKS *Kormoran*) in shallow water are relatively simple. It is assumed that shallow water refers to depths up to about the edge of the continental shelf (*c*. 200 m). The objectives of this report is to attempt to define the parameters that are involved in this type of work and the limitations and costing of the systems.

Two basic systems can be used for location of large iron objects such as a the *Sydney/Kormoran*, these are the magnetometer and sonar or side scan sonar (other systems have been suggested but currently none offer the proven reliability and at least one is the subject of a separate report by the Technical Committee). Recent work on the Deepwater Graveyard and the HMAS *Derwent* site off Rottnest present some interesting new information that can be used to assist in refining the parameters relating to the shallow water search. In particular, what is the optimal detection range, and thus operating costs per square km, of search area and how best to conduct a search in the shallow water area.

The parameters for magnetometer
The HMAS *Sydney* was about 6000 tonnes and 139 m long by 15 m wide (the HKS *Kormoran* was a larger vessel). In order to investigate the application of an airborne magnetometer a test run was made over the HMAS Derwent, sunk in 200 m off Rottnest in 1994. In this case an aerial magnetometer was flown by UTS in August 2001 and a 14.787 nT anomaly was detected over the *Derwent* area. The *Derwent* was a Type 12 frigate of 2100 tonnes, 112.8 m long by 12.5 m breadth. It was built in Williamstown in the late 1950s and did not have an aluminium superstructure as was the later Type 12 vessels HMAS *Swan* and *Torrens* built in the early 1970s (Geoff Hewett personal communication) So the tonnage represents a totally iron hull, there being about 1% aluminium, whereas the later Type 12 had about 20% aluminium superstructure.

Using the Hall equation (Hall, 1966):

Where

=nanoTesla
W= Tonnes
D= metres

=Length/breadth ratio

For HMAS *Derwent*
W= 2100 tonnes
D=225 m

= 112.8/12.5=9.02

$$\Delta N = \frac{9.02 \times 10^4 \times 2.1 \times 10^3}{(225)^3}$$

So'
ΔN=16.6 nT calculated

So this largely confirms the equation and in particular the application of the' ratio. There can be little doubt that the application of an aerial magnetometer will be the most effective application for shallow water work, the system has increased sensitivity over any in-water magnetometer and more particularly can cover areas faster and more reliably than the marine magnetometer. The in-water system has the advantage that it can be deployed closer to the seabed, but with the size of the anticipated anomaly, the advantage gained in decreasing target to sensor distance, is off set by low speed of operation, operational unreliability due to the effects of weather conditions and thus increased costs.

The *Derwent* experiment clearly shows that a vessel of 2100 tonnes can be detected at 250 m (50 m flying height) giving a 15 nT anomaly. For the *Sydney/Kormoran*, given the same parameters, the detection depth will be 270 m (using 50 m flying height). If, however, a smaller anomaly than 15 nT could be detected, then the following table indicates the theoretical detection depth for anomaly size. This also has considerable implications for the rate of coverage. Note the smaller detection sizes are for comparison purposes and do not imply that they are practical:

Minimum detectable anomaly in nT	Detection range in m(subtract 50 m for flying height to obtain depth
15	332
10	381
5	480
2	651
1	820
0.5	1034
0.1	1767

However, there are some considerations that affect these distance, in particular the background noise and the half-width of the anomaly. Variations in the observed magnetic field of the earth can be attributed to the presence of a body that is capable of being magnetized. This measured variation can be quantified by two factors, the amplitude of the response, and the half width of the positive peak (see Figure 1).

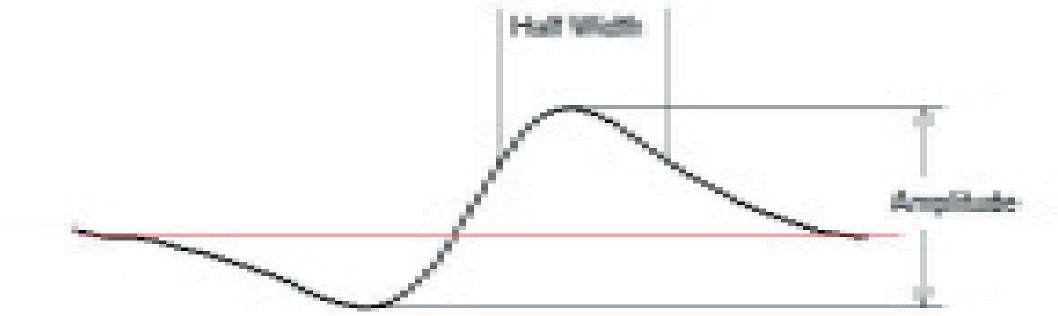


Figure 1. Amplitude and half width of a magnetic anomaly.

The magnitude of these variations can be considered a function of two factors:

i) the spatial geometry, which includes the size, orientation and depth of the causative body, and

ii) the magnetic susceptibility of the body. This is simply a measure of the body's ability to be magnetized.

To determine the feasibility of using airborne magnetic techniques, we can calculate or model the response of bodies with differing geometries and susceptibilities. The susceptibility of the body can be estimated, since the materials used for the construction of the vessels are known. Thus it is possible to model the response for various targets at varying depths.

Using this technique, the data collected from the *Derwent* survey area was inverted to provide an idea of the susceptibility of the targeted shipwreck. This information was then used to forward model a number of different sized targets at various water depths. The amplitude and half widths from these models was plotted, and the information used to determine optimum survey specifications required to detect the vessels (Figure 2).

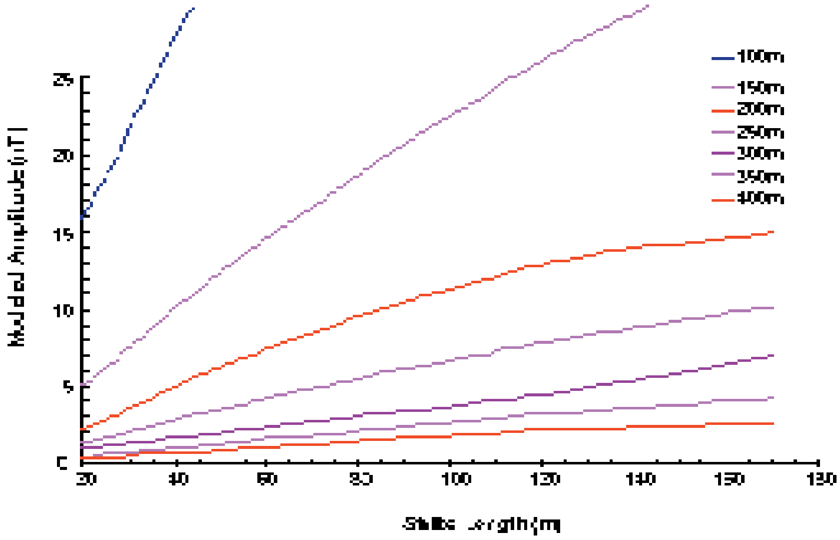


Figure 2.   Amplitude response v. strike length with varying water depth.

If we assume a minimum detection level of 1nT is required, from this chart it can be seen that in 350m of water the minimum target size is 40m along the flight line direction.

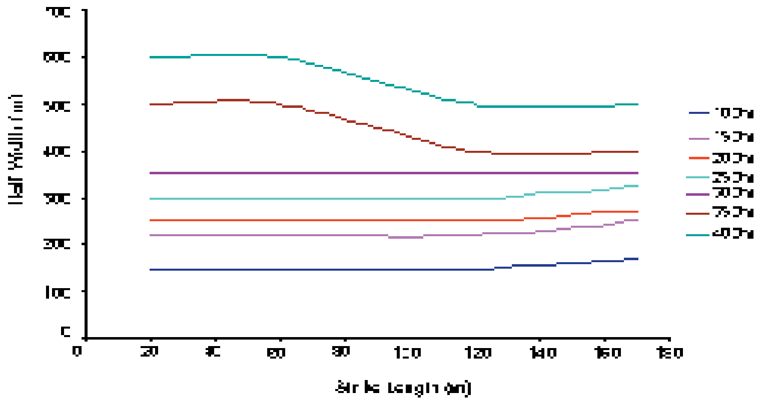


Figure 3.   Half-width response v strike length with varying water depth.

Using the same parameters as before, ie 40 m target size in 350m of water, then the half width is approximately 220m. The line spacing should be at least half this value again, to ensure that at least one survey line records values greater than half the maximum amplitude. For the example used, the suggested line spacing would be 110m (Figure 3).

The efficiency of the magnetometer system in detecting a site such as the *Sydney/Kormoran* will be limited by the following parameters:

1. The detection range and half-width response,
2. The background signal to noise ratios and
3. The relative density of geomagnetic magnetic and other anomalies.

Clearly, if one is searching areas well within the theoretical detection range, the main problem will be differentiating between anomalies of the same or similar size to that predicted for the *Sydney/ Kormoran*. In any give depth it will be possible to discount larger and smaller anomalies to the prediction, but some upper and lower theoretical limits will need to be applied. Where one is close to the theoretical detection range, the noise issues become significant.

Figure 4 shows the predicted anomaly on a logarithmic scale at horizontal distances across an anomaly of 10,000 ton vessel at various depths of water (mW = metres of water) and shows the half-width problem in slightly different way to Figures 2 and 3. Obviously a 5 nT anomaly will be hard to see when it is about 600 m wide, unless the signal to noise ratio is drastically reduced.

Figure 4. Plot of distance in metres against size of anomaly in nT for different depths of water.

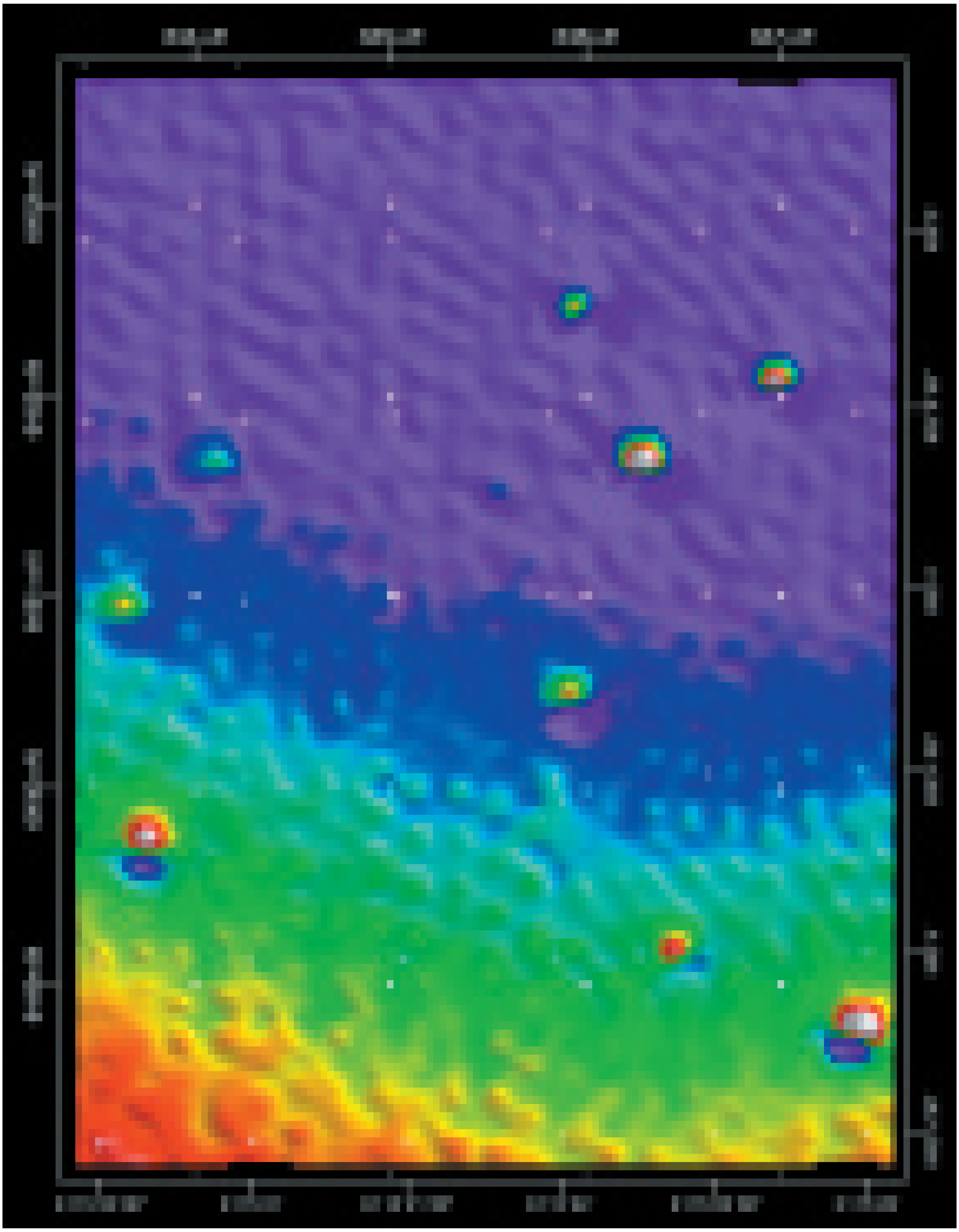


Figure 5. Showing Deepwater Graveyard survey and the magnetic field gradient and 'swell effect' (courtesy UTS Geophysics).

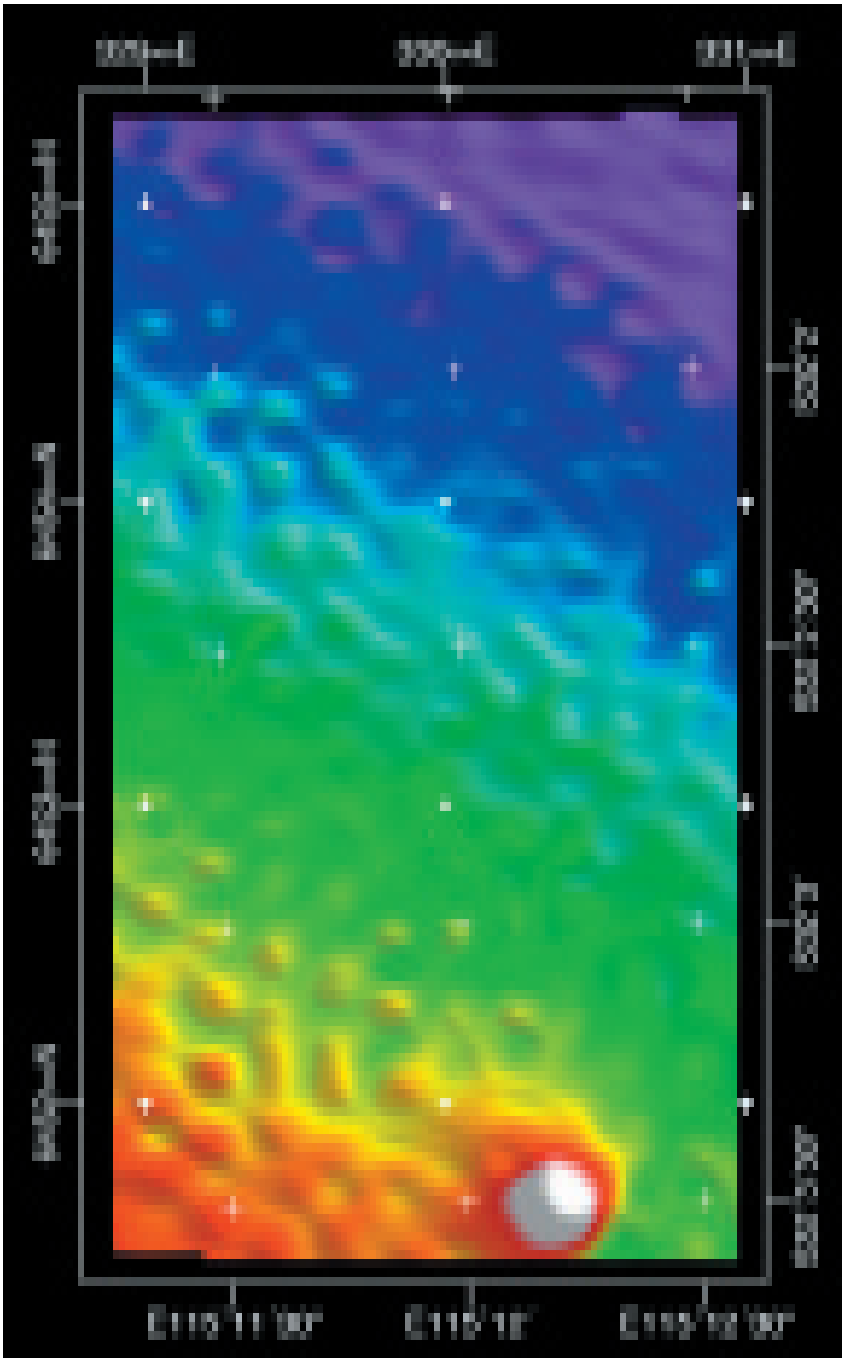


Figure 6. Magnetic survey over *Derwent* site (courtesy UTS Geophysics).

The results of the UTS survey of the *Derwent* and Deep Water Graveyard sites show a noticeable gradient across both search areas due to the natural variation in the Earth's magnetic field. In addition, a series of regular magnetic field intensity fluctuations can be observed and these are attributed to the effect of the swell (see Figures 5 … 6. 'Swell noise' is caused by the movement of a conductor body (the ocean salt water) through the Earth's magnetic field which produces eddy currents (Faraday's law). The magnetic component of the eddy currents thus increases or decreases the magnetic field intensity. It is not clear if this effect can be compensated for, if it could, then there would be a considerable gain in detection range. water mW.

Parameters for sonar and side scan sonar

It is assumed that this proposal for the shallow water survey will involves the use of existing commercial technology currently available in Australia; unlike the deep water region which will require specialised equipment that will be expensive and may not be readily available in Australia. For the shallow water survey, side scan sonar has a major and proven application, although not necessarily a direct alternative to the magnetometer. Conventional side scan sonar has a maximum range (looking both ways) of about 1000 to 2000 m, however, at this range there are some uncertainties as to the delectability of a vessel the size of the *Sydney/Kormoran*. Obviously, it cannot differentiate at long range between reef and shipwreck and it is limited, in the same way as the marine magnetometer, by its speed of operation. Conventional sonar also has an application, where targets that have major vertical relief can be precisely located from the echo sounder trace. It is likely, in shallow water, that the standard echo sounder could be used as the secondary location system after the magnetometer survey. This would depend on the nature of the magnetometer survey work and the number of targets, the echo sounder is likely to show the target, although it is unlikely to resolve the difference between reef and wreck. The main advantage of the side scan sonar is that, with current technology it is possible to track the sonar and produce a sonar mosaic of the survey area (Figure 7)

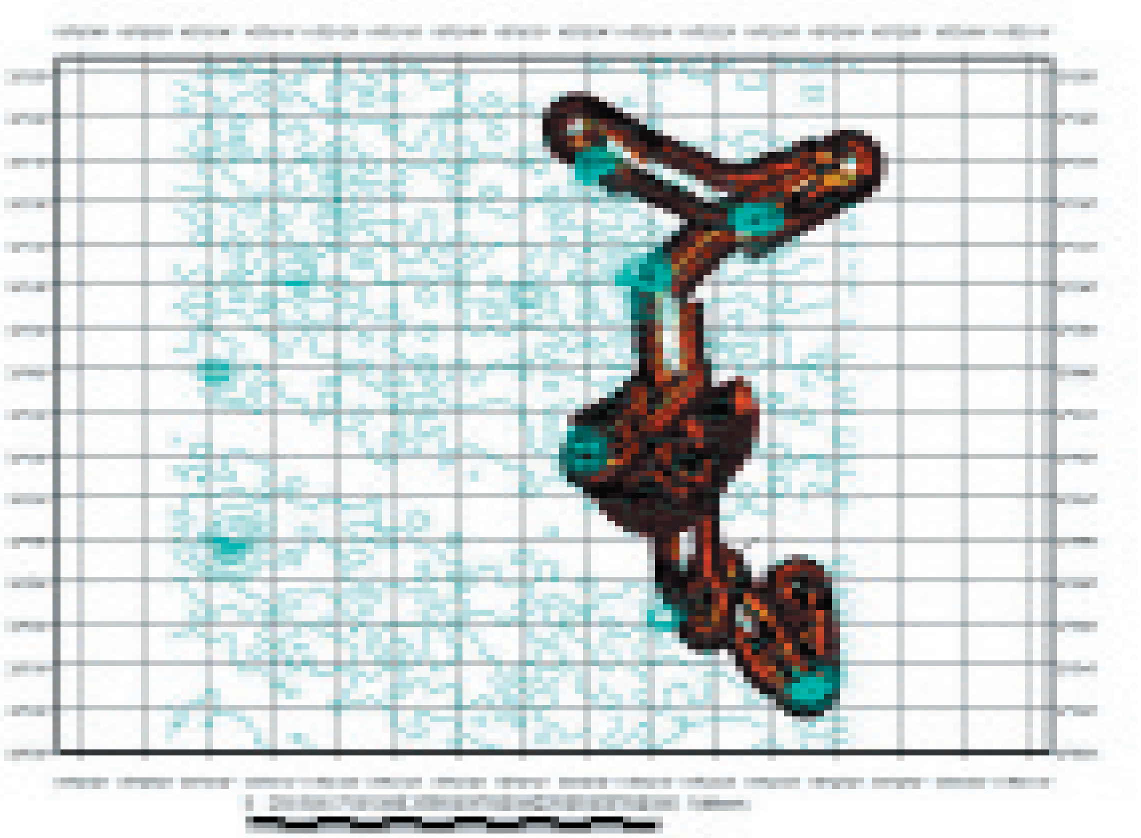


Figure 7. Sonar mosaic of the Deep Water Graveyard

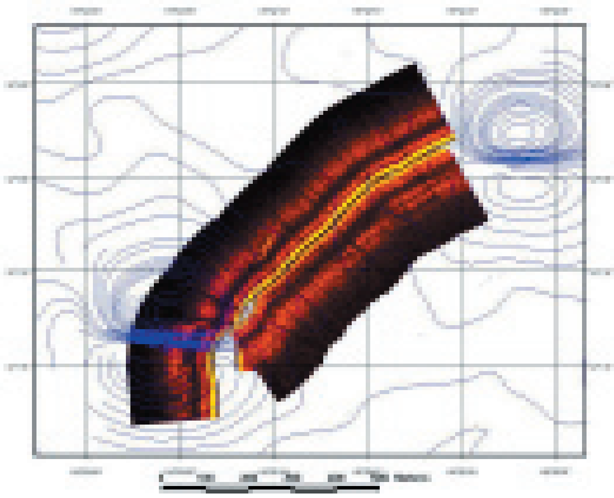


Figure 8. Side scan sonar trace showing large object slightly NE of magnetometer anomaly in lower left. Effect of layback is likely to account for offset.

The side scan sonar will have an important role in identification of anomalies. This has been shown in the work on the Deepwater Graveyard, off Rottnest, 20 nautical miles of the coast. Here a series of magnetic targets located by aerial magnetometer (described above) were subsequently investigated by side scan sonar. Given the conditions were neither optimum for the survey work (there was a 1.5 m swell and 10–15 knot winds), it was possible to identify one target as a shipwreck, some targets as reef and other targets as possibly dumping areas. Figure 8 shows the sonar trace of an side scan target, clearly showing a large, 'hard' target of approximate dimensions suggesting a wreck.

Subsequently, the site was located using an echo sounder and a group of technical divers using mixed gasses dived on this site. The shot line which was thrown overboard when the echo sounder indicated the site landed inside one of the hatches of the wreck. The wreck was reported to be in 84 m, to the top of the decks; iron hulled, wooden decked and with two masts. Subsequently, the anomaly in the top right of Figure 8 was located by echo sounder alone and this was also dived on with similar success, this site being 77 m to top of deck and 84–88 m to sea bed; iron hulled vessel about 120 m long.

Aerial magnetometer cost table

The following table provides estimates of undertaking a high-resolution aerial magnetic survey as part of the HMAS *Sydney* HKS *Kormoran* shallow water search. Specifications used for the purpose of this estimate are:

Survey line spacing:	100m
Magnetic sample interval:	5m
Magnetic sensor height (ASL):	50m
Survey speed:	100 kts (182km/hr)
Distance from base airfield:	60km
Base of operation:	Geraldton, WA

The cost estimates provided are full commercial rates and are 'all-inclusive' which includes aviation costs, aviation fuel, accommodation and all crew costs for the survey.

Square Km's	**Survey Line Km's**	**Survey Time**	**Survey Cost**	**Cost per Sq.Km**

1	11	$10,500.00	$10,500.00	1 day
10	104	$11,590.00	$1,159.00	1 day
50	508	$12,990.00	$259.80	2 days
100	1010	$14,990.00	$149.90	3 days
500	5023	$46,500.00	$93.00	8 days
1000	10,030	$89,500.00	$89.50	15 days

The above prices, while reasonably accurate, are estimates only and are subject to change based on the cost of supplies at the time of undertaking a survey and are subject to specific survey parameters. Prices are quoted exclusive of GST.

General conclusions

It is known that the area north of the Abrolhos Islands up to Cape Inscription (the most probable shallow water area for the search) has a number of known geomagnetic anomalies. Various investigations of these anomalies have been undertaken including the WA Maritime Museum's investigation, in conjunction with HMAS *Moresby*, in 1981 of an anomaly off the Zuytdorp Cliffs (Green *et al.*, 1984). This magnetic anomaly corresponded closely with the anticipated signal for the *Sydney/Kormoran* proved to be geomagnetic. In addition a number of natural features were found†in this area, many of which are known fishing sites, and which do not have a magnetic signature. A recent report on the Lucky Bay Lump, in the Kalbarri area is typical of the expected sea bed topography; in this case a large echo sounder target proved, on further investigation with a magnetometer to be a non-magnetic reef feature.

It is therefore, reasonable to say that with existing technology anomalies the size anticipated from the *Sydney/Kormoran* could be detected in about 400 m of water. With some application of post-processing or compensation for 'swell effect' this limit could possibly be extended deeper. Depending on the nature of the magnetic anomaly density in the survey area, it is likely that a side scan sonar would be used to investigate the anomalies, or if there were only a small number, the sites could be located with an echo sounder and a remotely operated vehicle or technical divers (for sites up to 100 m) would be used for the final visual identification.

Acknowledgements

The author gratefully acknowledges the assistance and information received from Neil Goodey and Russel McChesney of UTS Geophysics who provided the aerial survey data and technical advice on the magnetic data. In addition the members of the HMAS *Sydney* Forum Technical Committee: Prof. John D. Penrose of Centre for Marine Science and Technology, Curtin University of Technology; Dr Alan Theobald, and Dr Julian Vrbancich; DSTO; Mr Ted Graham, Mermaid Marine; and members of the Technical Committee of the HMAS *Sydney†*Trust: Mr. Ed Punchard, Prospero Productions; Mr. Bill Russell-Cargill, Fugro Survey Pty. Ltd; Mr. Adil Ali, Thales Geosolutions (Australasia) Ltd; Commodore Bob Trotter, RANR; and Peter Henley, Centre for Marine Science and Technology, Curtin University of Technology.

References

Hall, E.T., 1966, The use of the proton magnetometer in underwater archaeology. *Archaeometry*, **9**: 32–44.

Green, J.N., McCarthy, M. and Penrose, J. 1984, Site inspection by remote sensing - the HMAS Sydney search: a case study. *Bulletin of the Australian Institute for Maritime Archaeology*, **8**.1: 22-42.