THE GEOLOGICAL INTERPRETATION OF SIDE-SCAN SONAR

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Abstract. Recent developments in side-scan sonar technology have increased the potential for fundamental changes in our understanding of ocean basins. Developed in the late 1960s, "side looking" sonars have been widely used for the last two decades to obtain qualitative estimates of the acoustic properties of the materials of the seafloor. Modern developments in the ability to obtain spatially correct digital data from side-scan sonar systems have resulted in images that can be subsequently processed, enhanced, and quantified. With appropriate processing, these acoustic images can be made to resemble easily recognizable optical photographs. Any geological interpretation of these images requires an understanding of the inherent limitations of the data acquisition system. When imagery is collected, these limitations are largely centered on the concept of resolution. In side-scan sonar images, there are several different types of resolution, including along- and across-track resolution, display resolution, and absolute instrumental resolution. All of these parameters play a critical role in our ability to calibrate and ultimately to interpret the new pictures of the ocean floor. Acoustic image processing is a new application of an old and well-established technique. Digital optical images have benefited from several decades of development in processing techniques. These relatively sophisticated techniques have been applied to photographic images from satellites and spacecraft, images which are "noisy" and difficult to obtain but extremely valuable. Side-scan sonar systems, on the other hand, have only recently been able to produce spatially correct, digital images of the seafloor. The application of digital signal-processing techniques to side-scan sonar data will now allow us to quantify what had been previously very subjective and qualitative interpretations of images of the seafloor. The goal of all this processing of acoustic images remains clear: the development of an interpretable map of the geology of the seafloor.

INTRODUCTION

Our early perception of the deep ocean floor as a featureless, static environment has undergone dramatic modification in the last 50 years. Early depth sounding with mechanical devices, and even early wide-beam acoustic echo sounders, gave us an extremely low resolution picture of the ocean basins. This early image of the ocean bottom consisted largely of a flat lying seafloor with few hills and ridges of any consequence, completely covered with a thick layer of sediment, and only an occasional, inexplicable outcrop of hard rock. The few recovered rock samples were of little value in understanding the scientific processes of the deep sea because they could not be placed within any sort of geological and morphological context.

Acceptance of seafloor spreading and the Vine/Matthews hypothesis in the 1960s altered forever our perception that the floor of the ocean basins was unchanging, at least on a geological time scale. The initial drilling efforts of the Deep Sea Drilling Project also modified our view about the uniformity of the seafloor, even on a scale of a few hundreds (and perhaps tens) of kilometers. Higher-resolution bathymetry maps, using multiple narrow-beam echo sounders, strongly reinforced this newperception of a nonuniform and scientifically interesting seafloor [*Tyce*, 1986]. The initial interest grew to excitement as our perspective was extended by visual observation—in a very few places—down to the scale of a few meters by early submersible expeditions to mid-ocean ridge spreading centers [*Ballard and van Andel*, 1977].

Clearly, a new tool, beyond the wide-beam echo sounder, was needed to map features of the seafloor and to understand the processes at work there. To be effective, this would have to be a tool which had both a sufficiently wide "view" for tectonic context and adequate resolution for interpretation in terms of geological processes. The efficiency of sound transmission in seawater, and the development of both electronic and digital techniques capable of rapidly processing the high data rates necessary to generate images, dictated that this tool would be some form of acoustic swath mapping. The scientific need for

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