IN-SEAM SEISMIC METHODS: A REVIEW

David King & Stewart Greenhalgh

Earth Resources Foundation
Department of Geology & Geophysics (02 – 692 2038)
The University of Sydney

Seismic reflection methods sample targets *remotely* from the vicinity of the ground surface. This, as much as the dimensions and physical properties of the target itself, imposes limitations on the resolution attainable. The coal mining industry has evinced a need for structural information on a scale smaller than is routinely attainable in reflection profiling, and at a range beyond the penetration of ground probing radar. Seismic waves generated and detected *within* a seam can in principle be used to delineate putative targets (faults, seam-splits, wash-outs, intrusions, and so on) of dimensions less than a seam thickness at a range (from a working face, say) or at least a few tens of metres. Dispersive channel waves of both Rayleigh and Lowe type are potentially most suitable for in-seam mapping (Krey, *Geophysics,* 1963). Notwithstanding the intuitive simplicity of so-called in-seam methods, practical implementations have proved elusive, as evidenced by intensive research projects in Germany, Britain, Czechoslovakia, the U.S.A., and recently Australia. To date, mathematical modelling and two-dimensional analogue scale modelling have both revealed characteristics of the generation and propogation of channel waves which bear importantly on the potential exploitation of these waves. In particular, Dresen and co-workers at the University of Bochum have shown how distinct Rayleigh-type wave groups arise from the interplay between source resonance effects and the propagation path transfer function. These and other important results from model studies underpin both the technical specification of in-seam systems, and the processing and interpretation of in-seam data. The published literature on in-seam methods is sparse, particularly with regard to technical specifications of high frequency sources and detectors suitable for safe operation in mines, or for operation in boreholes. The present paper reports on recent progress in in-seam research overseas.

DEVELOPMENT OF AN ON-LINE PROCESSING SYSTEM FOR SHALLOW MARINE REFLECTION DATA

by Robert J. Whiteley*, Laric V. Hawkins*, David J. Robinson and W. Harvey Holmes****

**School of Applied Geology, University of N.S.W.*
***School of Electrical Engineering, University of N.S.W.*
02-663 0351

Elaborate digital signal processing has been a common component of land and marine seismic surveys for some time. Such processing, however, is not used in all types of exploration. In general, digital processing has been restricted to high cost industries involved in deep surveys such as petroleum exploration. Because of the high cost of computing time and the enormous volume of data collected, it has not been possible until recently to contemplate the application of these digital techniques to data acquired in low cost, shallow marine seismic surveys. Such surveys are widely used for mineral exploration and engineering investigations, either inshore in harbours, lakes or estuaries, or offshore near coastal regions.

Shallow surveys are characterized by low acquisition costs and conventional computer processing costs can rarely be justified even though such surveys are often plagued by well known problems which invariably degrade shallow reflection data. Such problems include siesmic source noise such as bubble oscillation for sparkers, reverberation, pulse distortion surface reflection, water-borne noise and multiple reflections. Source noise, reverberation within the water layer and multiple reflections from the sea floor are particularly serious problems in shallow water reflection surveys.

The recent development of relatively inexpensive microprocessors now makes it possible to implement a low cost, on-line digital signal processing system. Perhaps the most revolutionary development in computer technology in recent years, the microprocessor is a logic device which is able to function, sequentially, as an indefinite variety of logic devices. Coupled to a memory the microporcessor becomes a micro-computer and when used in an on-line configuration the problem of storage of huge data sets is circumvented. An on-line system has the farther advantage in that it allows feed back to the geophysicist so that decisions can be made during the survey and system parameters varied to take account of changing conditions or to emphasise particular features of interest.

Current analog equipment for shallow reflection data comprises an acoustic sparker or boomer source, hydrophone receiver, pre-amplifier, band-pass filters, amplifiers and an electrostatic recorder or profiler producing the seismic reflection section. A digital system replacing or parallelling this rudimentary system must be able to handle a fairly large amount of data in real time intervals and complete processing within a single cycle of operation i.e. between successive source energy emissions. Around 100 db of dynamic range is also required at a sampling rate of about 15 kilo samples/sec. Most microprocessors are not able to meet these requirements unassisted so some form of hardware assistance is necessary. This is actually an advantage, since it allows for other than the usual data representations. The first digital system was realized on the MC6800 microprocessor but this had limitations and a second more sophisticated system based on the LSI 11/23 microporcessor is being developed. Both systems, however, have the same design philosophy.

Hardware assistance to the microprocessor is in four main areas: data conversion, system timing, data input and output and arithmetic manipulation. In the MC 6800 version of the system all input and output is interrupt driven from external devices such as the digital-to-analog converter or the profiler. The overheads associated with interrupting the processor placed severe limitations on the system. To avoid this, direct memory access devices are used with the LSI 11/23 and a hardware clock is standard. Analog data from the hydrophone is passed through a high cut anti-aliasing filter prior to digitization. Rather than using a conventional analog-to-digital converter for data entry a novel design has been developed which has an inherent floating point format in its operation. This floating point converter based on a digitally controlled automatic gain control allows the data to be probed into a single sixteen bit word and can be followed by digital-to-analog conversion in the standard manner. Software requirements are quite complex, since a fairly intelligent operating system is needed to cope with all the demands made of it. This operating system has, as system calls, several signal processing building blocks, including basic digital filter routines, a fast fourier routine and filter design routines. Other system utilities include an editor to allow manipulation of the data buffers, drivers for input and output devices and routines to allow the conrol of such operational parameters since data sampling rate and control over how many samples are taken in each cycle. Emphasis has been placed on an operating system which allows both foreground and background processess to run concurrently. This facility allows the user to interact with the system while the more important task of data processing continues with priority in the foreground. The operating system has been designed to allow efficient access to the same signal processing routines for either the foreground or background. When the system is initiated there are no foreground processors running, and the user must initialize all relevant paramenters, which include programming the foreground process with a series of system calls designed to execute the desired processing. Once this program is complete the task of data collection and processing can commence. Every time the seismic source is triggered, the foreground process is run causing data to be processed. Any time left after the processing is complete, before the next cycle begins is used for executing the background process.

In the background process the user can interact with the system, employing all the system calls available to the foreground process, plus some others. The basic system calls and utilities provided are an editor for data buffers, efficient digital filter routines, data acquisition and display device drivers and routines to design filter coefficients. Considerable effort has been expended to develop interactive software packages for the digital filters. These programmes currently run on a PDP 11/70 but are mostly transportable to the LS1 11/23. The package, thus far, provides for the design of standard Wiener filters and their extension for use in predictive deconvolution.

Although the on-line microprocessor based digital acquisition and processing system is still incomplete and further development is required, improvements to shallow marine reflection data from tests surveys are readily seen.

ESTIMATION OF RIPPABILITY AND EXCAVATION CONDITIONS IN CALCRETE DEPOSITS WITH SEISMIC REFRACTION METHODS.

by Laric V. Hawkins and Robert J. Whiteley

School of Applied Geology, University of N.S.W. (02-663 0351)

Seismic P-wave velocities in surficial materials, determined from seismic refraction surveys, can be used to assess excavation conditions at engineering sites such as roads and pipelines. These velocities are important in establishing whether and to what extent blasting is required. Certain contractors have produced rippability versus seismic velocity charts which are widely used to assess excavation conditions on a preliminary basis. Unfortunately these charts are limited in the number of rock types included and fail to take account of other complicating factors such as degree of weathering and nature of occurrence. They are particularly limited in treating surficial deposits such as calcrete, the nearest charted equivalent being caliche which may or may not be equivalent to calcrete.

Strong, sheet-calcrete deposits are widespread in Australia and throughout the world particularly in highly weathered, arid environments and are sometimes associated with significant mineral deposits such as uranium. When these deposits are encountered within the depth of excavation they are often very difficult and costly to remove particulary if their presence was not previously expected. Calcrete deposits, which can attain laboratory seismic velocities in excess of 5,500 m/s, can also pose substantial technical problems in carrying out seismic surveys particulary if they occur at the surface and a number of thin sheets are present. Such problems include lack of energy, shingling, and poor data quality generally due to a substantial component of horizontally travelling energy and other factors. First arrivals used for refraction interpretation can be confused with surface wave and other arrivals. Sheet calcretes can also create serious problems in interpretation of refraction data, of which the most common is velocity inversion. These problems are surmountable but require modified field and interpretation procedures. If these are not undertaken then very large errors in calculated seismic velocities and depths can result. In particular, for first arrivals, it is often necessary to orient vertical component geophones by tilting in a vertical plane away from the shot. While this may alter the damping of the geophones somewhat it serves to considerably improve data. Current shallow refraction instrumentation also suffers from the problem of cross-feed between channels often due to large amplitude, high frequency seismic waves travelling through hardpan calcrete. This necessitates a careful choice of charge sizes and gain settings. Geophone spacings must also be carefully chosen to ensure that information to the desired depth of excavation is obtained. In addition it is often necessary to drill shallow shot holes to the base of or through shallow calcrete layers to overcome velocity inversion problems and ensure that sufficient shot energy is converted to seismic body waves.

Seismic refraction field examples from sections of recently constructed Flinders Highway, South Australia, where extensive calcrete deposits occur, are discussed. These data provide a good ilustration of the care needed to achieve