ANALOG SEISMIC RECORDING REVISITED

by
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ABSTRACT

Analog single channel seismic recording is a conventional technique commonly used in subsurface profiling. One of its advantage is the resolution much higher than that of digital seismic recording. This advantage can be very useful in interpreting detail stratigraphic and structural subsurface features of the digital seismic section. In this case both profiles are complementary.

The implementation of single channel analog seismic profiling is simple and cheap, moreover it can be carried out simultaneously with multichannel digital seismic survey. Recording must be made in the deep sea where the sea bottom multiples or reverberations will be shifted far below the horizon of interest.

The improvement of the quality of single channel analog seismic record to some extent can be accomplished by using a simple circuit of electronic equipment such as analog filter and amplifier.

Examples from the deep sea to the south of Nusa Tenggara exhibit the capability of single channel seismic profiles in displaying interesting sub-bottom stratigraphic and structural features.

I. INTRODUCTION

Digital computer cannot be separated from our modern society. Its application has penetrated into so many fields and activities. It has revolutionized the way we solve our technical problems. In our professional lives, the digital computer has become an integral tool in performing many jobs.

Digital computer was first introduced in 1946, but its impact on seismic technology was only started nearly two decades later. The first Digital Field Recording System was manufactured in 1963 by Texas Instrument, a subsidiary of Geophysical Service Inc. The industrial application of digital processing of seismic data was started in 1968 after an intensive research on the possibility of applying digital concept to enhance time series reflection seismic data by the Geophysical Analysis Group at the Departement of Mathematics and the Departement of Geology, Massachussets Institute of Technology. Since then a rapid development of digital processing methodology was accelerated in line with the progress and development in digital computer hardware.

Today, nearly all seismic sections used in hydrocarbon exploration are produced through a chain of sophisticated digital processing software. There are so many oil and gas fields have been discovered with the aid of digital technology. Research and development in this direction is still progressing intensively.

The problem of hydrocarbon exploration today is that the remaining reservoirs which have yet to be discovered are thin; they are located either in the deep seas or in remote areas. The geology is complicated. The hydrocarbon trap are a combination of structural and stratigraphic traps. To reveal this kind of trap clearly we need a very high resolution seismic data and a very sophisticated subsurface imaging techniques. Have these challenges been overcome by today's digital technology ? Does digital technology have no limitation to answer today's exploration problems ? Does the 'analog technology' have no more contributions rather than seismic reconnaissance survey ?

In this paper, the analog seismic recording is investigated from different angle of view so that it can be used complementary to the digital seismic data for the purpose of hydrocarbon exploration in deep sea areas. Example will be given to demonstrate the resolving power of the seismic sections generated by the analog seismic recording, especially in revealing the subsurface structural and stratigraphic features below the deep sea bottom. It will also be demonstrated that the basement configuration can be shown clearly. This kind of display will be very difficult to compete by the same section produced by digital processing technology. In addition, it can be observed the capability of the analog seismic recording to display the depositional sequence.

Despite its weakness and limitation the analog seismic recording provides specific features which will certainly fill the lack of resolution in the seismic data produced by digital technology. This paper proposes to record single channel analog seismic trace simultaneously when people are doing multichannel digital seismic recording in the deep sea.

II. ANALOG SEISMIC RECORDING

Analog, single channel seismic recording (profiling) is an old technique. It was used in the 1920's when people started using seismic method for oil exploration. The first reproducible analog seismic record was known as Rieber Sonograph, introduced in 1936. With the progress and development in electronics technology, today we can find a very high resolution thermal plotter such as used bý the EPC recorder (see Figure 2).

Compared to multichannel digital recording technique, the analog single channel seismic profiling is very simple and conventional. However, its operation is very cheap and practical. The bandwidth is very wide yielding an extremely high resolution seismic data. The schematic diagram of an analog single channel seismic recording at sea can be illustrated as shown in Figure 1-a and 1-b. To produce the subsurface profiles, the seismic vessel moves with a constant speed and a shot is fired at a constant time interval, say at every 8 milliseconds. Thus, this operation yields a nearly normal incidence single trace at every shot. The seismic section is obtained by shooting along the survey line. This section is roughly equivalent to the near trace gather (NTG) section of multichannel digital seismic data, of course with the resolution which is much higher.

One of the disadvantages of the single channel analog seismic profiles is that the sophisticated seismic processing techniques cannot be applied to this data. There is no way to apply dereverberation or multiple elemination process to this data. The disadvantage causes a big problem in the shallow sea.

However, in the deep sea, the sub bottom multiple will appear far beneath the horizon of interest, so that the destructive interference has been avoided naturally.

Another disadvantages of the single channel analog seismic profiles is that the focussing and migration cannot be applied to this data. In an area where the sub-bottom structure is relatively gentle, we do not need an extensive

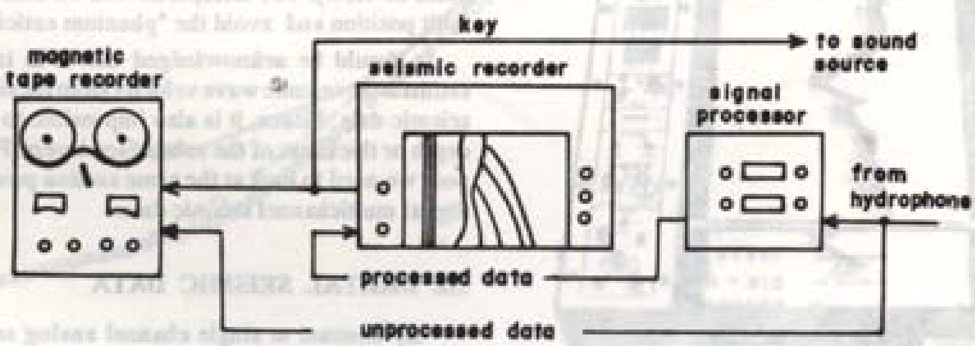

Figure 1-a. Single channel analog seismic recording system (from Geyer, 1983)

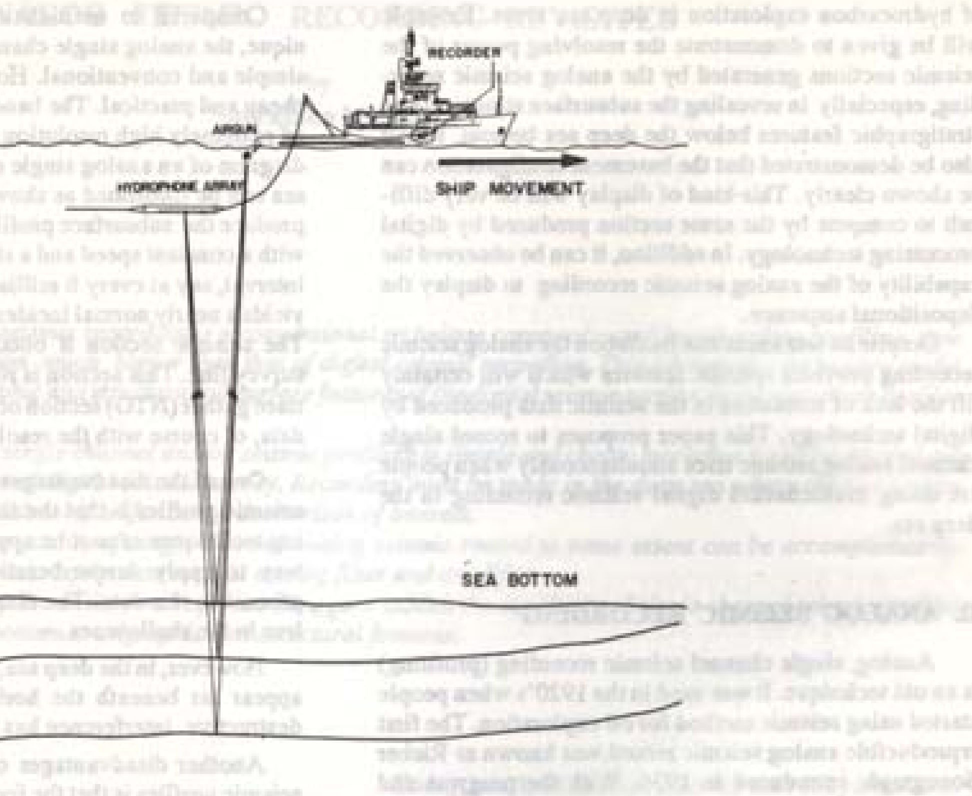

Figure 1-b. *Sub surface profiling can be done by firing the airgun at a constant time interval (eg. 8 msec) and the survey ship moving with a constant speed*

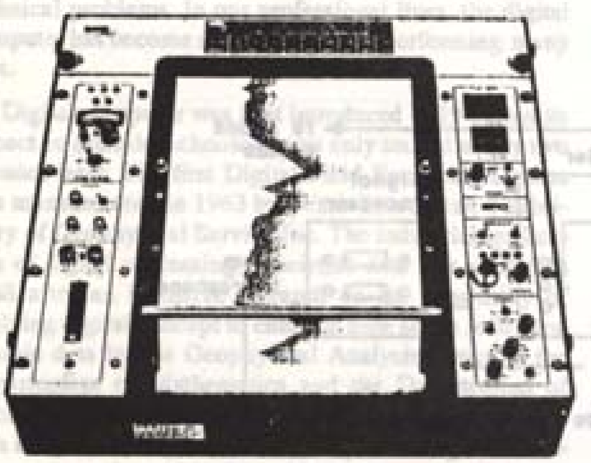

Figure 2. A high resolution graphic recorder EPC - 1600

focussing and migration process. However, if recording was made in a relatively complicated sub bottom geology, we can easily recognize an artificial structure produced by scattering or diffraction (from qualitative interpretation point of view). The interpreter will be able to place the fault position and avoid the "phantom anticline".

It should be acknowledged that it is impossible to estimate the seismic wave velocity from the single channel seismic data. Hence, it is also impossible to estimate the depth or thickness of the subsurface layers. For this purpose we need to look at the same section produced by the digital multichannel seismic data.

III. DIGITAL SEISMIC DATA

By contrast to single channel analog seismic recording, the digital seismic recording is much more complicated, but it records the multichannel seismic data at once. This function has been made possible with the use of a multiplexer. The schematic diagram of the digital seismic recorder is illustrated in Figure 3. With this arrangement the magnetic tape does not record the time series seismic trace representing seismic waves traveling through the subsurface layer, but instead it records the sequential trace. This sequential trace contains digital sample number one, trace number 1, sample number one, trace number two, sample number 1, trace number three, etc. A demultiplexing step is required prior to further processing. Also at the end of the digital process, a digital to analog conversion is required to display the processing result.

One of the advantages of the digital seismic data is that nearly all sophisticated mathematical operations can be applied in order to enhance the quality of the subsurface picture. This includes rejecting unwanted events, focussing scattered and diffracted events, suppresing multiple reflections and many others. In addition, a more accurate estimation of the subsurface informations can be deduced. This subsurface information includes velocity, depth, thickness and many others.

There are many things which can be listed as the advantages of digital seismic data. There are also so many success in hydrocarbon exploration which can be credited to digital processing technology. However, whatever good is the result of digital processing of the seismic data, its vertical resolution will not be as high as the analog recording of seismic data. Today the common sampling rate used in hydrocarbon exploration at sea is 2 milliseconds. This means, that the maximum frequency which can be accomodated by this type of digital data is 250 Hz. An analog seismic recording given in the examples can accomodate as much as 800 Hz. This proves the resolving power which is more than three times stronger.

IV. EXAMPLE

The following examples are the seismic sections profiles which were obtained from analog seismic recording but have been reprocessed using simple electronic equipment as shown in Figure 4. The process consists of band pass filtering, readjustment of amplitude, intensity, horizontal scale and vertical scale. The raw single channel analog seismic data were recorded to the southern part of Nusa Tenggara during the Snellius II expedition Leg G-6 in 1985 (see Figure 5). The deep of the sea bottom ranging from 2000 to 6000 meters.

Figure 6 is an example of analog profiles crossing a quite complicated structure around accretionery wedge (see van Weering et al, 1989). Observe the different in seismic characters which are deposited in the slope basin.

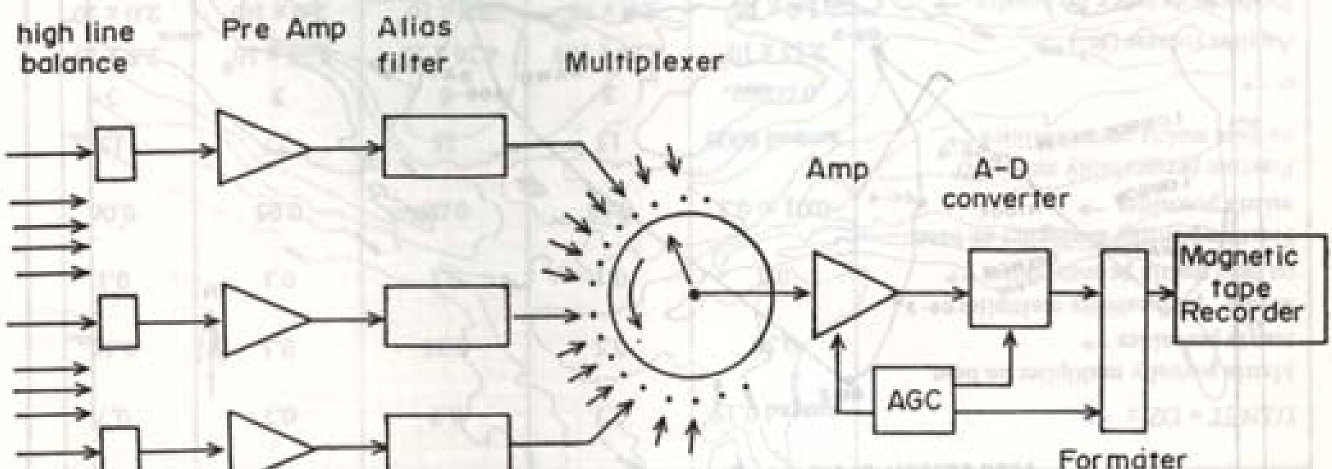

Figure 3. Digital seismic recorder (Anstey, 1979)

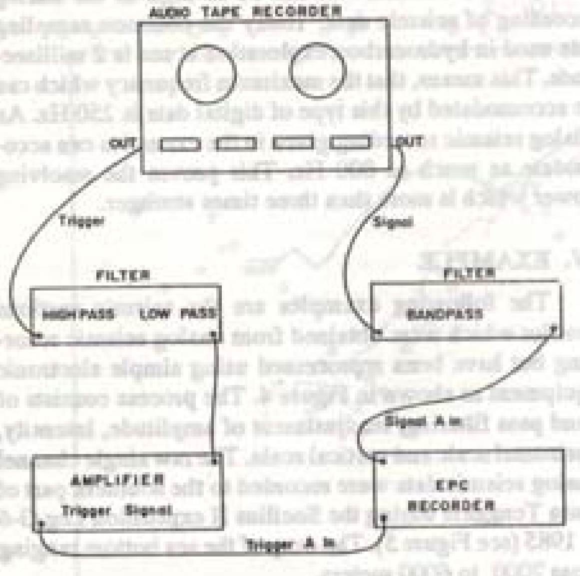

Figure 4. A circuit of electonic equipments used to reprocess the single channel analog seismic data

Also observe that sea bottom multiples appear around 4 seconds which do not interfere the horizon of interest.

Figure 7 is another example of a high resolution single channel analog seismic profiling. It demonstrates how this resolution is capable of distinguishing clearly the different between the basement and sediments. Within the basin we can see two different seismic characters in the sediment. One with parallel layers signifies normal sediment, and another one with white characters signifies slump sediment. Another interesting feature is that with this display the faults can also be seen in the sediment as well as in the basement which facilitates finding the trapping areas.

Figure 8 is another interesting example of high resolution single channel analog seismic profiling. We can see clearly several depositional sequences deposited in the basin. Observe the downlapping pattern on the older "slump" sediment. The different in seismic character between the sediment and the basement can be seen clearly. On the left side, we can see the oceanic crust subducts the continental crust. This profile was taken across the Java Trench from south to the north.

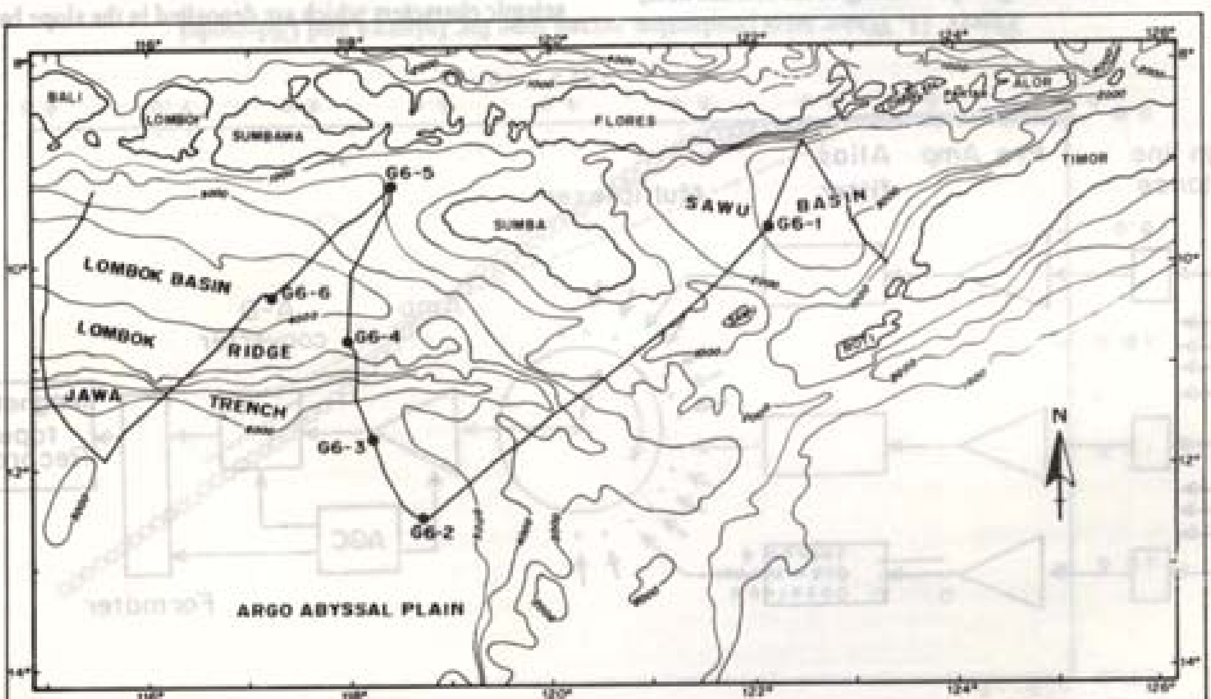

Figure 5. Single channel analog seismic profiling to the south of Nusa Tenggara of Snellius II expedition leg G-6

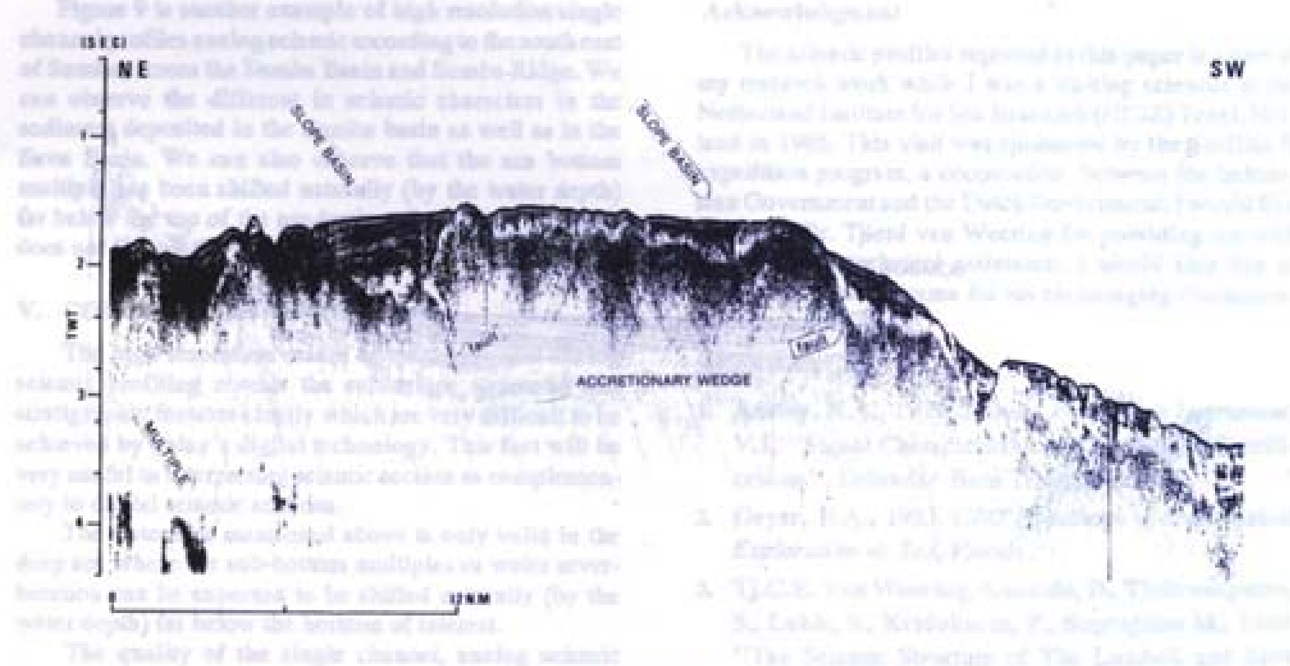

Figure 6. The result of single channel analog seismic profiling crossing quite complicated structure around the accretionery wedge (see also van Weering et al, 1989)

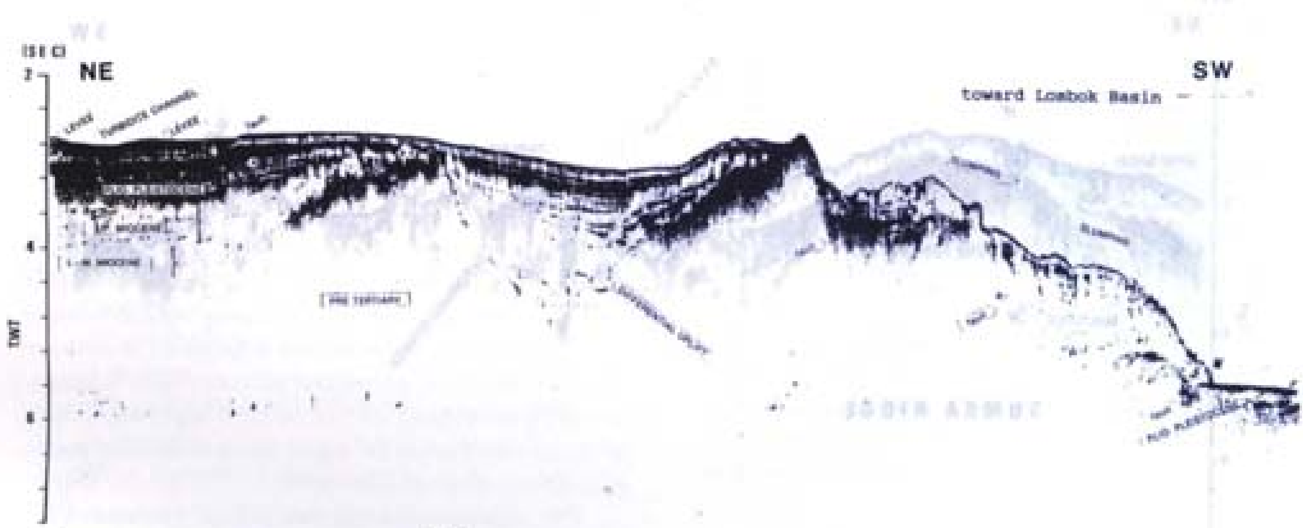

Figure 7.The result of single channel analog seismic profiling demonstrating its capability to distinguish the different in seismic character between the basement and the sediment (see also van Weering et al, 1989)

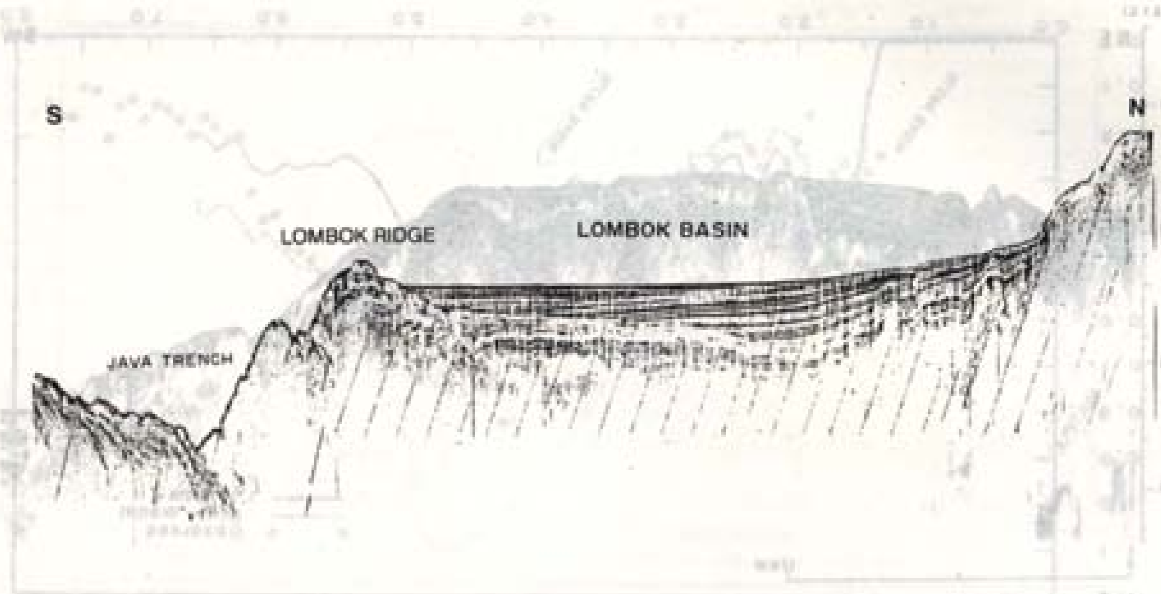

Figure 8. The result of single channel analog seismic profiling demonstrating its capability to reveal several depositional sequences deposited in the basin

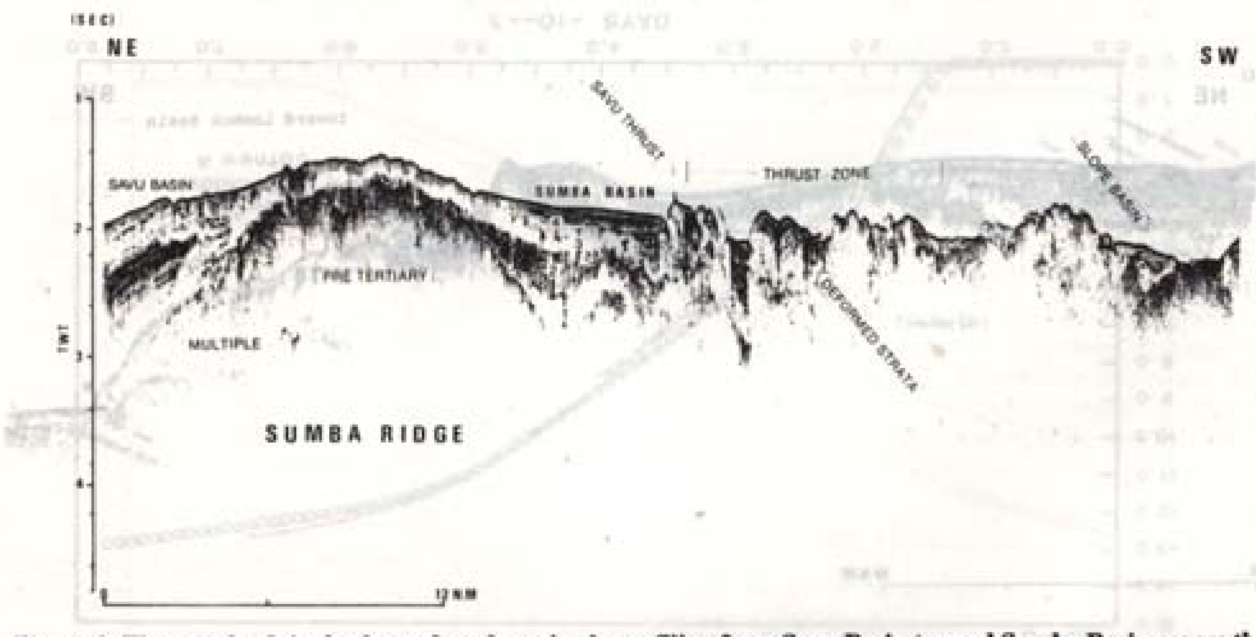

Figure 9. The result of single channel analog seismic profiling from Savu Basin toward Sumba Basin across the Sumba Ridge Observe the different in seismic characters between the sedimentary layers and the pre tertiary basement (see also van Weering et al, 1989)

Figure 9 is another example of high resolution single channel profiles analog seismic recording to the south east of Sumba, across the Sumba Basin and Sumba Ridge. We can observe the different in seismic characters in the sediment deposited in the Sumba basin as well as in the Savu Basin. We can also observe that the sea bottom multiple has been shifted naturally (by the water depth) far below the top of the pre-tertiary 'basement' so that it does not disturb the horizon of interest.

V. CONCLUSION

The high resolution nature of single channel analog seismic profiling reveals the subsurface structural and stratigraphic features clearly which are very difficult to be achieved by today's digital technology. This fact will be very useful in interpreting seismic section as complementary to digital seismic sections.

The statement mentioned above is only valid in the deep sea where the sub-bottom multiples or water reverberation can be expected to be shifted naturally (by the water depth) far below the horizon of interest.

The quality of the single channel, analog seismic profiles can be improved to some extent by a simple electronics equipment.

Acknowledgment

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