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VII.7 US ice-drift station FRAM IV: Preliminary analysis of multichannel seismic refraction data

The US ice-drift station FRAM IV was deployed in the Arctic Ocean on 15 March 1982 about 200 n.m. north of Svalbard and operated for 57 days during which the station drifted about 165 n.m. southwestwards from the Eurasian Basin onto the northern flank of the Yermak Plateau (Fig. VII.7.1). This was a multidisciplinary geophysical-geological expedition involving scientists from the US and Norway. A review of seismic operations in the Arctic has been given by Baggeroer and Duckworth (1983). Details of the Norwegian part of the field program per se and preliminary results from the rather extensive reflection surveys have been reported respectively by Kristoffersen (1982) and Kristoffersen and Husebye (1984).

A main component of the joint MIT/WHOI and Norwegian Polar Research Institute/ NORSAR program was acquisition of seven 20-30 km long lines of seismic 20 channel refraction data by dropping charges in open or newly refrozen leads less than 0.5 m thick, and detonated by depth sensitive primers set at 256 m depth. 55 lbs cans of TNT were used out to 40 km range and 110 lbs farther out. These shots were recorded on a linear array about 1.3 km long. This contribution outlines the initial phase of the refraction data analysis.

The DFS-V was started recording at the second minute mark after the reported charge drop time (average sinking time 2 mins 40 sec) and run for 100 seconds. A drum recorder was used as single channel monitor. The relatively long recording window proved necessary for safe recording of all shots due to deviations in estimated arrival time incurred for various reasons. However, the long records which require near 3 Megabyte of memory for the demultiplexing operation necessitated very special software action and full dedicated capabilities of the currently configured IBM 4331.

Further outstanding problems exist; upon inspection of the playouts, different shot parameters to those of MIT-logged parameters are obtained. In addition, the hydrophone response function is markedly different for many sensors in the array. Considerable editing of data was required. The latter problem may be circumvented by bench-testing of the sensors before deployment.

A record section showing the filtered output of one hydrophone for Line 4 is given in Fig. VII.7.2. The most obvious arrivals are those of the water-wave and its multiple seabed-surface ice bounces. The amplitudes are considerably larger than the subsurface refracted arrivals in the trace-normalized section. Indeed, some of these arrivals have very low S/R. In order that some information be gleaned on the small amplitude arrivals, some form of array processing must be used.

Classical methods of array analysis such as beamforming and multichannel Wiener filtering are of little benefit due to the poor spatial-frequency response of linear arrays and the non-space stationarity of the hydrophone response functions. However, semblance (Taner and Koehler, 1969) is a fairly robust form of velocity spectra computation in these circumstances, and is the ratio of stacked trace energy to input energy

$$S_T = \frac{\sum_t s_T^2}{M \sum_t \sum_{i=1}^{M} f_{it(i)}^2}$$

where the i-th output of M channels at time t is f(i,t(i)), and the velocity stack over M sensors in which t(i) corresponds to a trajectory with a particular velocity is given by

$$s_T = \sum_{i=1}^{M} f_{i,t(i)}$$

Semblance may be described as a multichannel filter which measures the common signal power over the channels according to a specified lag pattern.

It has a possible range of 0 to 1 and is a measure of coherency which is independent of the joint power level of the traces.

By way of example, this analysis is applied to a narrow time window for shot 1 in Line 4 (Fig. VII.7.3). The data are dominated by the large amplitude water-wave, with indications of a faster arrival. Fig. VII.7.4 shows the contoured velocity spectra using the semblance measure for the data displaying power as a function of slowness and travel-time. The energy corresponding to the water-wave is obvious with a velocity of 1.45 km/s. Additional peaks in the spectra with velocities of 4.17 and 1.85 km/s indicate the success with which this measure is able to stack and display low-amplitude coherent energy. This analysis is continuing prior to τ-p inversion for the seven lines.

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Taner, M.T. and F. Koehler (1969): Velocity spectra-digital computer derivation and application of velocity function. Geophysics, 34, 859-881.

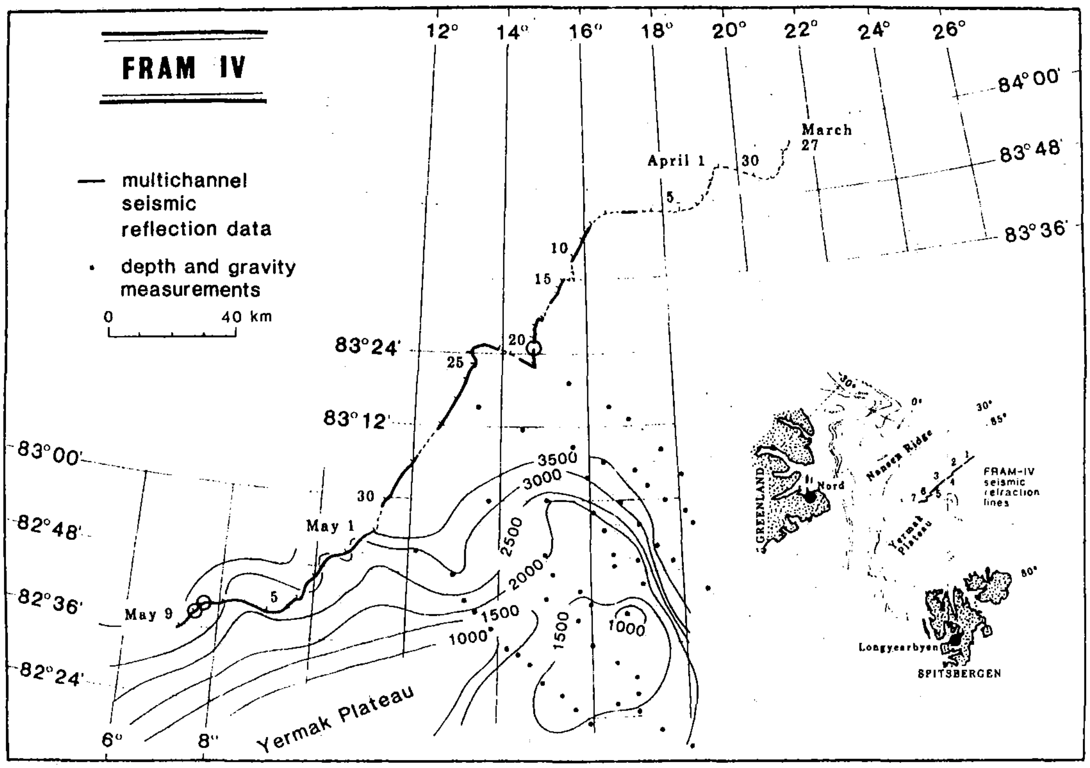

Fig. VII.7.1 Drift track of US ice drift station FRAM IV, March-May 1982, and location of refraction lines. Depth in meters.

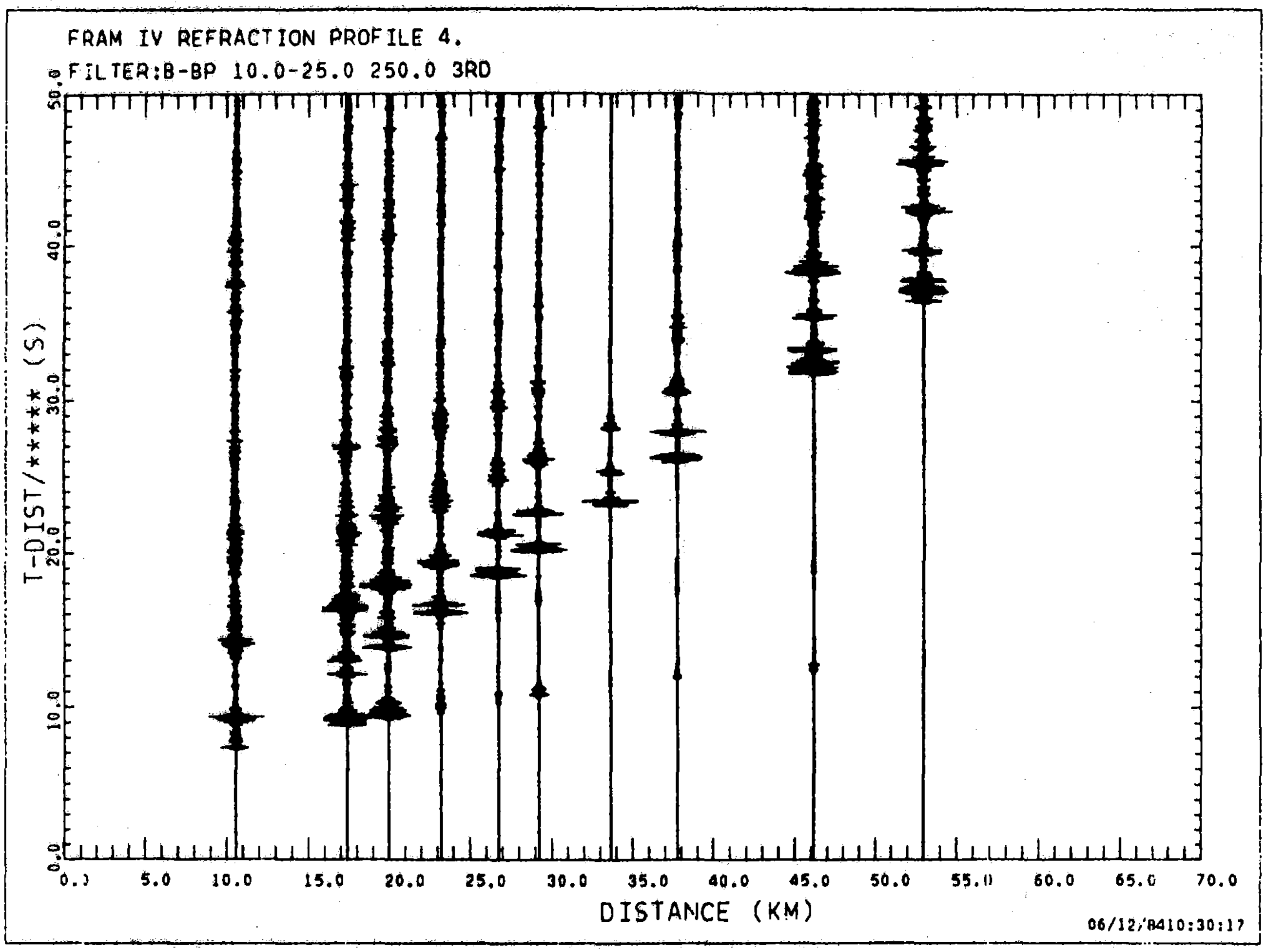

Fig. VII.7.2 Record section of filtered hydrophone playout for Line 4. Ten shots were recorded on 19th and 20th April 1982. Sampling rate in 4 ms. The dominant arrivals are the water-wave and multiple reflections.

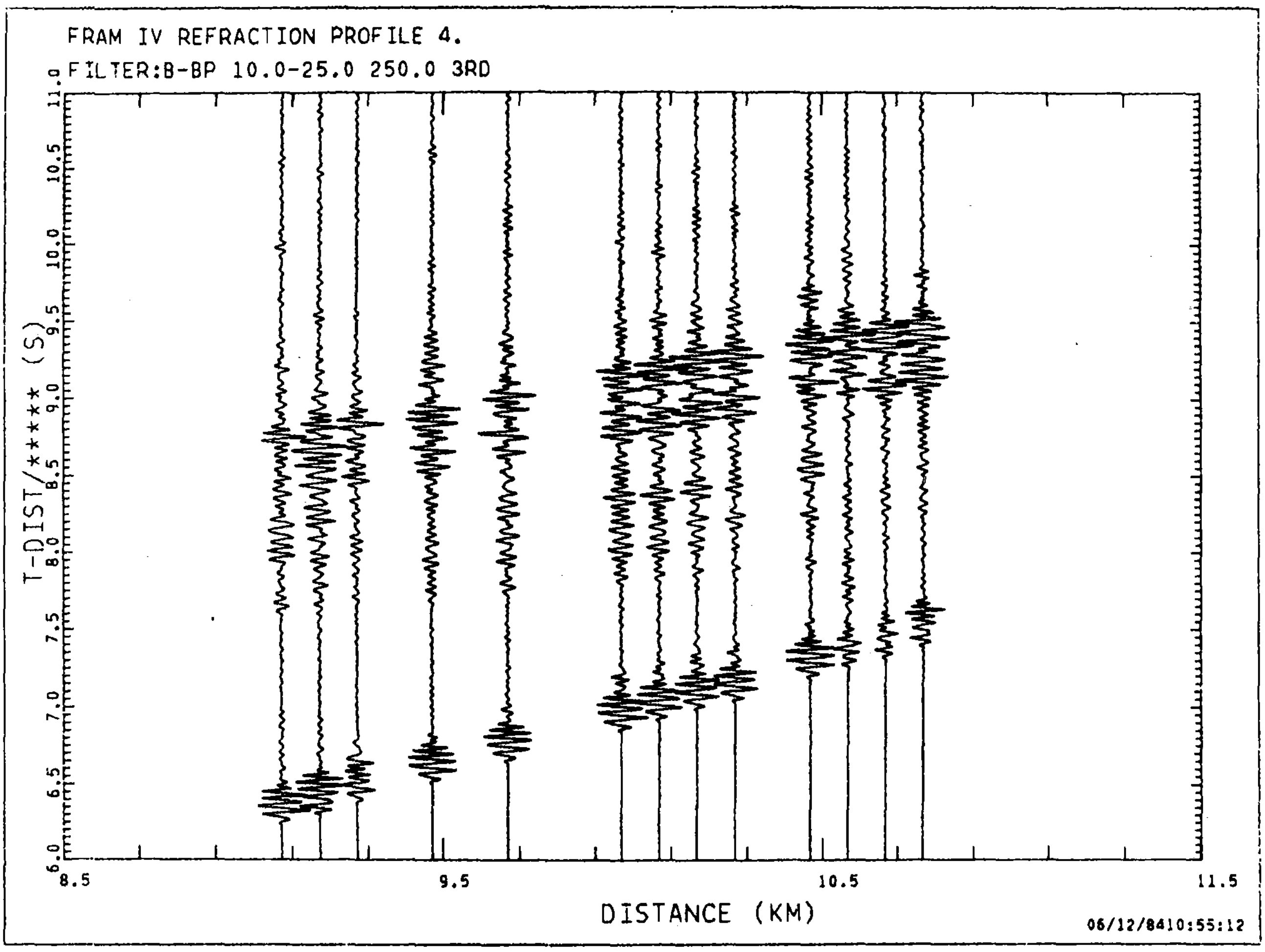

Fig. VII.7.3 Record section of filtered hydrophone playouts for a short time window, shot 1, line 4. Data have been edited for dead channels and polarity reversals of some channels. Note the large amplitudes of the direct water wave and its first multiple reflection, and the fast, low amplitude refracted arrival.

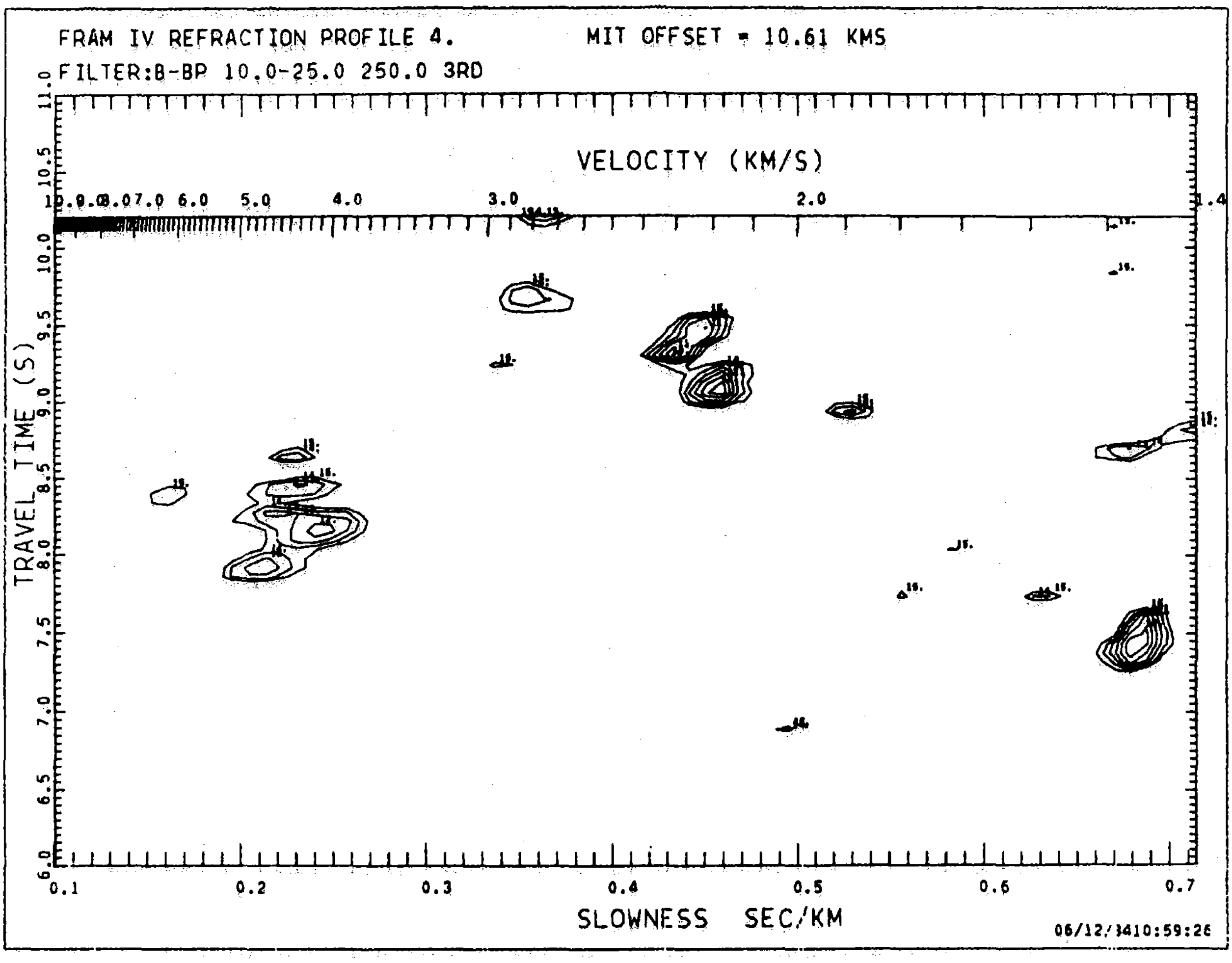

Fig. VII.7.4 Velocity spectra of the data in Fig. VII.7.3 using the semblance estimator. The direct water wave has a slowness of 0.69 s/km (vel. = 1.45 km/s), the first multiple of 0.47 s/km (2.12 km/s) and the refracted arrival of 0.26 s/km (3.85 km/s).

VII.8 The New Regional Array: 1983 Vertical and Three-Component Instrument Field Experiments

Introduction

During the period June 10 - July 5, 1983, data were recorded of a 5-element array of three-component instruments. The geometry of that array is shown in Fig. VII.8.1. During this period a number of local events were recorded.

The new array to be installed in 1984 will initially comprise 4 three-component instruments, whereof one will be located in a borehole at the center of the array. A proposal for location of the remaining 3 sets of three-component instruments is the purpose of the document.

Preliminary work

Before an analysis of the recorded three-component data can be conducted, it is important to reconsider the design of the 21-element vertical instrument regional array installed during the summer of 1983. The array configuration (Fig. VII.8.2) was based on an idealized analysis of the presumed noise field structure conducted by Mykkeltveit et al (1983) thereby enabling more than $\sqrt{N}$ (N = number of sensors) reduction in noise by simple beamforming. However, Husebye et al (1984) reported that there may be a coherent component in the noise field, thereby reducing the effective gain attainable by simple beamforming to be considerably less than $\sqrt{N}$. This has prompted reanalysis of the vertical component array data.

To examine the tenet proposed by Husebye et al, the experiment performed by Mykkeltveit et al is repeated here, i.e., computing correlation curves as a function of inter-sensor spacing and frequency, but with two innovations:

- During the period February - March 1984, the gain of each array element was raised by 12 dB. Effectively, this implies that the noise analysis can be conducted to a maximum frequency of 7 Hz before discretization levels are reached. This is in contrast to the upper limit in frequency of 4 Hz imposed on the Mykkeltveit et al experiment.
- A search for the coherent and/or propagating component in the noise field is possible by beaming the array to orthogonal directions (e.g., 0°