# Interval Velocity Analysis after Wave-Equation Datuming

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## Summary

Vast reserves of gas hydrate occur in deep oceanic environment, where the thick water column exert enough pressure to stabilize the gas hydrate. The gas hydrate is usually identi.ed on the seismic data using the bottom simulating re.ector (BSR), which mark the bottom of the hydrate stability zone. The excess gas that was captured at and beneath the base of gas hydrate stability manifest itself as free gas that is usually associated with the BSR. The presence of free gas decreases the seismic velocity and can be identi.ed in the interval velocity model. Building an accurate interval velocity models is also important for estimating the hydrate and gas saturation. The velocity can also be used for accurate seismic imaging and AVO (amplitude variation with o.set) analysis. Since the resolution of interval velocity is decreased by the presence of thick water column, I used the wave-equating datuming to remove the traveltime of the overburden so that the interval parameters can be estimated with reasonable accuracy. The algorithm makes use of the fact that the velocity of P-wave in water is known ($\approx$ 1500 *m/s*).

The proposed layer-stripping technique uses waveequation datuming to downward continue the prestack seismic data and then estimate the stacking velocities from conventional semblance analysis. The interval velocities are obtained from the stacking velocities using the Dix's equation. By incoorporating the *apriori* information of the water layer velocity in the Dix's equations, the accuracy of the estimated interval parameters is increased. Here, I develop the neccessary theoritical framework to support the above argument.

## Introduction

Velocity analysis based on re.ection moveout is an important tool for estimating subsurface velocity .elds. Since the re.ection traveltime and normal-moveout (NMO) velocity are in.uenced by the medium properties along the entire raypath of the re.ected wave, it becomes essential to estimate the interval parameters to study the properties of individual re.ectors. The interval parameters such as the interval velocity and layer thickness are also required for purposes of prestack and poststack migration. The interval velocity can be obtained either by layer stripping (Dix, 1955) or tomographic (Stork, 1991) methods. In the context of gas hydrate study, the interval velocity can help to estimate the hydrate concentration and gas saturation. The decrease in interval velocity immediately beneath the BSR helps in locating the free gas associated with the BSR (Bangs et al., 1993), thereby increasing the con.dence in ideni.ng the BSR.

In horizontally layered, isotropic media, the NMO velocity of reflected waves is equal to the root-mean-square (rms) of the interval velocities (Dix, 1955). This simple relationship makes it possible to obtain the interval velocity using only the NMO velocities for the re.ections from the top and bottom of the layer. The accuracy of the estimated interval velocity can be increased by incoorporating the *apriori* information such as the velocity of the overburden water layer.

The gas hydrates are widely present in permafrost and deep oceanic environment (Kvenvolden, 1988). The thick water column is homogeneous, isotropic medium with a velocity of $\approx$ 1500 *m/s*. Here, I consider a scenario of estimating interval velocity of the target layer by stripping the contribution of the thick water column (Figure 1). For a known velocity model, the overburden effect can be removed using wave-equation datuming as discussed by Berryhill (1979,1984). While computing the interval velocities by downward continuing the datum, two issues need to be addressed. The propagation of error from the rms velocities to the interval velocity in the Dix's equation and the velocity resolution of the target layer. Here, I develop the necessary theoritical foundation for the proposed algorithm.

## Theory

To understand the error propagation in the Dix's equation and the interval velocity resolution of the target later, let's consider a thin target layer beneath a thick water column (Figure 1). The goal is to obtain the standard deviation of the interval velocity as a function of the thickness of the overburden ($z$).

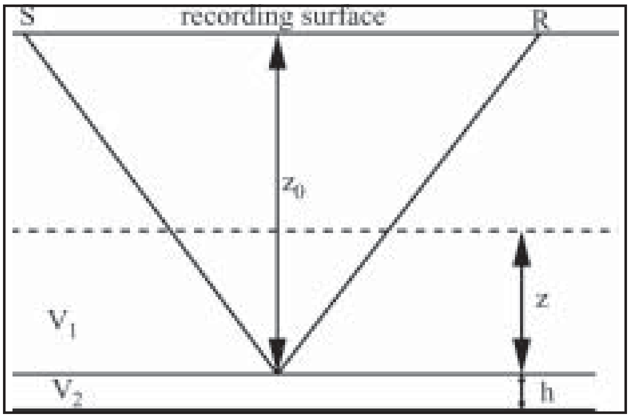


**Fig. 1:** Illustration of interval velocity analysis after waveequation datuming. The overburden and the target layers are laterally homogeneous medium. The thickness of the overburden and the target layer are represented by *z* and *h* respectively.

## Error propagation in the Dix's equation

The rms velocities obtained from conventional semblance analysis of noisy seismic data are erroneous. As a result, the interval velocities derived from these rms velocities will also be erroneous. A elaborate discussion of the uncertainities in the estimated interval velocity is discussed in Hajnal & Sereda (1981).

## Velocity resolution of the target layer

Let's also consider the velocity resolution of the seismic data i.e., the accuracy with which the velocity can be estimated from the conventional semblance analysis. Rms velocity picking errors mainly depend on the width of the maximum semblance at a re.ector. The semblance can be calculated in terms of the sum-of-crosscorrelations approach of Neidell and Taner (1971). The unnormalized crosscorrelation measure (UC) for a .xed o.set-to-depth ratio can be represented in terms of the trial velocity (*vtrail*) and two-way zero-o.set traveltime *t*0,

$$UC(vtrial, t0) = \sum_{k=1}^{M-1} fk, t(k) \sum_{j=k+1}^{M} fj, t(j), \qquad (1)$$

where *M* is the number of traces in the common-mid point (CMP) gather, and *fj*,*t*(*j*) is the amplitude of the *jth* trace along the re.ection-time trajectory *t*(*j*) on a hyperbolic moveout curve governed by the trial velocity *vtrial* and zero-o.set time *t*0.

Using the approximate semblance function, I derived the error in the target layer interval velocity ($\sigma V_{int}$) for a small velocity contrast (*dv*),

$$\sigma V_{int}(z) \approx k' \frac{dv\,(\sqrt{2}\,z + h)}{(z + h)} \qquad (2)$$

where $k'$ is a function of rms velocities, thickness of the target layer and seismic wavelet. The thickness of the overburden and the target layer are represented by *z* and *h* respectively. The above equation assumes that the standard deviations of the rms velocity of the overburden and the target layer are equal. Equation (2) shows that if the e.ect of overburden is removed, the estimate of interval velocity will *improve* by a factor of $\sqrt{2}$ i.e., $\sigma V_2(0) = \sigma V2\,(z \rightarrow \infty)/\sqrt{2}$.

## Methodology

As discussed in the previous section, the accuracy of the estimated interval velocity increases as the datum is moved deeper into the subsurface. The wavefield is downward continued using Wave-equation datuming as discussed by Berryhill (1979,1984).

In order to move both receivers and sources from one datum to another, the following steps are prescribed by Berryhill (1984). First, operate on the common-source order and downward continue the receivers. Sort the resulting data into common-receiver groups and downward continue the shots. The .rst pass moves the geophones, and the second moves the shots. Substantial computation is required to execute this scheme, as a high-quality marine seismic line may consist of over 100,000 traces. Since the goal is to obtain interval velocity using the conventional Dix's equation, which assumes the medium to be laterally homogeneous, the process can be simplified as follows,

- Extract the CMP gather at the location of interest.
- Assuming 1D medium, CMP gather can be consider as a common-shot gather while the receivers can be continued downward.
- The downward continued receivers can be considered as common-receiver gathers while the shots can be continued downward.
- The downward continued shots and receivers can now be considered as a CMP gather for velocity analysis.

## Conclusions

By downward continuing the datum to di.erent depths below the sea level, the interval velocity can be computed in a stable fashion. The accuracy for the interval velocity increases as the datum is continued downward.

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