34. TECHNICAL NOTES AND ADDITIONS TO: ORIGIN OF BOTTOM-SIMULATING REFLECTORS: GEOPHYSICAL EVIDENCE FROM THE CASCADIA ACCRETIONARY PRISM[1,2]

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EXPLANATION

These notes provide supplemental figures and technical information that could not be included in the original publication due to restrictions on length.

VSP INTERNAL VELOCITIES

Table 1 shows the VSP (vertical seismic profile) velocity–depth values used in figure 2 of MacKay et al. (1994). The velocity shown for the uppermost interval (for Site 892, 34.3–56.5 mbsf, and Site 889, 61.7–130.5 mbsf) is an average velocity obtained from the difference in arrival time of the shallowest sonic log position (after correction of the sonic log to the VSP) and the direct arrival time at the uppermost VSP station.

Table 1. VSP interval velocities.

	Depth (mbsf)		Velocity
	Top	Bottom	(km/s)
Site 892			
	34.3	56.5	1.685
	56.5	61.5	1.737
	61.5	66.5	1.757
	66.5	71.5	1.753
BSR			
Low-velocity free gas zone	71.5	76.5	1.252
	76.5	81.5	1.253
	81.5	87.5	1.288
	87.5	91.5	1.322
Site 889			
	61.7	130.5	1.570
	130.5	135.5	1.756
	135.5	142.5	1.766
	142.5	150.5	1.750
	150.5	155.5	1.693
	155.5	160.5	1.706
	160.5	165.5	1.737
	165.5	170.5	1.766
	170.5	175.5	1.815
	175.5	180.5	1.831
	180.5	185.5	1.852
	185.5	190.5	1.810
	190.5	193.5	1.798
	193.5	195.5	1.792
	195.5	200.5	1.791
	200.5	203.0	1.842
	203.0	205.5	1.864
	205.5	208.0	1.906
	208.0	213.0	1.917
	213.0	218.0	1.855
	218.0	223.0	1.787
	223.0	228.0	1.767
BSR			
Low-velocity free gas zone	228.0	233.0	1.507
	233.0	238.0	1.517
	238.0	243.0	1.532

COMPARISON OF VELOCITY MEASUREMENTS AND ESTIMATES FOR SITE 889

Figure 1 shows the sonic log and VSP velocities for Site 889 along with velocity–depth estimates from a number of different sources. The purpose of this figure is twofold: (1) to compare sonic log and VSP velocities with those obtained from MCS (multichannel seismic) data by detailed semblance analyses (Yuan et al., 1994) and by waveform inversion (Singh et al., 1993); and (2) to compare sonic log and VSP velocities with general velocity–depth functions from Cascadia Site 888, Nankai (Hyndman et al., 1993), and Hamilton (1979). Comparison of measured values with general velocity–depth functions is one means of identifying areas of "anomalous" velocity (similar to the comparison of $V_{obs} - V_{calc}$ in MacKay et al. [1994]).

Velocities obtained from semblance analyses of the MCS data (Yuan et al., 1994) agree extremely well with the sonic log and VSP velocities above the bottom-simulating reflector (BSR). MCS semblance velocities beneath the BSR lie deeper than the sonic log and VSP data so velocities cannot be directly compared; however, MCS velocity values are much lower than other estimates (Fig. 1). Waveform inversion gives anomalously high values, however, in the low-velocity region above 130 mbsf where underconsolidated slope basin sediments overlie the accretionary prism.

If substantial hydrate were present in the interval from 130–228 mbsf, we would expect the velocity of these sediments to be higher than that of "normal" (i.e., non-hydrate bearing) sediments of similar porosity and composition. MacKay et al. (1994) calculated "normal" velocity (V_{calc}) from the neutron porosity log, using the velocity–porosity relationship of Hyndman et al. (1993). The velocity–depth functions shown in Figure 1 provide a different means of assessing anomalous velocity. Sediments at Site 888 were much sandier than at Site 889 and would be expected to have a higher velocity than Site 889; the general agreement of the two suggests that velocities in the

[1]Carson, B., Westbrook, G.K., Musgrave, R.J., and Suess, E. (Eds.), 1995. *Proc. ODP, Sci. Results,* 146 (Pt. 1): College Station, TX (Ocean Drilling Program).

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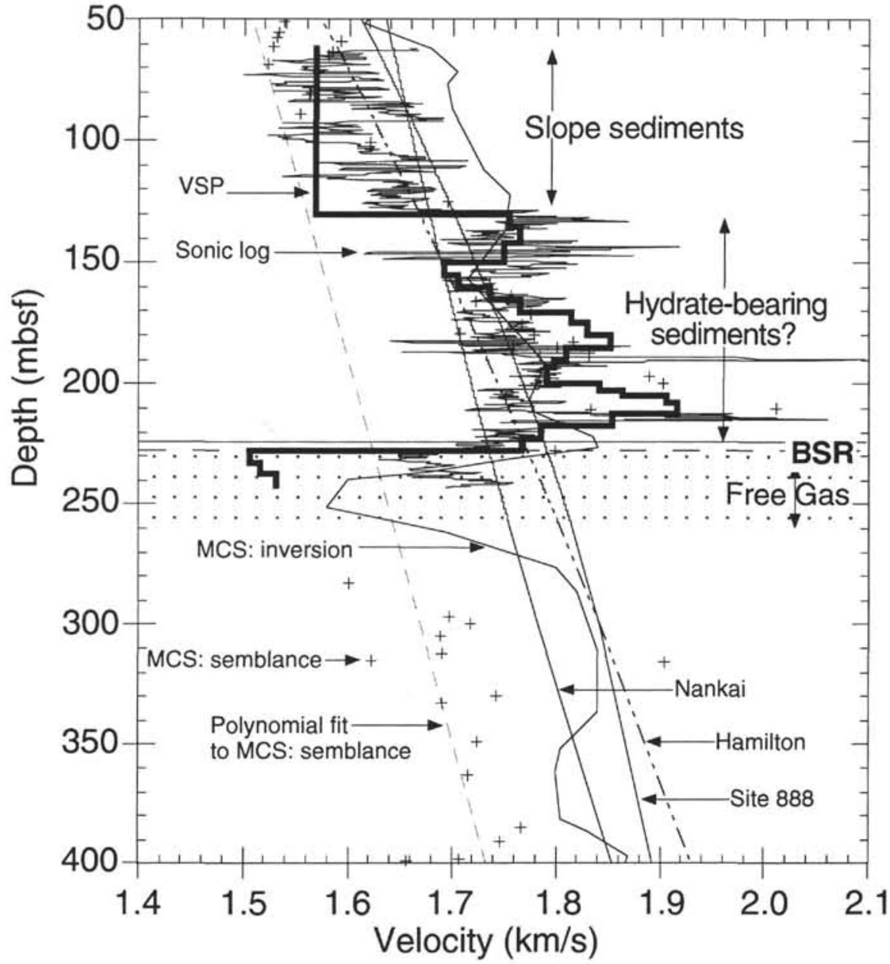

Figure 1. Comparison of sonic log and VSP velocities for Site 889 with those obtained from MCS semblance analyses (Yuan et al., 1994), MCS waveform inversion (Singh et al., 1993) and general velocity–depth functions. The curve labeled "Site 888" is a second-order polynomial fit to sonic log velocities from 130–500 mbsf at Cascadia Site 888. The curve labeled "Nankai" is a combination of the velocity–porosity and porosity–depth functions derived by Hyndman et al. (1993). The curve labeled "Hamilton" is from Hamilton (1979) for terrigenous sediments. The curve labeled "Polynomial fit to MCS: semblance" is a second-order polynomial fit to the MCS semblance velocities from 0–1200 mbsf. The solid horizontal line marks position of BSR observed in MCS data; the dashed horizontal line marks velocity drop in VSP data. Stippling indicates low-velocity free gas region below the hydrate stability field.

interval from 130–228 mbsf are somewhat higher than "normal," perhaps indicating the presence of gas hydrate. The velocity–depth functions shown for Nankai (Hyndman et al., 1993) and the empirical relationship of Hamilton (1979) fall in the same general region as the Site 888 curve and the sonic log values for Site 889, supporting the interpretation of slightly elevated velocity above the BSR. In contrast, the regional curve obtained from the MCS-semblance data is much lower velocity than the other estimates. If correct, the regional MCS curve would suggest that velocities in the interval from 130–228 mbsf are much higher than "normal," because of substantial quantities of gas hydrates. Unfortunately, we do not know either the "normal" velocity for these sediments or the relationship between quantity of hydrate and its effect on velocity.

ESTIMATED HYDRATE ($P_{obs} - P_{calc}$)

To estimate the amount of hydrate present in the pore space, we calculated the expected porosity (P_{calc}) from the sonic log using the empirical relationship of Hyndman et al. (1993): $P = -1.180 + [8.607 \times (1/V)] - [17.89 \times (1/V^2)] + [13.94 \times (1/V^3)]$. Because hydrate has high velocity and porosity is inversely related to velocity, P_{calc} should be less than P_{obs} where hydrate is present (i.e., $P_{obs} - P_{calc} > 0$). If we assume that replacing pore water with hydrate affects velocity in the same manner as replacing pore water with sediment matrix (Hyndman and Spence, 1992) (i.e., sediments having 50% porosity with 10% of the pore space filled by hydrate are assumed to have the same velocity as water-saturated sediments with 40% porosity), the difference between the neutron porosity (P_{obs}) and P_{calc} provides a semi-quantitative estimate of the amount of pore space filled by hydrate (Fig. 2). There are several sources of uncertainty in this estimate, the greatest being the velocity–porosity transform validity and the unknown effect of small quantities of hydrate on velocity. Nevertheless, at Site 889, $P_{obs} - P_{calc}$ suggests that less than 10% of the pore space above the BSR (130–228 mbsf) is filled with hydrate; this may rise to 10%–20% in the interval immediately above the BSR (215–220 mbsf). Sediments above the BSR at Site 892 appear to have a normal velocity–porosity relationship; there is no indication of anomalously high velocity (relative to porosity), and sediments may contain very little hydrate. The variation of ±10% in $P_{obs} - P_{calc}$ reflects the normal scatter seen in velocity–porosity relations. For Site 892, this 10% scatter about a constant near-zero value results in meaningless negative values for percent hydrate.

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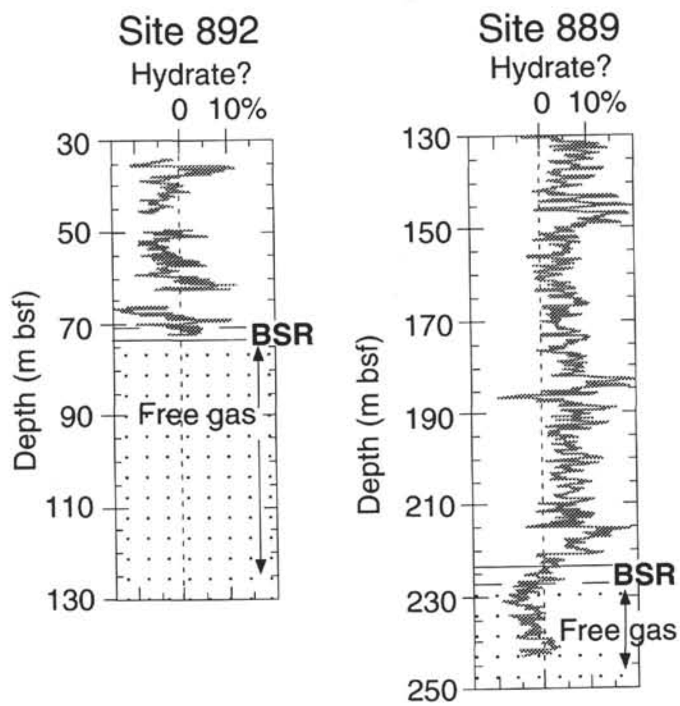

Figure 2. Semiquantitative estimate of percent pore space filled by hydrate (P_{obs} - P_{calc}). The solid horizontal line marks position of BSR observed in MCS data; the dashed horizontal line marks velocity drop in VSP data. Stippling indicates low-velocity free gas region below the hydrate stability field (i.e., no hydrate).