Anisotropic NMO Removal

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Introduction

The normal moveout equation relating traveltime (t) to shot-receiver offset (x) for a single layer, homogeneous, *isotropic* medium of velocity v is:

$$t^2(x) = t^2(0) + \frac{x^2}{v^2}. \tag{1}$$

A slightly modified version of this formula—

$$t^2(x) = t^2(0) + \frac{x^2}{v^2(t(0))} \tag{2}$$

—is used extensively in seismic data processing as a practical, paraxial approximation for more complicated media. The single parameter $v(t(0))$ is usually related to actual earth parameters through the layered-isotropic, Dix Model.

Elsewhere in this volume, Muir presents the elements of a general anisotropic system, where Equation 2 is replaced by a more general, two-parameter, rational form—

$$t^2(x) = \frac{t^4(0) + \frac{(1+q_w(t(0)))t^2(0)x^2}{v^2(t(0))} + \frac{{q_w}^2(t(0))x^4}{v^4(t(0))}}{t^2(0) + \frac{q_w(t(0))x^2}{v^2(t(0))}} \tag{3}$$

—which reduces to Equation 2 when the anelliptic parameter, $q_w(t(0))$, is unity. In this paper we explore the usefulness of Muir's Equation by applying it to a classic Gulf Coast data set.

Anisotropic vs. Isotropic Normal Moveout

Equations 2 and 3 are compared in Figures 1 and 2, with synthetic models of *isotropic* and *anisotropic*, single layer, homogeneous media. Figure 1a shows two superimposed common mid-point gathers, the upper and lower curves corresponding to media described by $\{v = 2000$ m/s, $q_w = .85\}$, and $\{v = 2000$ m/s, $q_w = 1.0\}$, respectively. Figures 1b and 1c show the effect of hyperbolic ($q_w = 1$) moveout correction of the superimposed gathers with $v = 2000$ m/s and 2150 m/s,

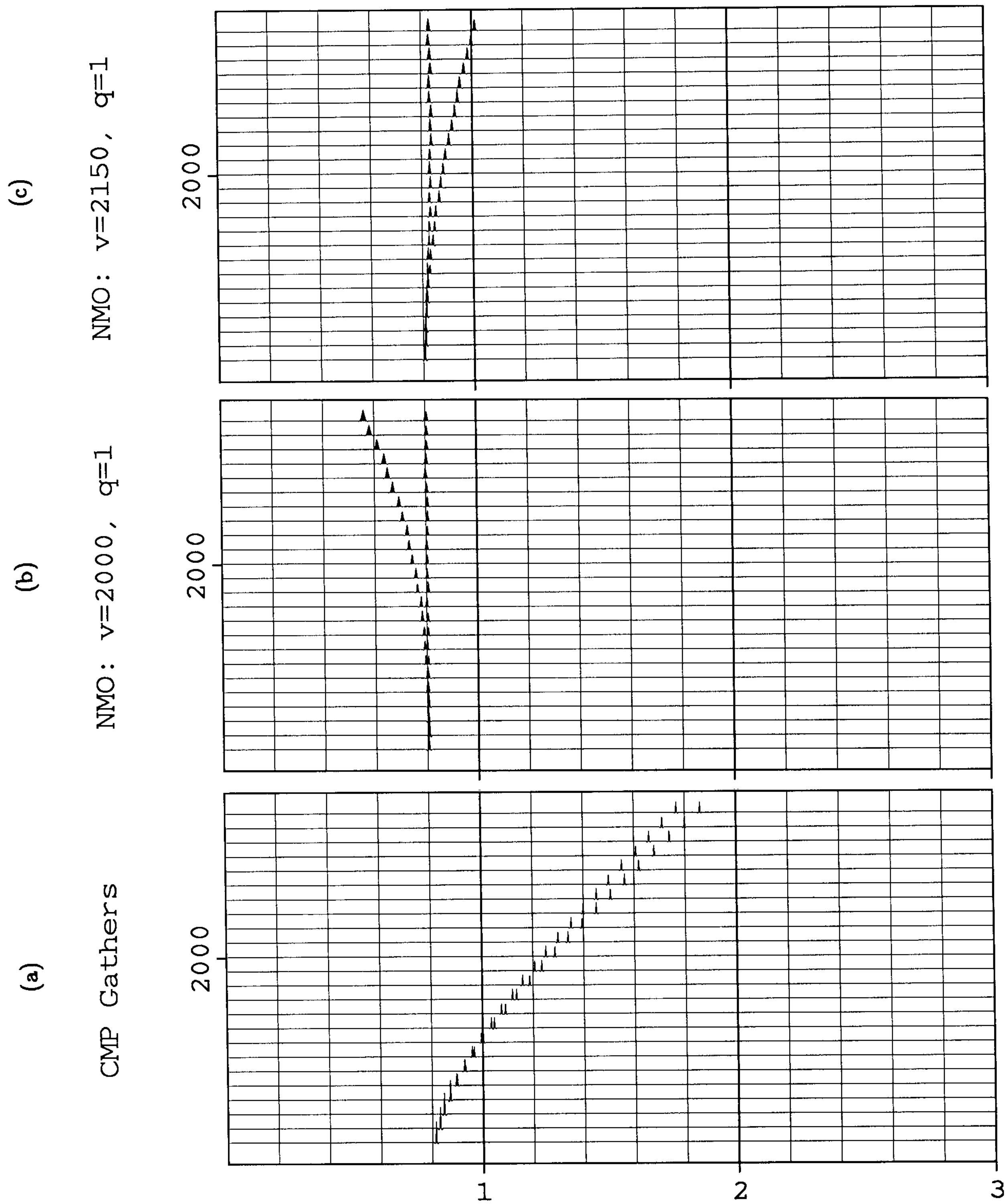

FIG. 1: A comparison of isotropic and anisotropic NMO. Panel (a) shows two superimposed synthetic gathers with events at .8 s and $v = 2000$ m/s; the upper curve corresponds to $q_w = .85$, the lower to $q_w = 1.0$. Panels (b) and (c) show the two gathers corrected hyperbolically with $v = 2000$ m/s and $v = 2150$ m/s, respectively.

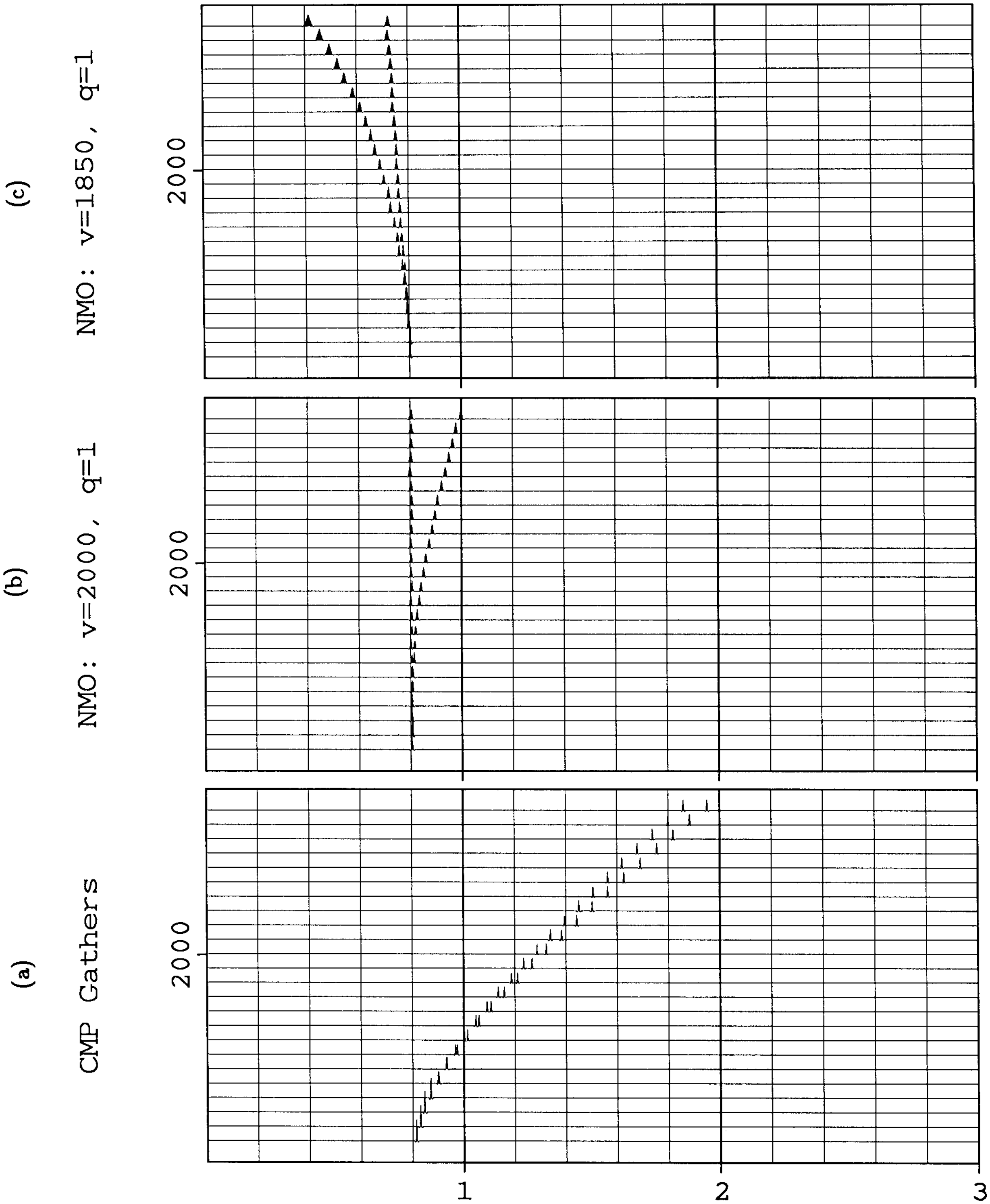

FIG. 2: A comparison of isotropic and anisotropic NMO. Panel (a) shows two superimposed synthetic gathers with events at .8 s and v = 2000 m/s; the lower curve corresponds to $q_w = 1.15$, the upper to $q_w = 1.0$. Panels (b) and (c) show the two gathers corrected hyperbolically with v = 2000 m/s and v = 1850 m/s, respectively.

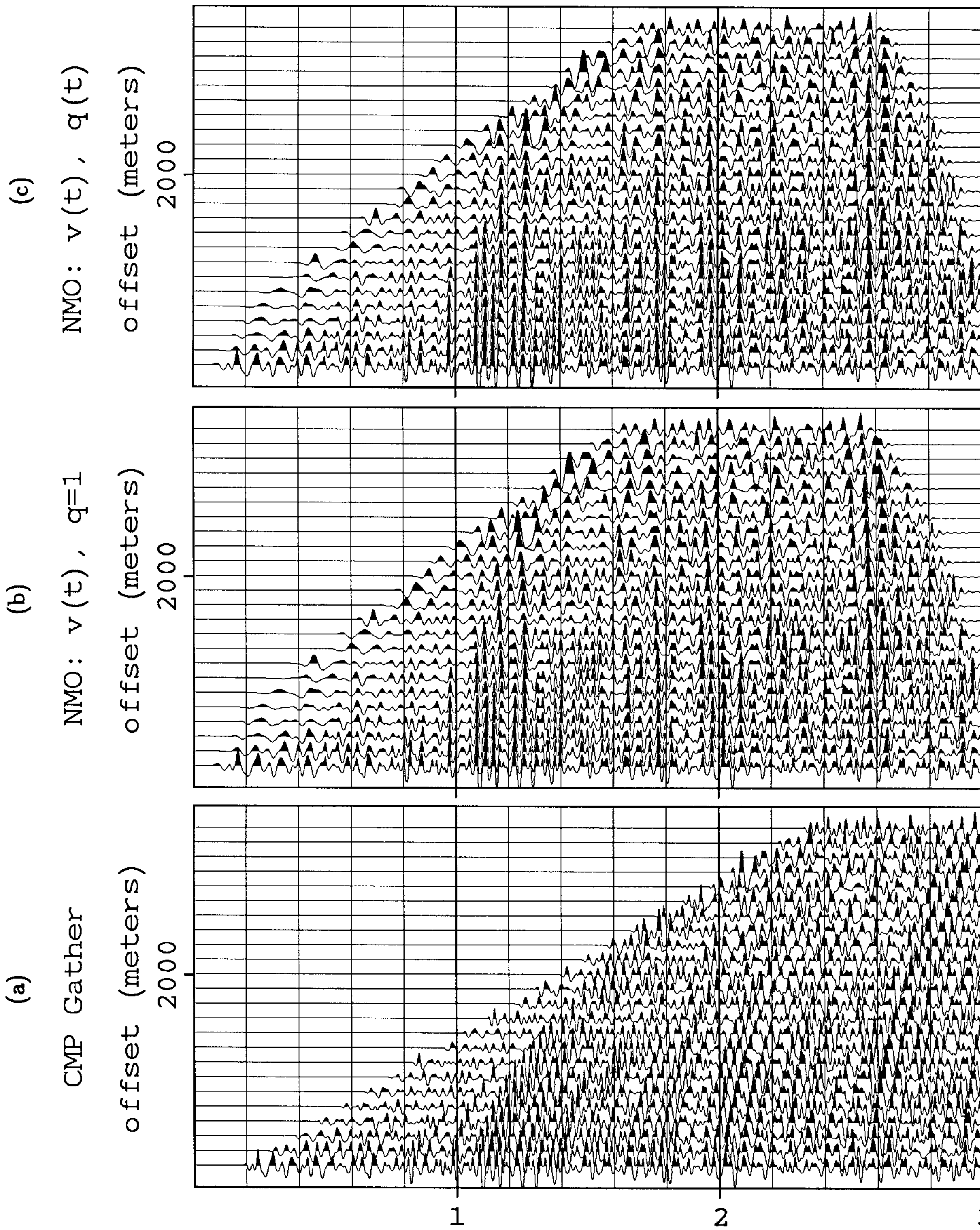

FIG. 3: An application of Muir's Equation for anisotropic NMO. Panel (a) shows the uncorrected CMP gather. Panel (b) shows the gather corrected with $v(t(0))$ picked from semblance contours, and $q_w = 1$. Panel (c) shows the gather corrected with Muir's Equation, with both $v(t(0))$ and $q_w(t(0))$ picked from semblance contours.

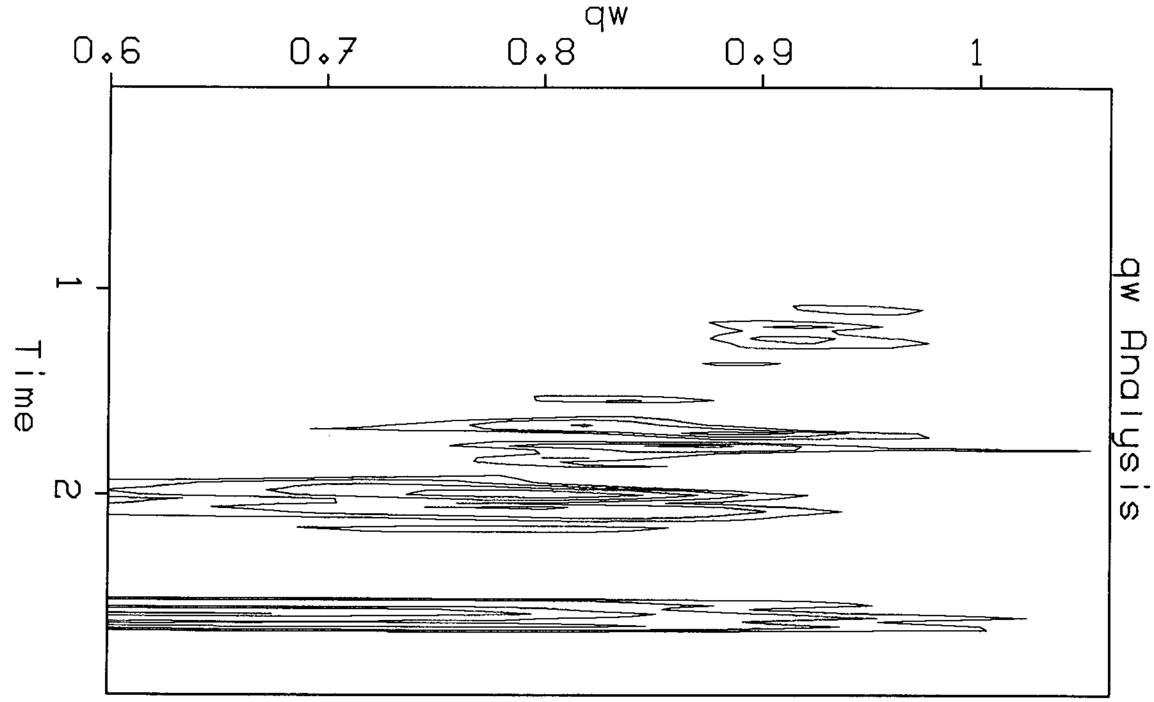

FIG. 4: Contour plot of semblance for q_w versus time.

respectively. Figure 2 is similar to Figure 1, with the anisotropic gather described by $q_w = 1.15$. The hockey-stick-like, bow-like and slanted line shapes appearing in the pictures demonstrate the strength of the fourth and higher order terms in Equation 3. They also suggest that application of semblance methods of hyperbolic velocity analysis to anisotropic data sets will tend to overestimate horizontal velocity when $q_w < 1$ and to underestimate horizontal velocity when $q_w > 1$.

Data Example

Figure 3a shows a common midpoint gather from a marine survey off the Gulf Coast (data courtesy of Western Geophysical). Figure 3b shows the same gather corrected for hyperbolic moveout ($q_w = 1$), with a velocity function chosen by semblance contours. The CDP gather consistently exhibits the hockey-stick-like shapes of nonhyperbolic events corrected hyperbolically. The concavity of the velocity-corrected events indicates that, if the data is to be fitted with the anisotropic model, $q_w(t(0))$ must be less than 1.0.

Fitting the data with the anisotropic model requires estimation of an anelliptic parameter function $q_w(t(0))$. For this preliminary experiment, $v(t(0))$ and $q_w(t(0))$ were estimated sequentially. The gather was repeatedly NMO-corrected with Equation 3—using the velocity function corresponding to Figure 3b in combination with constant q_w for a wide range of q_w. The resulting contour plot of semblance for q_w versus time is shown in Figure 4. Note the relatively smooth

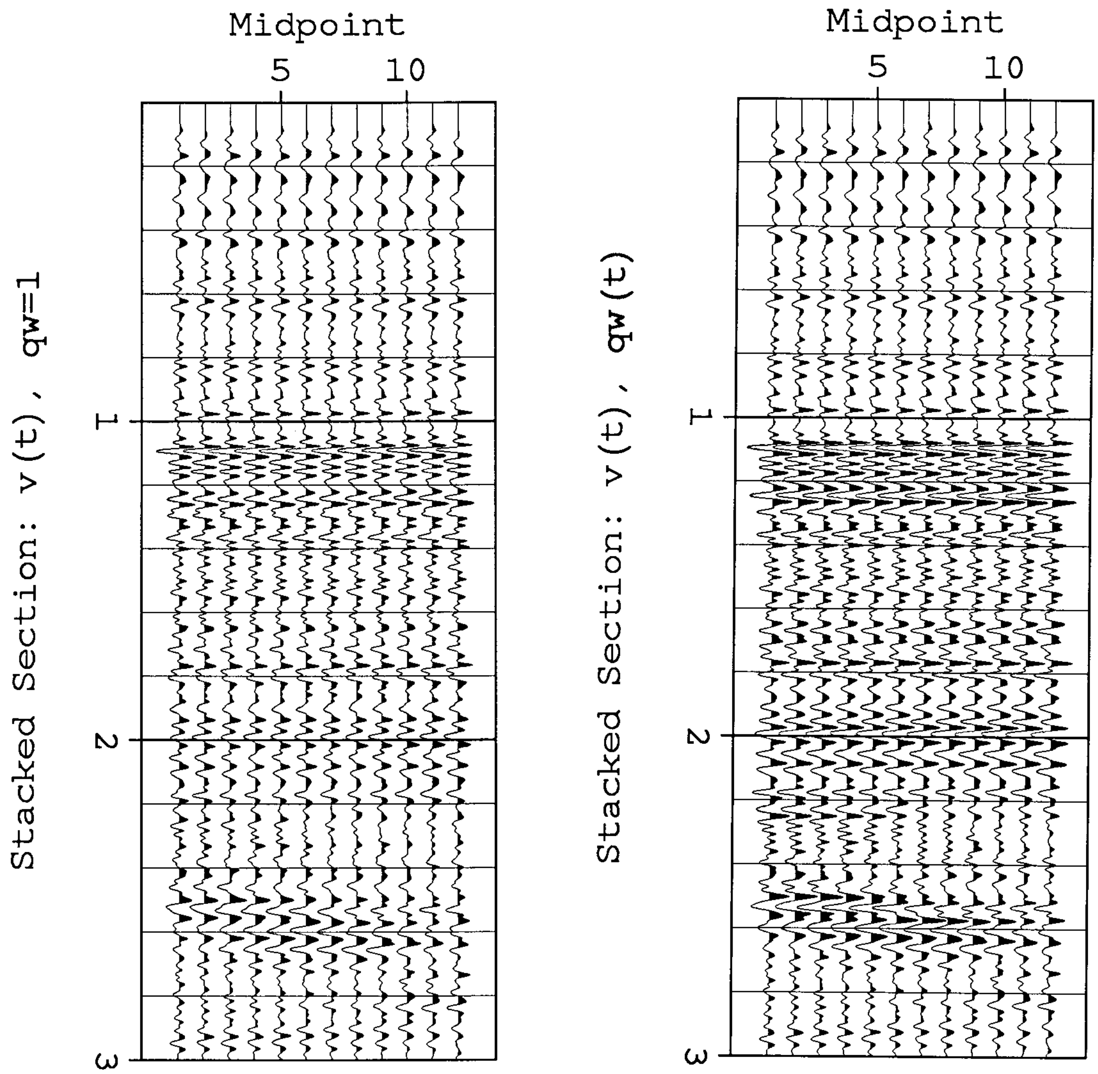

FIG. 5: A comparison of two 12-midpoint sections: the one on the left was stacked after correcting the gathers with $v(t(0))$ and $q_w = 1$; the one on the right was stacked after correcting the gathers with $v(t(0))$ and $q_w(t(0))$.

increase of q_w with depth—a plausible relation if $q_w(t(0))$ is hypothesized to represent some average of interval q_w's. Note also that the variation of $q_w(t(0))$ from 1.0 to .70 falls within the allowed q_w range of 3/7 to 7/3 (Muir, this volume), and that the anelliptic parameter increases with depth of burial.

Figure 3c shows the result of correcting the gather with the original velocity function and a $q_w(t(0))$ function picked from the semblance contours of Figure 4. While the events retain some curvature, they have been flattened sufficiently to increase the peak semblance value from .52 for Figure 3b to .84 for Figure 3c. The success of the method for fitting nonhyperbolic NMO curves is further demonstrated in Figure 5. The left and right panels compare 12-midpoint stacked sections formed using hyperbolic and $v(t(0))$-$q_w(t(0))$ NMO correction, respectively. The stack corresponding to the latter demonstrates 75% greater power than that corresponding to the former.

Conclusion

We have demonstrated that, relative to Equation 2, the two-parameter, anisotropic NMO model of Equation 3 produces significant increases in the semblance of moveout-corrected gathers and in the energy of their stacks, where $q_w(t(0)) \neq 1$. An efficient and accurate method of estimating the two, interdependent parameters—$v(t(0))$ and $q_w(t(0))$—remains to be developed. Also, it remains to be shown whether the anelliptic parameter estimated in this procedure can be related back to any or all of the three ($v(z)$, Dix, or Backus) models normally used in clastic provinces—and, in turn, to useful lithologic parameters.

References

Muir, F., and Dellinger, Joe, 1985, A practical anisotropic system, SEP-44.

Greatest CPU Users 1/84 - 8/85			
User	*Jobs*	*CPU min*	I/O calls
shuki	807476	71304.95	55575930
dan	147358	66142.50	9246511
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system	2662136	26988.52	45345830
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bill	117399	25132.87	3139340
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paul	114265	19847.00	5601881
jon	247040	14568.13	4750458
marta	163941	13950.47	7402494
jill	86523	12154.38	6116908
dezard	78117	11944.40	2352519
rick	135367	9574.82	4493640
joe	284454	9481.23	3681117
okaya	106028	9458.52	5745293
daemon	168448	8746.88	5447241
harb	119854	7361.35	2790792
biondo	54716	6199.32	1233962
erik	69214	5436.70	3523157
fawcett	54029	5334.00	923618
chuck	210286	5131.53	4412692
thor	183876	3143.20	1876951
ivan	22034	1571.22	465137
hitosi	7416	1284.30	232861
clem	18676	990.93	321714
mgd	30807	982.12	671553
pat	36982	955.15	663445
mac	37145	932.73	554274
einar	24521	806.83	597921
rufus	20884	735.63	232815