Introduction

The resolution of near surface problems has a serious impact on the seismic processing results. There are serious near surface problems in the Qaidam Basin in western China. The project includes 4 seismic surveys of different years, spanning three terrains of desert, Gobi, and mountain, with a height of 3000-3600 m, a near surface speed of 500-2500m/s, and the low deceleration zone thickness of 0-120m (Fig. 1). As a result, the seismic data are inconsistent in time, amplitude, frequency, and phase. In this abstract, we focus on solving the problem of frequency inconsistency caused by near surface.

For many years, the commonly used method to resolve frequency inconsistencies in seismic data processing is four-component surface consistent deconvolution (SCDEC). It is assumed that the decomposition of amplitude spectra into source, receiver, offset, and common-depth-point components enables deconvolution filters to be derived (Cary and Lorentz, 1993). In 2019, Su proposed the near surface Q compensation technology (NSQCT), which considers the absorption attenuation effect caused by near surface velocity and thickness changes. NSQCT seems to have more physical significance than SCDEC. In this abstract, the NSQCT is first briefly introduced, and then the effects of the two methods in solving frequency inconsistencies are compared in detail.

Figure 1 Topography and near surface model of a project in western China. a) Satellite photo with four seismic surveys (s1, s2, s3 and s4) and three types of topography (desert, gobi and mountainous region); b) The corresponding near surface model with velocity’s color covered. Note that the height difference in this project is about 600 meters.

Method

NSQCT mainly include the surface relative Q inversion and stable absorption compensation algorithm.

(1) The surface relative Q inversion
The surface relative Q inversion aims to obtain the relative magnitude relationship of the near surface Q values in the area. The spatial variation of Q values can be determined through the frequency relationship of seismic recordings in common shot domain, or common receiver domain and the corresponding near surface travel time. The following formula is the frequency shift method to obtain the Q values:

\[
Q = \frac{\pi t f f_m^2}{2(f_m^2 - f^2)}
\]

where \(Q\) is the surface relative quality factor, \(t\) is near surface travel time and can be calculated by near surface velocity model \((t = \int \frac{dz}{v})\), \(f\) is the frequency at physical station and \(f_m\) is the reference frequency.

(2) The stable absorption compensation algorithm
After the calculation of the spatial variation quality factor \(Q\), the prestack data is spatially compensated in the frequency domain by a stable compensation algorithm. The compensation formula is derived from the wave equation:

\[
U(\tau + \Delta\tau, \omega) = U(\tau, \omega)\exp\left[\frac{(\omega/\omega_h)^{-\gamma} \omega\Delta\tau}{2Q}\right]\exp\left[i\left(\frac{\omega}{\omega_h}\right)^{-\gamma} \omega\Delta\tau\right]
\]

where \(U\) is the prestack data, \(\omega\) is the frequency, \(\omega_h\) is the reference frequency, \(Q\) is the surface relative quality factor, \(\Delta\tau\) is the time shift.
where $U(\tau, \omega)$ is the uncompensated frequency domain data, $U(\tau + \Delta \tau, \omega)$ is the frequency domain data after amplitude and phase compensation, $\exp\left[\left(\frac{\omega}{\omega h}\right)^{-\gamma} \frac{\omega \Delta \tau}{2Q}\right]$ is amplitude compensation term, $\exp\left[i \left(\frac{\omega}{\omega h}\right)^{-\gamma} \omega \Delta \tau\right]$ is phase correction term. In order to improve the stability of the algorithm in high frequency compensation, the amplitude compensation term of the gain control (Wang, 2002) is used:

$$\Lambda(\omega) = \frac{\beta(\omega) + \sigma^2}{\beta^2(\omega) + \sigma^2}$$

(3)

In order to compare the effects of the two methods in solving the problem of frequency inconsistency in parallel, a processing workflow shown in Fig. 2 is designed. SCDEC uses mature algorithms in commercial software. NSQCT uses the method described above.

![Figure 2 The designed workflow for comparison between SCDEC and near surface Q compensation.](image)

**Examples**

Taking the Qaidam Basin as an example, NSQCT is performed. Figure 3 is the surface relative Q inversion process at the receiver station. The process at the shot station is similar. First, the near surface model (Fig. 1b) is loaded and the near surface travel time (Fig. 3a) is calculated according to the formula $t = \int \frac{dl}{v}$. Then, to obtain the frequency values at the receiver stations (Fig. 3b), the frequency values of all the traces of the prestack seismic data are picked, and the pickups are decomposed using the surface consistency solve formula. Next, the relative Q values (Fig. 3c) are calculated according to the formula (1). Finally, the gain control terms are calculated according to formula (3).
**Figure 3** The intermediate results of near surface $Q$ compensation at receiver station. a) Calculated travel time of near surface; b) Offset corrected and surface consistency decomposed frequency; c) Calculated relative $Q$ by formula (1); d) The corresponding gain factor of relative $Q$.

Fig. 4 is the shot gather results comparison between SCDEC and NSQCT. In Fig. 4a (the raw shot), the white rectangular bands along the time axis is obviously shown, which is caused by near-surface factors. With SCDEC (Fig. 4b), the white bands are partial elimination. With NSQCT (Fig. 4c) the white bands are almost eliminated. Zoomed the red rectangular, from Fig. 4d, 4e, and 4f, it is shown that with SCDEC (Fig. 4e), distorted wavelet is better consistency than the raw shot, with NSQCT (Fig. 4f), the distorted wavelet is more consistency than the other two.

**Figure 4** The result comparison between SCDEC and near surface $Q$ compensation. a) The raw shot; b) The SCDEC result shot; c) The near surface $Q$ compensation result shot; d) The figure a zoomed in rectangle; e) The figure b zoomed in rectangle; f) The figure c zoomed in rectangle.

Fig. 5 is the frequency map comparison between SCDEC and NSQCT. Fig. 5a is a reflection layer frequency map of raw data, Fig. 5b is the map of SCDEC, and Fig. 5c is the map of NSQCT. It can be
seen that after two kinds of processing, whether in the same survey or between different surveys, the frequency consistency has been enhanced. However, after comparing Fig. 5b and Fig. 5c, it can be seen that the effect of NSQCT on restoring frequency consistency is significantly better than SCDEC.

**Conclusions**

Due to the different years of seismic data acquisition and large changes in topography, there are serious near surface problems in the Qaidam Basin in western China, especially frequency inconsistencies. Compared with SCDEC, the NSQCT has a clearer physical meaning because it considers the absorption and attenuation caused by near surface velocity and thickness changes. By designing a parallel processing workflow and comparing shot gathers and map results processed by different methods, it is confirmed that the NSQCT in this area has a significantly better effect of restoring frequency consistency than SCDEC.

**References**


**Figure 5** The dominate frequency map comparison between SCDEC and near surface Q compensation. a) The raw result; b) The SCDEC result; c) The near surface Q compensation result.