SV-P Primary Reflections or P-P Interbed Multiples?

Introduction

SV-P reflections appear in P-source, vertical-geophone, trace gathers as events that have greater curvatures (i.e. slower velocities) than curvatures of faster-velocity P-P reflections embedded in the same data. Some data processors assume such high-curvature reflections have to be P-P interbed multiples. They then delete the events and implement imaging strategies that allow only P-P primary reflections to be in vertical-geophone data. Data processors now need to ponder an important question – “how are P-P interbed multiples and SV-P primary reflections related in vertical-geophone data”.

Example of Real-Data P-P Interbed Multiples

A CDP trace gather of vertical-geophone data is shown in Fig. 1a after a P-P normal-moveout (NMO) correction has been applied to flatten P-P primary reflections. The gather still exhibits many down-curving events that overlay the flattened P-P reflections, so the processor applied a Radon filter to delete these slow-velocity events (Fig. 1b). In this case, there are log data inside the 3D image space (Fig. 2) that indicate that most of these down-curving events probably are P-P interbed multiples. These log-data identify a shallow interval **IM** where there is a stacked series of rock boundaries where P-P reflection coefficients have huge magnitudes ranging from 0.4 to 0.2. Shallow high-contrast rock layering of this nature is mandatory for creating land-based P-P interbed multiples that have amplitudes that can compete with deep-boundary SV-P primary reflections. Such shallow layering like this example is rare.

Conditions That Create Interbed Multiples

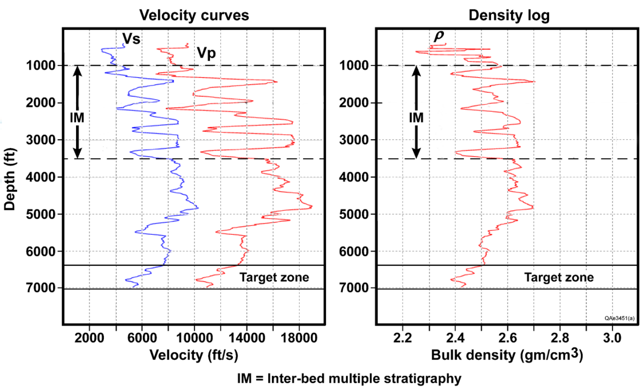

Fig. 2

Typical Analysis of Vertical-Geophone Data Trace Getherers

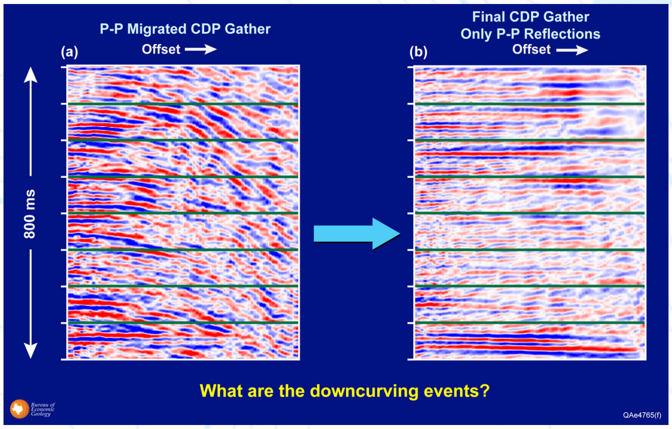

Fig. 1

What VSP Data Teach About Interbed Multiples

Vertical seismic profile (VSP) data that contain robust P-P interbed multiples are shown as Fig. 3. Experienced VSP data processors know that an upgoing P-P primary reflection (e.g. event **1**) and all of its associated interbed multiples (e.g. event **2**) propagate with the same velocity and so do the downgoing P-P first arrival (event **3**) and all of its associated downgoing interbed multiples (e.g. events **4**). This wave propagation physics leads to the principle stated on Fig. 3 – “P-P interbed-multiple reflections have the same propagation velocities as their parent primary P-P reflection”. This principle means that in P-P stacking-velocity panels such as the one exhibited in Fig.4, interbed multiples of primary P-P reflection **A(PP)** will appear at later times (direction arrow 2) in the same velocity-moveout panel that flattens the curvature of reflection **A(PP)**. Interbed multiples cannot move laterally (e.g. in direction arrow **1**) to velocity panels that differ from the velocity panel where their parent primary reflection resides.

Comparing P-P Interbed Multiples and SV-P Primary Reflections

Using procedures discussed in a companion brochure, event **A(SVP)** in Fig. 4 is identified as a primary SV-P reflection that is depth-equivalent to P-P reflection **A(PP)**. If a person wants to argue that **A(SVP)** is a P-P interbed multiple, not a primary SV-P reflection, then **A(SVP)** has to be a multiple of P-P reflection **B(PP)** positioned at an earlier time in the same velocity panel. The yellow dots between events **A(SVP)** and **B(PP)** show time positions where successive multiples of **B(PP)** would occur as they march toward the time coordinate of **A(SVP)**. This logic shows that **A(SVP)** would be the third multiple of **B(PP)**. If the P-P reflection coefficient at the interface where **B(PP)** was generated has a magnitude of **R**, then the amplitudes of multiples of **B(PP)** are: **RB(PP)** (1st multiple), **R^2B(PP)** (2nd multiple), and **R^3B(PP)** (3rd multiple). Even if **R** has a large magnitude of 0.1, the amplitude of the 3rd interbed multiple of **B(PP)** would be reduced by a factor 1000, compared to the amplitude of **B(PP)**, and would be only background noise in the immediate vicinity of event **A(SVP)**. If **R** is assigned a huge value of 0.2, the third multiple of **B(PP)** is still reduced by a factor of 125 when it reaches SV-P primary reflection **A(SVP)**. One is left with the conclusion that **A(SVP)** must be a primary SV-P reflection, not a P-P interbed multiple. In order for land-based P-P interbed multiples to compete with deep-interface SV-P primary reflections, there must be shallow interfaces that have huge P-P reflection coefficients of magnitude 0.3 or 0.4 as shown in Fig. 2. This type of shallow, high-contrast layering exists but, fortunately, is rare.

Inter-Bed Multiples and SV-P Reflections in CMP Constant-Velocity Stacks of Vertical-Geophone Data

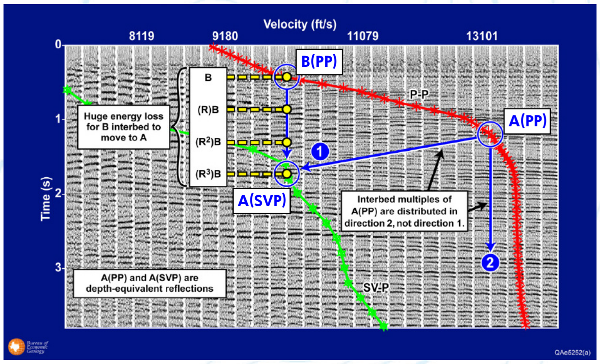

Fig. 4

Physics of Interbed Multiples is Best Studied with VSP Data

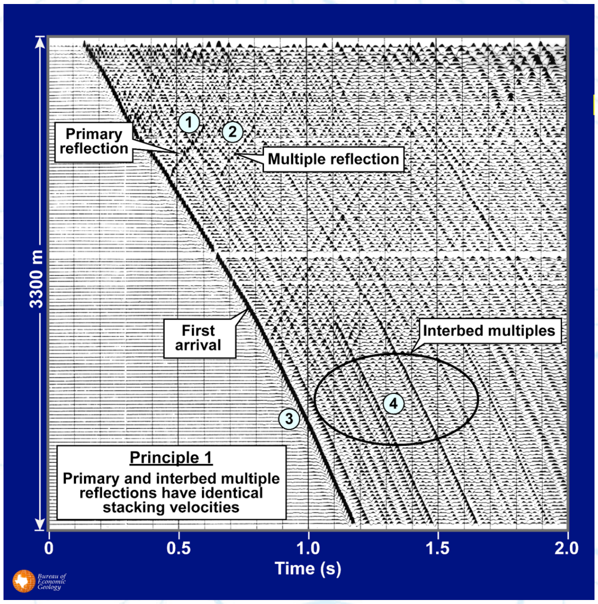

Fig. 3

Conclusions

1. Slow-velocity, down-curving events in NMO-corrected, P-P, CMP trace gathers are, in almost all instances, primary SV-P reflections from deep interfaces, not interbed multiples of a P-P reflection generated at a shallow interface.

2. Slow-velocity interbed multiples of a P-P reflection generated at a shallow interface have amplitudes that compete with amplitudes of primary SV-P reflections generated at deep interfaces only when the magnitude of the P-P reflection coefficient at the interface where the parent P-P reflection originated has a magnitude greater than 0.25.

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