# Modeling helps interpretation in areas with severe timing problems

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There are many parallels between exploring the subsurface using seismic reflections and looking at objects below the water's surface.

In the atmosphere, our vision involves only line-of-sight travel from the object to our eye. But when you look at a fish in a pond, water is added to the visual path. If the surface of the water is glassy smooth, we see the fish in its true form and shape, but its location is not where it appears. The apparent position shifts because the water's differing velocity for light propagation changes the direction of travel for that reflecting off the fish.

It gets worse. Suppose we drop a rock in our fish's pond. The surface ripples break the fish's image into pieces. If a brisk enough breeze comes up, we may even fail to recognize the object as a fish through the rough surface.

The same phenomenon is a geophysicist's dilemma. He must "look" at geologic targets (the fish) using sound (light) that travels through rocks whose velocities (refractive indices) differ. What he sees is then distorted to the extent that varying velocities obscure the sharpness of his seismic image.

The most offensive rocks are those closest to us—near the surface—just below the seismic source and receivers.

We acquire redundant seismic data and "process" several traces to get a more noise-free view of the subsurface. But this processing (addition of the redundant data) is ineffective if the reflections being added are not in time register. And that becomes the problem.

In the Texas Panhandle, the Blaine Gyp, just below our shot holes, is leached out by surface water and replaced by lower velocity material. At some places, surface water fails to penetrate to the Blaine, and leaching does not occur. Thus seismic receivers at different positions see reflections from the same geologic boundaries at different times, creating the timing problem.

Or, in Michigan, the problem is caused by glacial till whose constituent material is so varied that velocity variation from one receiver location to the next causes the same timing problem. Almost every land location presents this same generic timing problem, although its cause may vary.

Fig. 1

**GEOLOGIC COLUMN, FISH CREEK**

| Age | Group and formation |
|---|---|
| Late Cretaceous | Colville group |
| Early Cretaceous | Nanushuk group |
| | Torok formation |
| | Pebble Shale unit |
| Jurassic | Kingak shale |
| Triassic and Permian | Shublik fm and Sadlerochit group |
| Pennsylvanian and Mississippian | Lisburne group |
| | Endicott group |

## The Alaskan surface

In Alaska, this same problem is occasioned by the permafrost—that perpetually frozen material that runs from near the surface to depths of 1,000 ft. Ice sound velocity is about 10,000 fps; water is more like 5,000 fps.

All we need is a sheet of variable-thickness ice at the surface to create our seismic timing problem. It never fails to happen.

There are even cases of supercooled ice reported, with temperatures well below 32° F. These ice velocities can get as high as 20,000 fps for ice around 0° F.

Because of this contrast between water and ice velocities and the prevalence of the permafrost, timing problems are automatically anticipated for every seismic survey in the Alaskan North.

As if this were not enough, more problems with velocity exist much deeper in the subsurface.

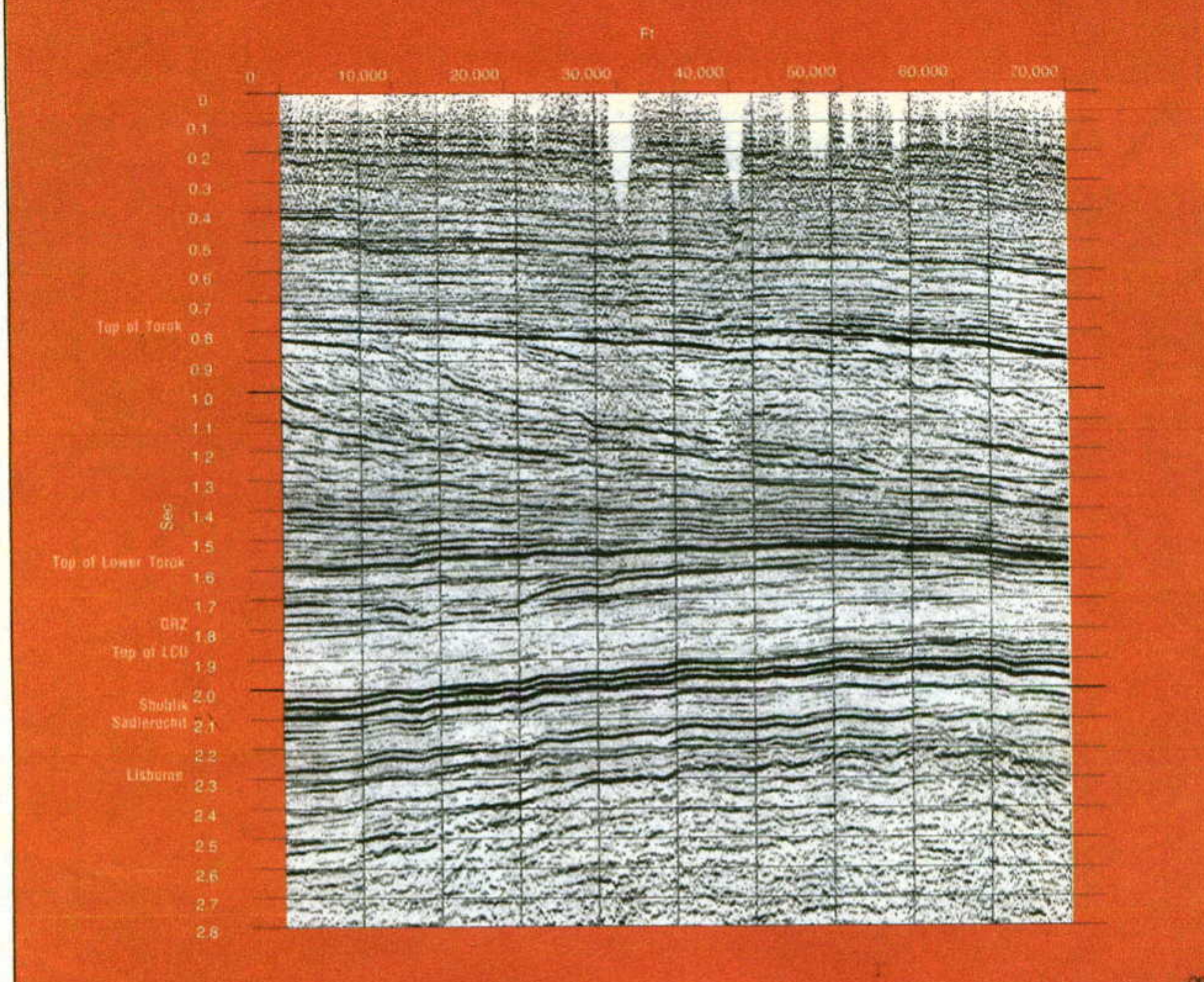
Fig. 1 shows a geologic column for the Fish Creek Area at the eastern edge of National Petroleum Reserve-Alaska (NPRA). Above the Pebble Shale and Kingak formations, which contain many rocks of exploration interest on the North Slope, is the Torok formation.

The Torok sits on a shale with high organic content and a large gamma ray response. It is commonly called the Gamma Ray Zone (GRZ). Where dip is present, the lower Torok units depend on frictional forces at the GRZ interface to maintain their integrity.

But the GRZ possesses good lubricating qualities, and as a result, the Torok "fails," breaking into large disconnected chunks that push the GRZ into thick mounds as they slide along

Fig. 2

**SEISMIC SECTION FROM FISH CREEK AREA, NORTH SLOPE**




the interface under gravitational force.

These failures can occur in a variety of ways, as discussed in an article by Paul Weimer of the Department of Geological Sciences at the University of Colorado.

The mounding of masses of the GRZ creates a highly changing ratio of GRZ to Torok thicknesses.

GRZ shale velocity is about 9,000 fps; the Torok velocity is more like 12,500 fps. And so we have another timing problem for seismic data processors.

The GRZ-Torok problem affects only seismic times for reflections from below the GRZ level. Above this point, the permafrost is the only cause of timing problems. Below the Torok, both the permafrost and the GRZ affect reflection times.

## Picture of the problem

Fig. 2 is a portion of a seismic line from the Fish Creek Area in the eastern part of NPRA. The portion shown covers 70,000 ft of traverse.

Formations of interest are labeled along the timing scale in the figure. The "wavy" characteristic of all reflections in the sequence below the Torok is evidence of our GRZ and permafrost in action. Above the GRZ, most visibly in the foreset bedding of the Upper Torok, the effects of permafrost alone are seen.

Fig. 3 is a cross section with the same horizontal dimensions as Fig. 2. It is inspired by Fig. 1. No attempt has been made to exactly dimension the depth cross section of Fig. 3 to the seismic picture of Fig. 2. This is of secondary importance since we only wish to study the nature of these two timing problems.

All of the important interfaces seen in Fig. 2 are included in the cross section of Fig. 3. Our goal is to demonstrate our hypotheses about the permafrost and GRZ timing effects by calculating the seismic response of Fig. 3. If we are successful in designing a cross section with timing properties similar to real seismic data, the basis for the design of methods to correct these aberrations is our cross section, or model. This is the investigative, tutorial, and design use of seismic simulation.

Fig. 3 is designed to include permafrost and Torok failure. To properly model any physical feature, its description must be provided in sufficient acoustic detail. This includes the