A More General Refraction Theory (AMGRT)

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Summary

AMGRT describes a new understanding of the land near surface. First breaks used in conventional refraction statics are actually a combination of a superficial, near-surface statics component and deeper, long-wavelength component. AMGRT separates these two components into shot and receiver reflection statics and a tomographic model. The tomographic model sanitized in that it has no superficial imprint and is thus an ideal starting model for FWI. Likewise, AMGRT's reflection statics will also improve all subsequent land processing, including migration and FWI.

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Introduction

Conventional refraction analysis incorrectly associates seismic first breaks purely with refractors. However, first break times are a combination of shallow anomalies imprinted on refracted arrivals. As a result, first breaks produce inaccurate tomographic models and statics. These flawed models are routinely being used as the near-surface components for depth migration and for initial FWI models.

AMGRT assumes that first-break picks are comprised of two separate components: a superficial, short-wavelength, surface-consistent component and a deeper, long-wavelength refracting component. We show, using seismic data from the Anadarko Basin, how the components are separated. Shot and receiver statics are derived from the superficial component and long-wavelength statics are computed from a tomographic model constructed from the refracted component. The statics from both components are added. These data are then stacked, demonstrating the efficacy of AMGRT.

The True Nature of First Breaks

Current refraction-based algorithms see first breaks as associated with refracting events in the near-surface. In other words, first breaks are essentially “refracted arrivals”. Figure 1 shows a representative near-surface model with a gradient of increasing velocities starting at surface topography. Refraction tomographic algorithms generate turning-ray paths through this model starting and ending at the surface as shown for the shot S into receivers R. However, turning-ray algorithms cannot localize the shallow velocity anomalies because they are really not part of the turning-ray component.

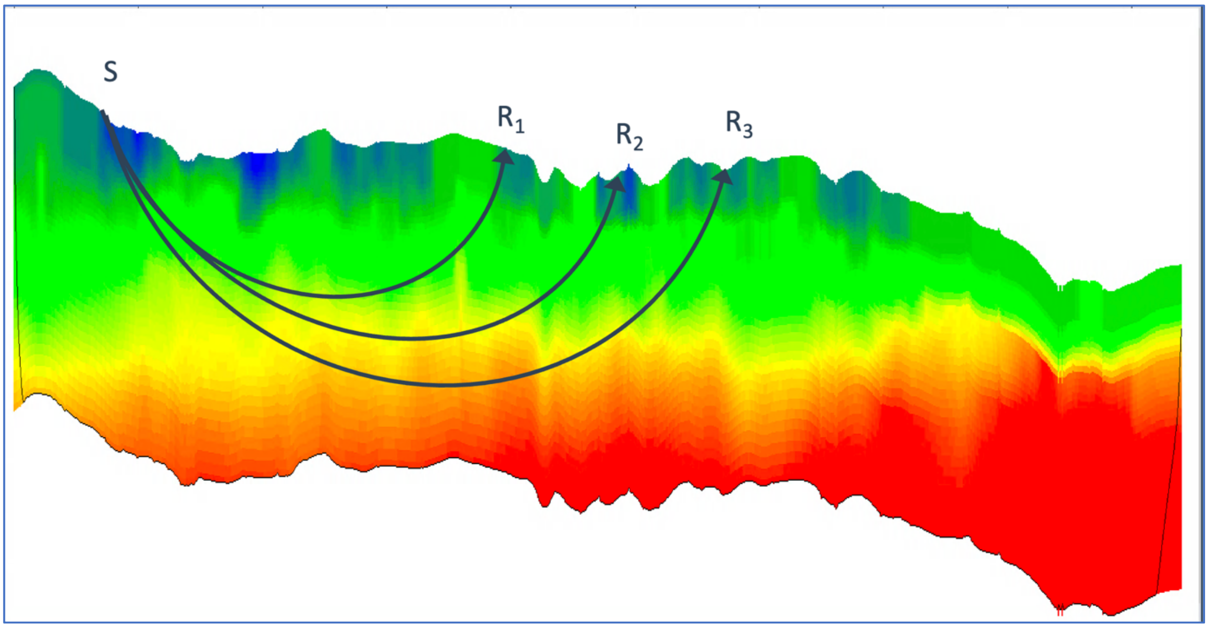

Figure 1. *Cross-section of a turning-ray tomography model from the Anadarko Basin data used in this paper. Hypothetical turning-ray paths are shown from a shot at S to three receivers at R. Tomography models do not show discrete layers. Instead, tomography models show a continuous velocity gradient from the surface.*

In other words, the conventional view of first breaks is not correct. In AMGRT, first breaks are seen as a combination of static and refracted components. The non-refracted component is generated at the very near-surface and is thus surface-consistent. Figure 2 shows how surface-consistency implies anomalies must be at the surface. Daly, et al (1988) discuss how surface-consistent anomalies must be generated by very shallow geology.

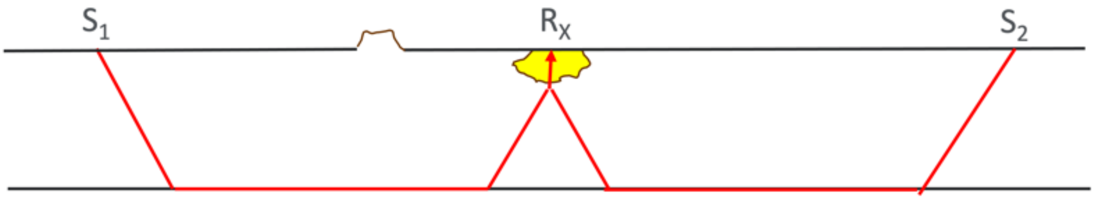

Figure 2. *A slow-velocity pocket right beneath the surface under R_X must be surface-consistent.*

Figure 3 shows a model with a shallow layer with vertical travel paths in the shallowest layers and turning rays in the deeper model characterized by a velocity gradient.

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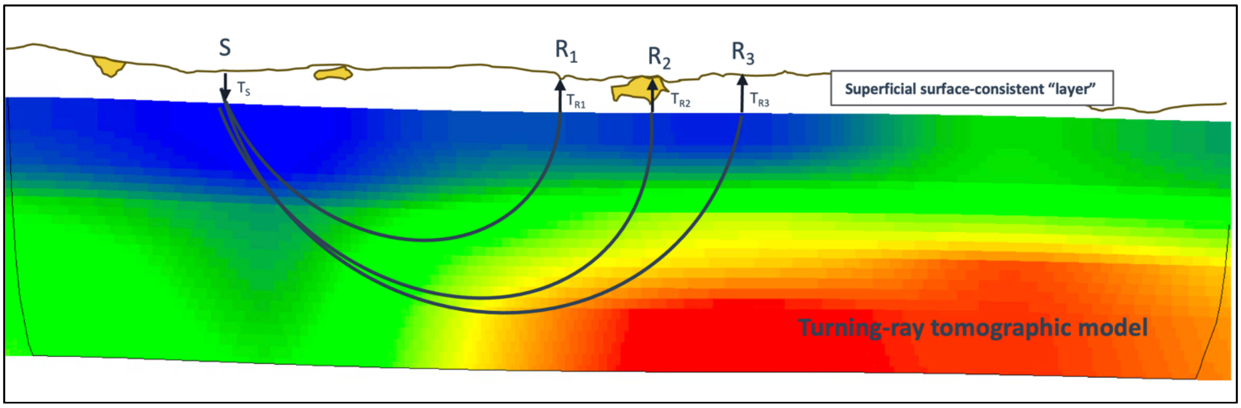

Figure 3*. Conceptual near-surface model used by AMGRT showing shallow, surface-consistent component above and the deeper turning ray component below.*

AMGRT sees first breaks as comprising two distinct components: a shallow component and a deep component. This is expressed in the AMGRT pick time equation,

$$t(x) = t_s + \tau(x) + t_r$$

Where $\tau(x)$ is the long-wavelength refraction time at offset, x. The short-wavelength surface consistent source and receiver statics are t_s and t_r. Figure 4 shows this equation graphically after the input first break pick times were decomposed into t_s, $\tau(x)$ and t_r, respectively.

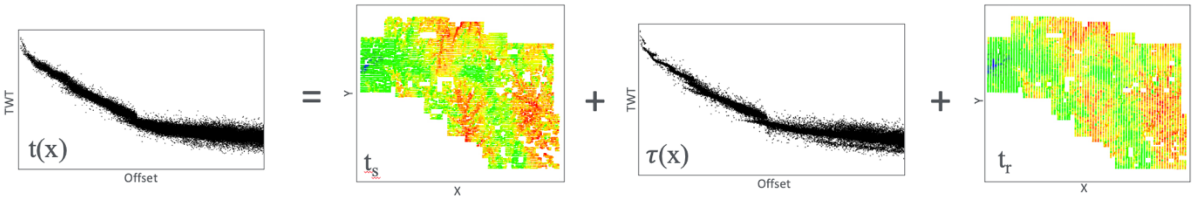

Figure 4. *AMGRT pick time decomposition expressed graphically. Note how the $\tau(x)$ term above shows the linear refracted events more clearly than the input picks $t(x)$.*

The $\tau(x)$ term will be used to construct a “sanitized” tomographic model. This model will have none of the surface-consistent statics embedded in the picks and thus will result in a more accurate near-surface long-wavelength model than conventional the conventional approach. This is shown in Figure 5.

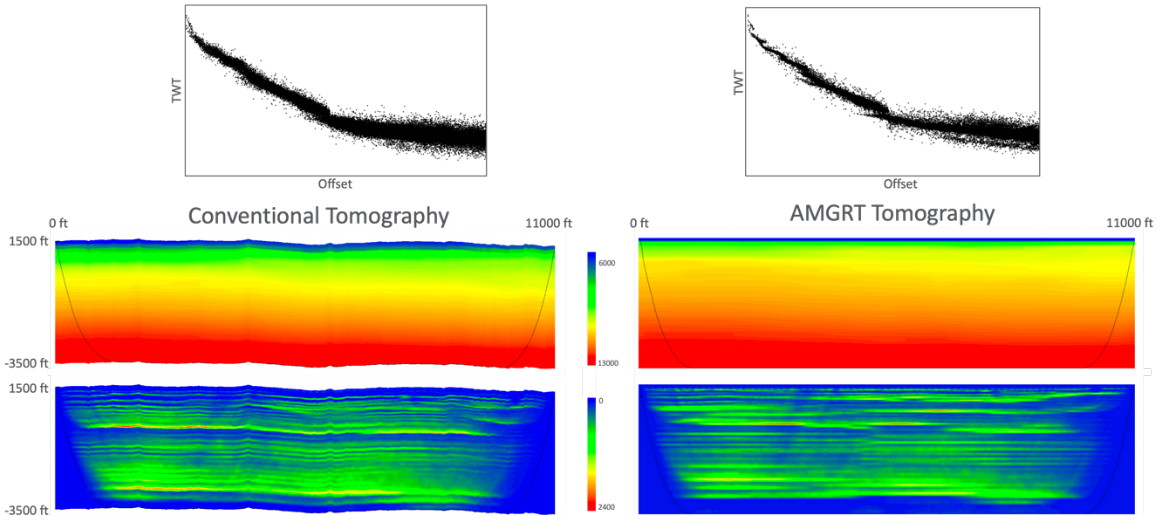

Figure 5. *Conventional tomographic model (left) versus AMGRT-derived tomographic model (right)*

Figure 5 demonstrates that AMGRT does not have the imprint from surface-consistent components that would otherwise be present.

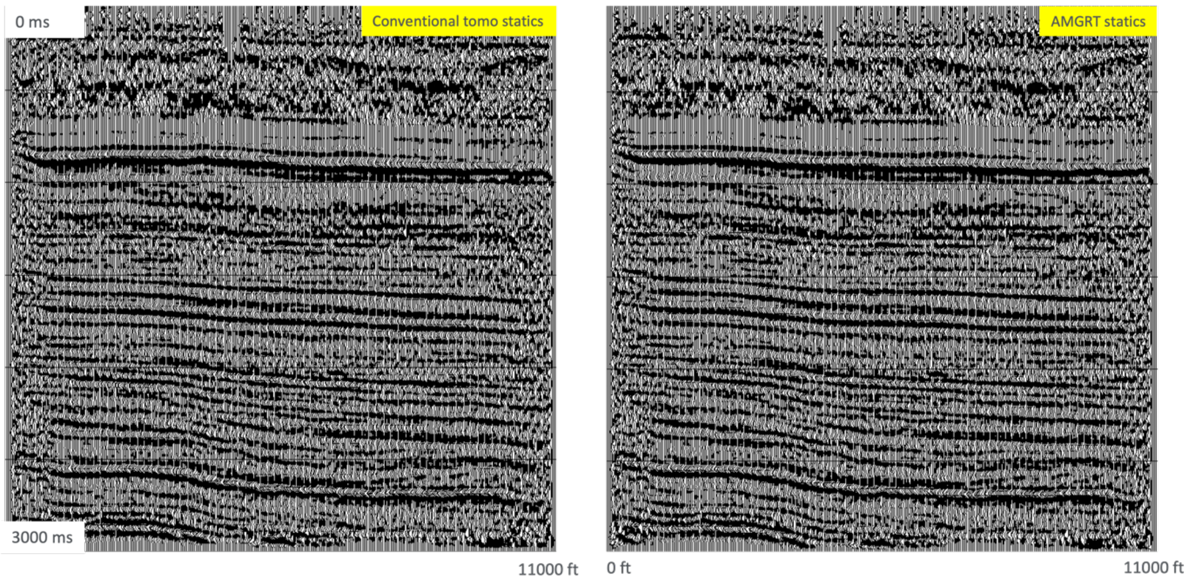

Figure 6. *Stack QC showing application of conventional tomographic statics (above) versus AMGRT-derived tomographic statics (below).*

Figure 6 shows a stacked comparison between conventional tomographic statics and AMGRT-derived tomographic statics. Note the simpler structure in the AMGRT tomographic stack. More importantly, AMGRT-derived surface-consistent statics can be applied directly to the pre-stack data prior to further processing. Furthermore, we claim that the AMGRT-derived tomographic model is free of the near-surface imprint and is a more accurate geological model than the conventional tomographic model.

Conclusions

AMGRT recognizes that first breaks are composed of a combination of superficial surface-consistent short-wavelength statics and deeper long-wavelength refracted arrivals. By decomposing the first breaks into surface-consistent statics and long-wavelength refracted arrivals, AMGRT generates better surface-consistent statics and more accurate tomographic near-surface models than conventional refraction statics approaches.

AMGRT is deterministic: AMGRT decomposes the first break picks into statics and model without user involvement. Thus, there will be less need for "refraction statics expertise" once AMGRT is implemented as part of the land processing flow.

AMGRT's surface-consistent statics are true "reflection" statics and should be applied directly to the reflection data as part of the data processing flow. Given good first break picks, AMGRT should reduce the burden of deriving statics directly from the reflection data using residual statics software.

AMGRT's statics will improve both time and depth processing, including preparing seismic data prior to FWI. AMGRT provides a more accurate model of the near surface as well as improved starting models for FWI compared to the conventional approach. Thus, we see AMGRT as an important component for land FWI processing.

Acknowledgments:

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References

Daly, C, and Diggins, C. [1988]. Use of refraction elevation models in the computation of refraction statics, SEG Technical Program Expanded Abstracts: 574-577.