Interactive *Explorers*: Useful geophysical tools

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ABSTRACT

In this Research Note, an overview is presented of some useful visual web-based programs for investigating topics of geophysical interest. The *Zoeppritz Explorer* allows one to display all reflection and transmission coefficients for arbitrary earth parameters, and to view the effect of interactively changing the earth parameters. This may be done both with the exact coefficients and with two approximations as well. The *Reflectivity Explorer* focuses on R_{PP}, R_{PS}, and R_{SS}, but explores a wider range of approximations, particularly those of interest to AVO studies. The *AniZoeppritz Explorer* allows one to manipulate the γ, δ, and ε anisotropy parameters and angle of azimuth for a linear approximation to R_{PP}. This is also useful in AVO applications. The *AVO Inversion Explorer* is somewhat different than the other explorers. It was designed to permit the assessment of AVO inversion schemes for various choices of lithology, V_P-V_S ratio, and offset range.

INTRODUCTION

Geophysics is a very visual science. Large amounts of complex information must be presented in a manner that can be absorbed, understood, and interpreted as efficiently as possible by its practitioners. Computers are appreciated, not only for their number-crunching ability, but because they can be employed to display information in a variety of useful ways.

Because of the ever-increasing role of the internet in communication and learning, we felt it would be a valuable initiative to begin developing a suite of *Java*-based utilities which would make standard geophysical tools available in new, interactive ways, and also facilitate their application at the boundaries of research. *Java* is a programming language developed specifically for the internet, which makes its web-based applications very convenient to use anywhere in the world. This paper reviews the initial contributions in this project.

ZOEPPRITZ EXPLORER

The Zoeppritz Equations are one of the fundamental cornerstones of seismic exploration (Aki & Richards, 1980, chapter 5). They are relevant to both students and experts. The Zoeppritz Explorer utility, displayed in Figure 1 below, allows one to interactively change densities and velocities, or ratios thereof, and to display any of the reflection and transmission coefficients as a function of angle of incidence. Linear approximations have played an important role in the application of the Zoeppritz coefficients, and the early Bortfeld approximation (Bortfeld, 1961) as well as the better-known Aki-Richards approximation (Aki & Richards, 1980) are both given. The CREWES web page in which this applet is embedded also contains a thorough explanation of the Zoeppritz Equations in layman's terms, making it a useful pedagogical and public communication tool as well.

Beyond the critical point the coefficients become complex, and are displayed as a modified magnitude and phase. They are modified in the sense that the magnitude may be negative if that is consistent with a zero-phase below the critical point and a continuous-phase thereafter.
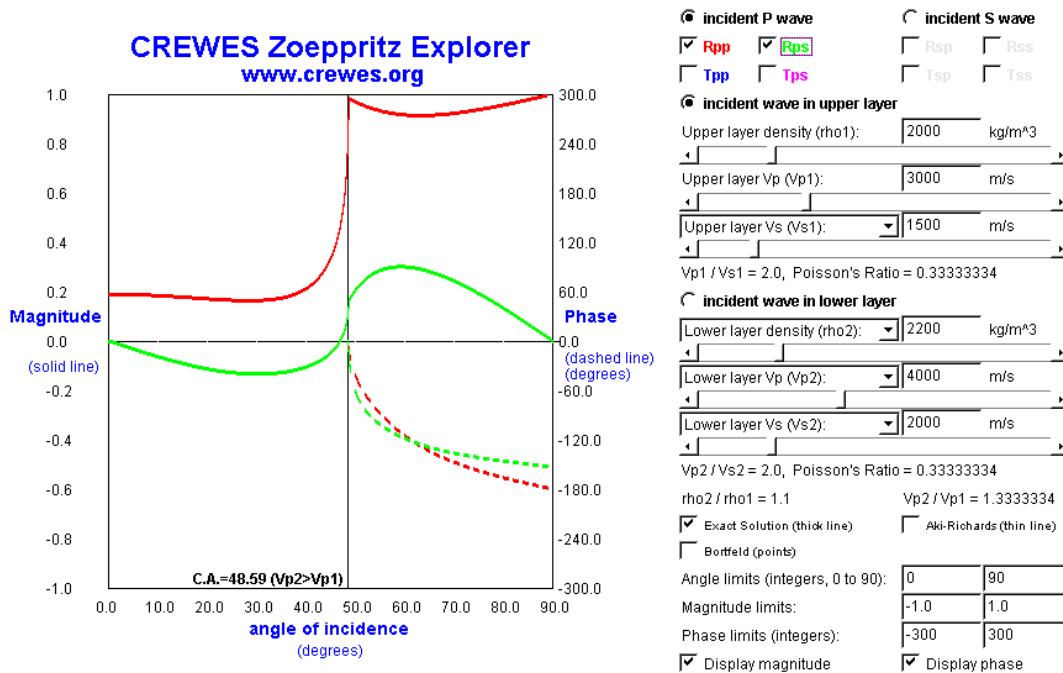
FIG. 1. A screen capture image of the *Zoeppritz Explorer* utility. Manipulation is straightforwardly carried out through use of checkboxes, sliders, and textboxes. Printed black and white versions of this article will not show the colours that in practice make this display particularly easy to digest visually.

REFLECTIVITY EXPLORER

In some respects similar to the *Zoeppritz Explorer*, the focus of this tool is toward AVO studies. Thus it is restricted to only a few reflection coefficients, but explores a wide variety of approximations relevant to this field. One feature of this explorer is that coefficients may be displayed as functions of either angle or offset. Like the *Zoeppritz Explorer*, each earth parameter may be displayed individually, or one may select up to four ratios, e.g., Poisson's ratio instead of V_S, ρ_2 / ρ_1 instead of ρ_2, and so on. If all four ratios are chosen, then these completely determine the coefficients, irrespective of any of the individual parameter values.
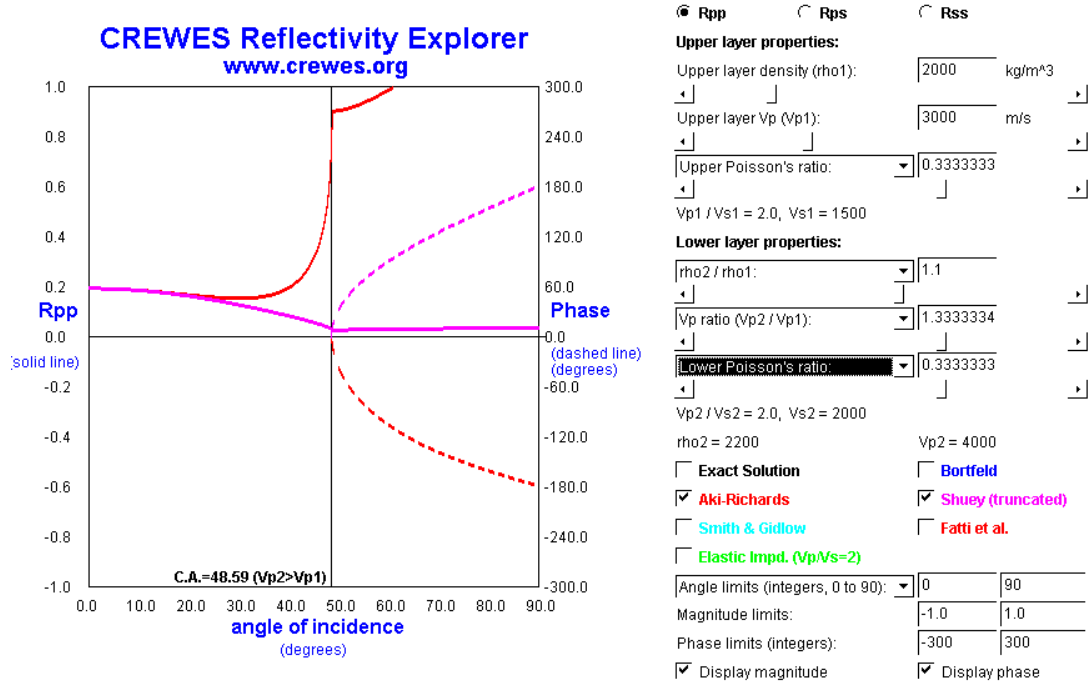
FIG. 2. Screen-capture image of the *Reflectivity Explorer* utility, which is of particular interest for AVO studies.

ANIZOEPPRITZ EXPLORER

A request from a sponsor using the above explorers led to the development of the *AniZoeppritz Explorer*, an anisotropic version of the *Reflectivity Explorer*. In addition to being able to interactively control density and velocities, one can also manipulate Thompson's γ, δ, and ε anisotropy parameters (Thompson, 1986) and angle of azimuth. The version displayed below implements a linear version of the P-P reflection coefficient (analogous to the Aki-Richards approximation for isotropic material), and exact anisotropic coefficients will also be added shortly to this applet.
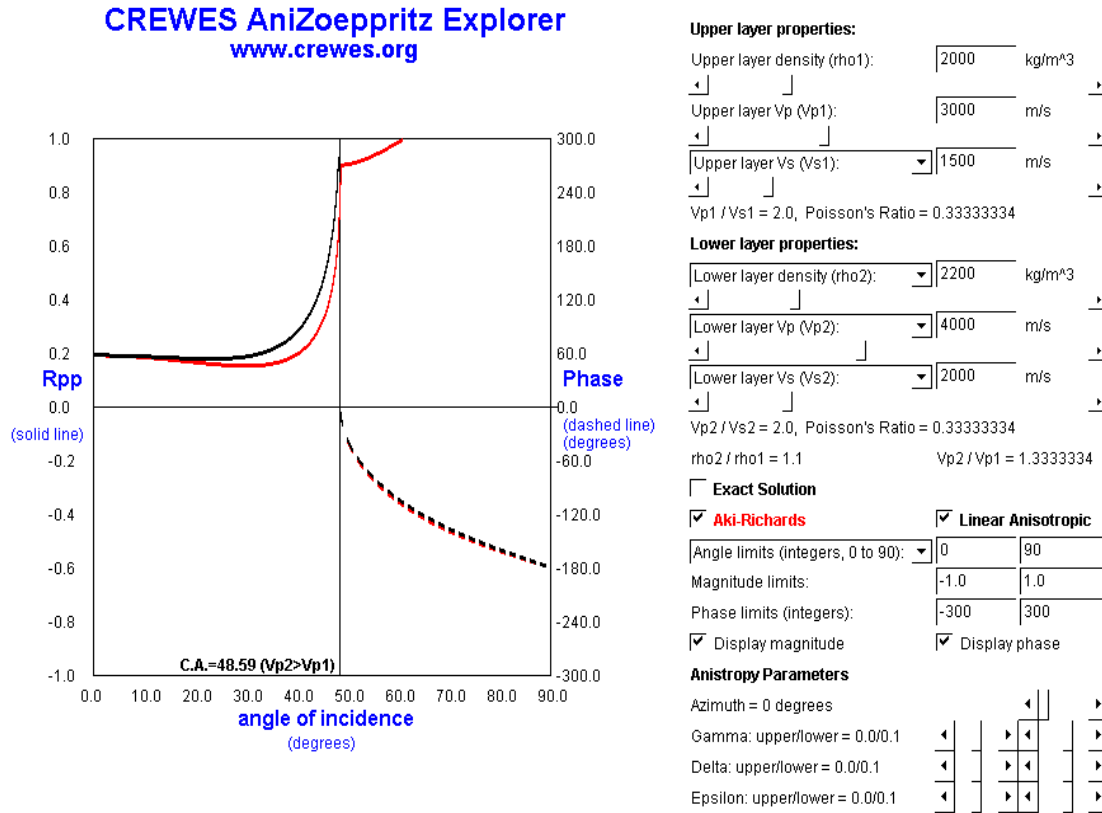

FIG. 3. Screen capture of the *AniZoeppritz Explorer*. This has been used to look at the effects of anisotropy on AVO.

AVO INVERSION EXPLORER

This utility was developed in connection with one of the studies in this Research Report (Ursenbach & Stewart, 2001). The objective was to provide a convenient means for evaluating the performance of various AVO approximations in the AVO inversion process. It considers two layers only, and assumes a spike wavelet, so that the reflection coefficients are used directly as input to the inversion without wavelet convolution. One can select from among various cap/reservoir lithologies, V_P-V_S relations (as this quantity is generally required for the inversion), and offset ranges from which data is selected for the inversion. It is anticipated that this tool will evolve significantly in the future, both to allow greater interactive control over various program parameters, as well as to explore, for instance, new approximations, joint inversion, non-linear inversion, and wavelet effects.

CREWES AVO Inversion Explorer

%-Error in Contrast and Impedance Predictions

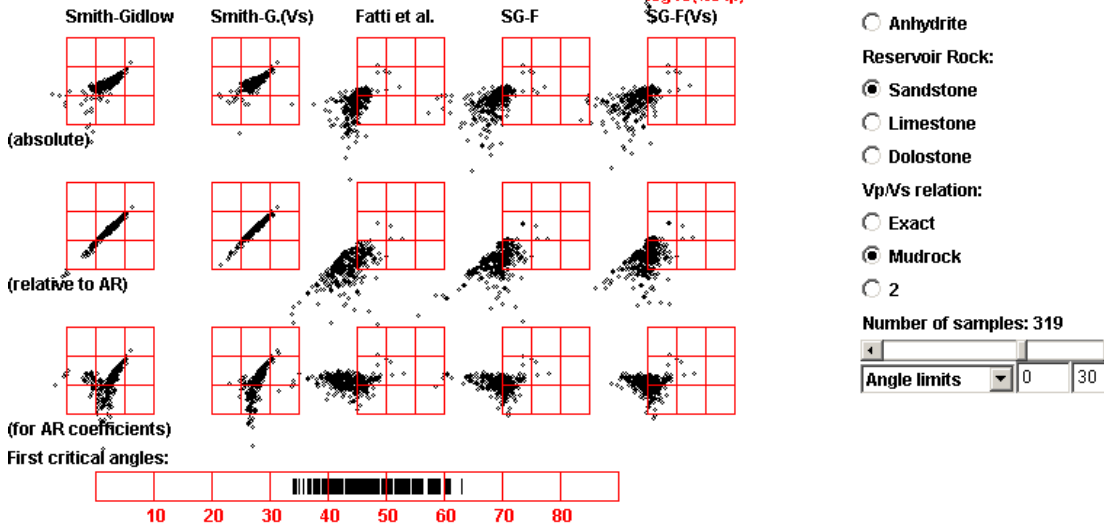|	absolute	relative to AR	for AR coefficients	
Smith-Gidlow	37.91, 34.7	38.6, 31.22	38.82, 22.69	**Aki-Richards**
Smith-Gid(Vs)	41.88, 37.7	42.53, 34.27	46.4, 25.02	1.15, 6.32 (for exact rho)
Fatti et al.	1.3, 8.72	1.1, 2.54	1.13, 15.42	
Full-Offset	0.97, 9.9	1.38, 3.45	1.43, 13.87	
Full-Off.(Vs)	0.92, 10.21	1.49, 3.88	1.64, 13.02	

FIG. 4. Screen capture of the *AVO Inversion Explorer*, used for testing the accuracy of various inversion approximations.

SUMMARY COMMENTS

The interactive utilities described above have begun to find a useful niche. They fill an educational role, and also allow one to try out ideas spontaneously and assess results visually without wading through long data files. New programs will continue to be developed, and sponsor input on improvements to existing Explorer applets or suggestions for new utilities is always welcome.

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Thompson, L., 1986. Weak elastic anisotropy. *Geophys.*, 51, 1954-1966.

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