ANALYSIS OF FRACTURE-RELATED SEISMIC ATTENUATION AND SCATTERING: INSIGHTS GAINED THROUGH NUMERICAL MODELING

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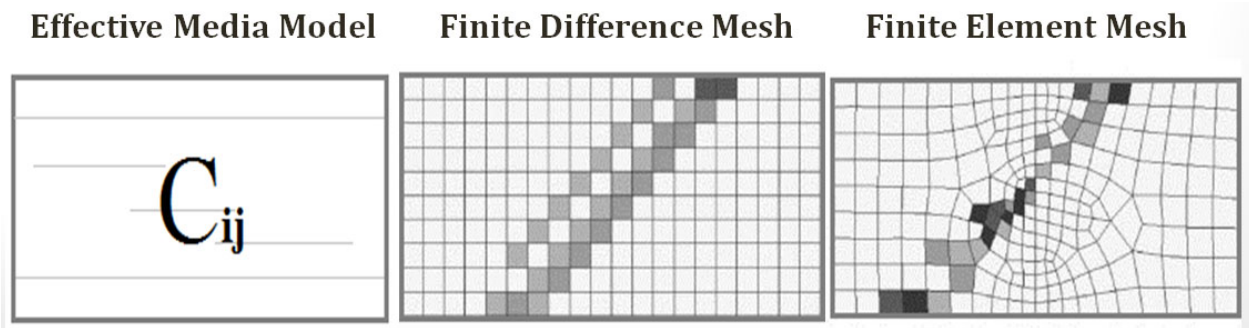
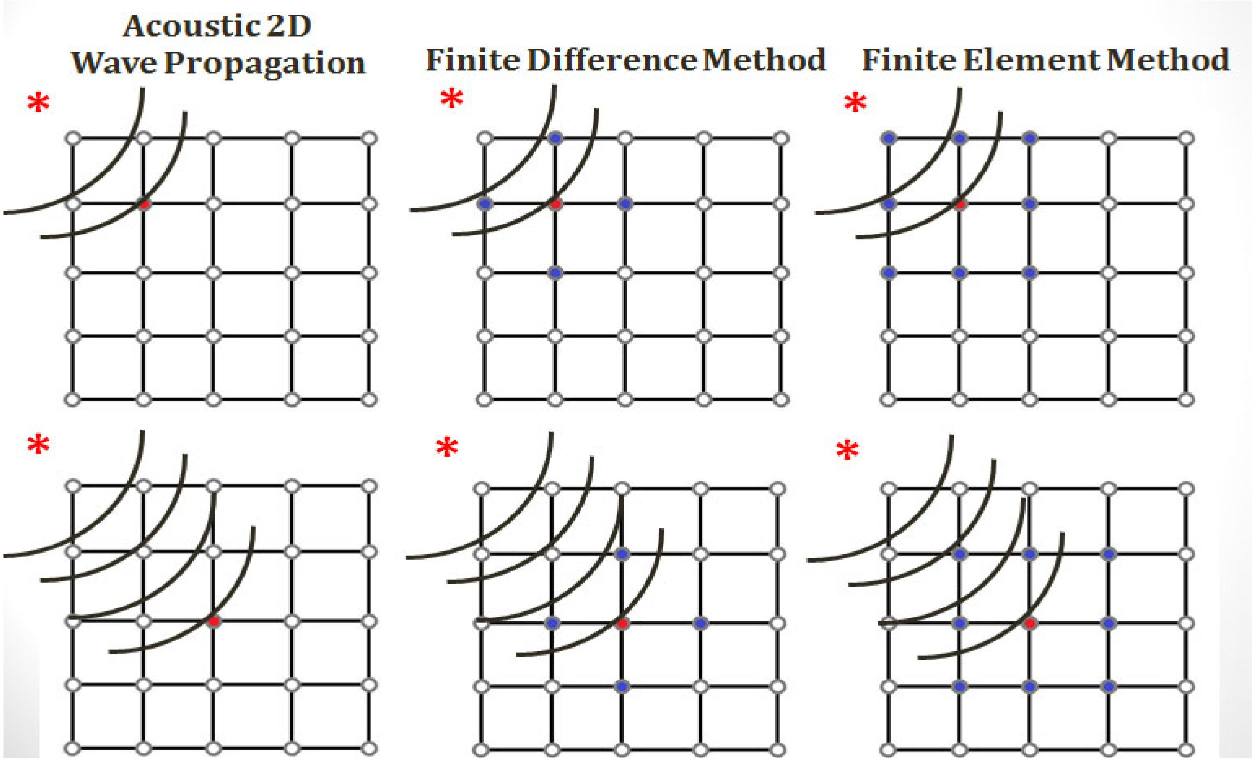
ABSTRACT

The orientation, geometry, and fill attributes of subsurface fracture networks can be characterized by seismic surveying through the study of seismic energy attenuation, wavefield scattering, and directional phase velocities. This method of understanding in-situ reservoir features is an indirect approach, however, and requires an in-depth understanding of the seismic response to each property and how the signatures of these properties combine to form seismic observations. To understand any characteristics of a fracture network, a model must be implemented to accurately represent the subsurface and predict the outcome of changes in individual fracture attributes. Previous studies using finite difference modeling techniques have correlated these properties to differing patterns in energy attenuation and scattering for transversely isotropic media. For more complex systems, such as orthorhombic symmetry or heterogeneous fracture clustering, this modeling technique is greatly limited in its ability to discern fracture parameters due to extensive wavefield interference and cancellation. To advance this study, I propose the use of finite element wave propagation techniques that offer more freedom to modeling parameters. This freedom allows for better contouring of the discontinuous fracture interface and, therefore, can more accurately represent the reflections and diffractions from these surfaces. Through the application of this better suited method of modeling, I will be able to more accurately identify the presence of and characterize complex fracture networks. This study is, however, still in the development stage of model validation. By first repeating the work of a finite difference study, I will be able quantify the superiority or inferiority of finite element methods over finite difference methods and then continue on to model implementation.

#1 Modeling Techniques:



#2 Wave Propagation Techniques:



A comparison of the differences between finite element and finite difference modeling methods 1) and wave propagation methods 1) is shown. The main modeling methods (1) for representing fractures are effective media models that average fracture attributes in each layer to compute the compliance tensor S_{ij}, discrete fracture finite difference models that compute the normal and tangential compliance in each of the uniform grids (a), and discrete fracture finite element models that compute the normal and tangential compliance in each unstructured grid (b). The main methods for solving the elastic wave partial differential equation (2) in a discontinuous media are finite difference methods that approximate the derivatives with Taylor series expansions, which only require five adjacent nodes for accurate calculation in an acoustic 2D case (c) and finite element methods that use the weak form of the elastic wave equation to solve the derivatives, which require nine nodes for accurate calculation in an acoustic 2D case (d). Note that in both cases the number of nodes required exponentially increases with added dimensions and complexity, as in an elastic case.