TOUGH2 Modifications for Anisotropic Geologic Media

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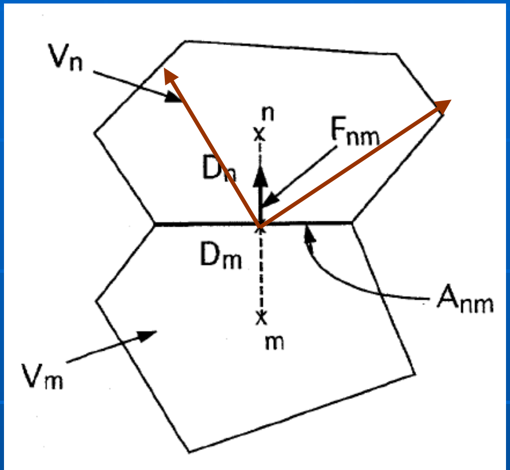
Limitations of Standard TOUGH2/iTOUGH2

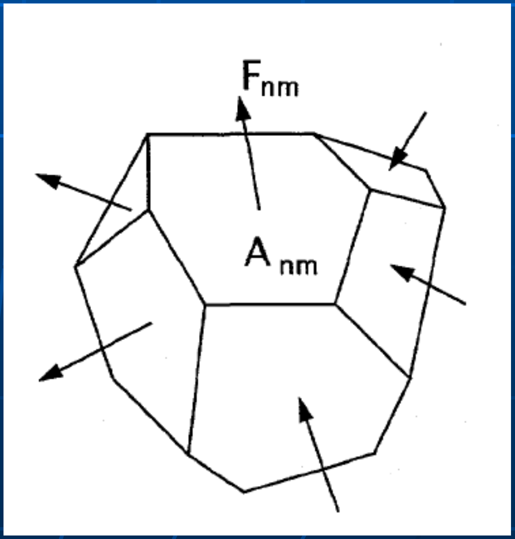
❖ Limitations

- Principal directions of permeability (X,Y,Z) must be known
- A regular mesh, consistent with the principal directions, is needed using ISOT indexing



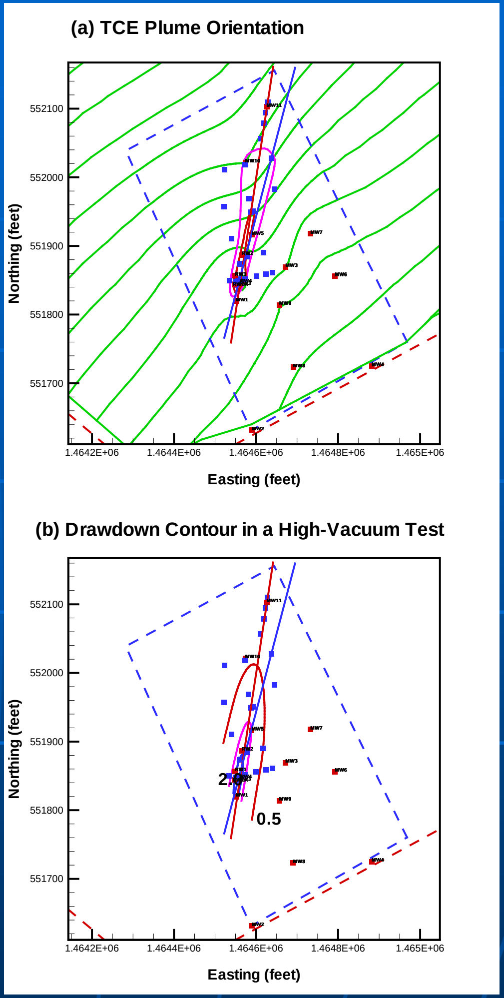
❖ General Cases

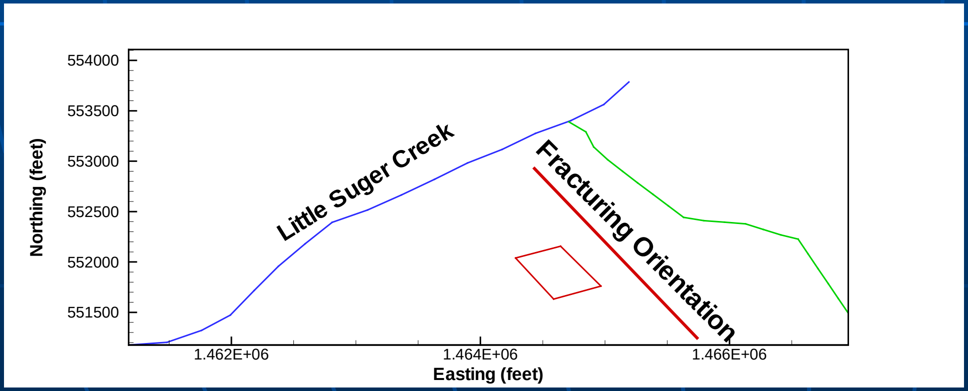
- The principal directions are a priori unknown
- The (X,Y,Z) directions are determined in an iterative calibration process of flow and transport modeling
- A more flexible, unstructured mesh is generated using WinGridder (Pan et al., 2001)
- The normal flux for a CONNECTION is determined by the permeability tensor and gradient vector



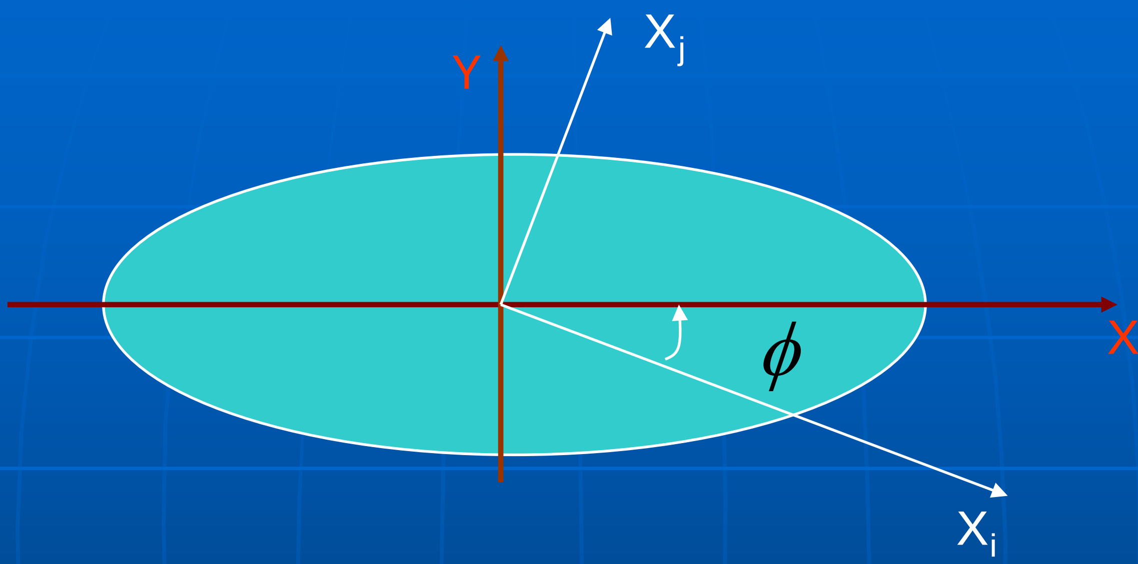
Evidence of Anisotropy for a Case Study

- TCE Plume Orientation
- Drawdown Configuration of a High-Vacuum Test
- General Fracturing Orientation in the Piedmont Province of North Carolina





Solution for Two-Dimensional Anisotropy



$$[k_{ij}] = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} k_X & 0 \\ 0 & k_Y \end{bmatrix} \begin{bmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{bmatrix}$$

$$F_n = \sum_{i,j=1}^{2} \left(-k_{ij} \frac{k_r \rho}{\mu} \left[\frac{P_1 - P_2}{(D_1 + D_2) n_j} - \rho g_{12} \right] n_i \right)$$

Applications

- Case 1: Anisotropic Media with $\phi = 0$: Unstructured Mesh with any normal directions

- Case 2: Anisotropic Media with $\phi \neq 0$