U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: AIR-PERMEABILITY TESTING - ROLE OF FRACTURES

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DETERMINATION OF UNSATURATED-ZONE GAS PERMEABILITY AND POROSITY OF FRACTURE NETWORKS

- REGULATORY CONCERNS
  - RELEASE OF TRITIUM, CARBON-14, ETC.
  - MOVEMENT OF WATER VAPOR AND ITS IMPACT ON LIQUID WATER FLUX

- GAS-FLOW MECHANISMS
  - BAROMETRIC PUMPING
  - TOPOGRAPHIC RELIEF
  - GEOTHERMAL GRADIENT
  - HEAT LOADING CAUSED BY CANISTERS
  - DIFFUSION

- *IN SITU* PNEUMATIC TESTING PROVIDES PARAMETERS FOR:
  - GAS-FLOW MODELING
  - TRANSIENT FRACTURE-FLOW MODELING

GAS-FLOW EQUATIONS

$$\nabla \cdot \left[\frac{k}{\mu}\nabla(p^2)\right] = \phi C_t \frac{\partial p^2}{\partial t} \qquad (1)$$

UNDERLYING ASSUMPTIONS:

1. FLUX OF ROCK GRAINS, q_g, IS NEGLIGIBLE
2. IDEAL GAS LAW APPLIES
3. GAS EXPANDS ISOTHERMALLY
4. GRAVITY'S INFLUENCE IS NEGLIGIBLE
5. FLOW IS LAMINAR
6. $S_g = 1.0$
7. EXTERNAL LOAD ON ROCK IS CONSTANT

k, μ, C_p and $\beta = f(p)$

RANGE OF VALUES OF COMPRESSIBILITY

	COMPRESSIBILITY, α (m^2/N OR Pa^{-1})
CLAY	10^{-6}-10^{-8}*
SAND	10^{-7}-10^{-9}*
GRAVEL	10^{-8}-10^{-10}*
JOINTED ROCK	10^{-8}-10^{-10}*
SOUND ROCK	10^{-9}-10^{-11}*
WATER (β)	4.4×10^{-10}*
GAS (β)	10^{-5}-10^{-6}

*FREEZE AND CHERRY (1979)

GAS-FLOW EQUATIONS

DIMENSIONLESS PARAMETERS

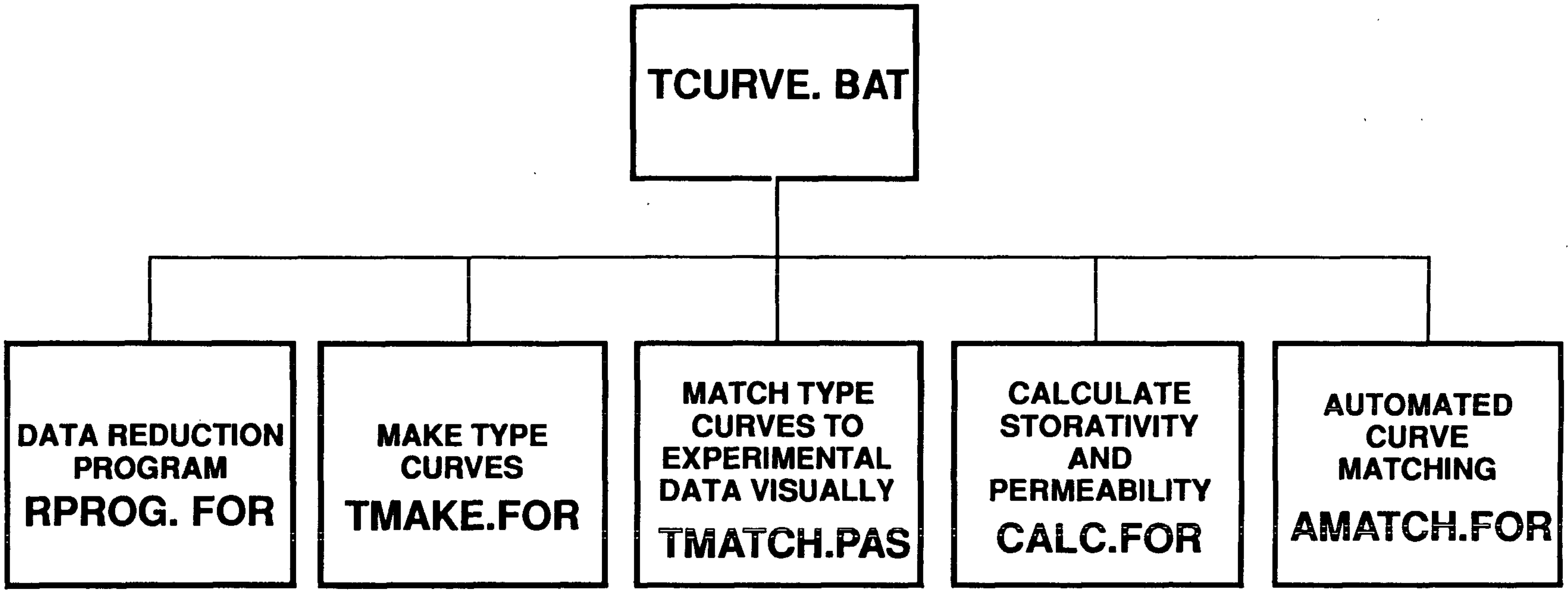
DIMENSIONLESS TIME $= t_D = \frac{kt}{\phi \mu C_t (r_w)^2}$

DIMENSIONLESS RADIUS $= r_D = \frac{r}{r_w}$

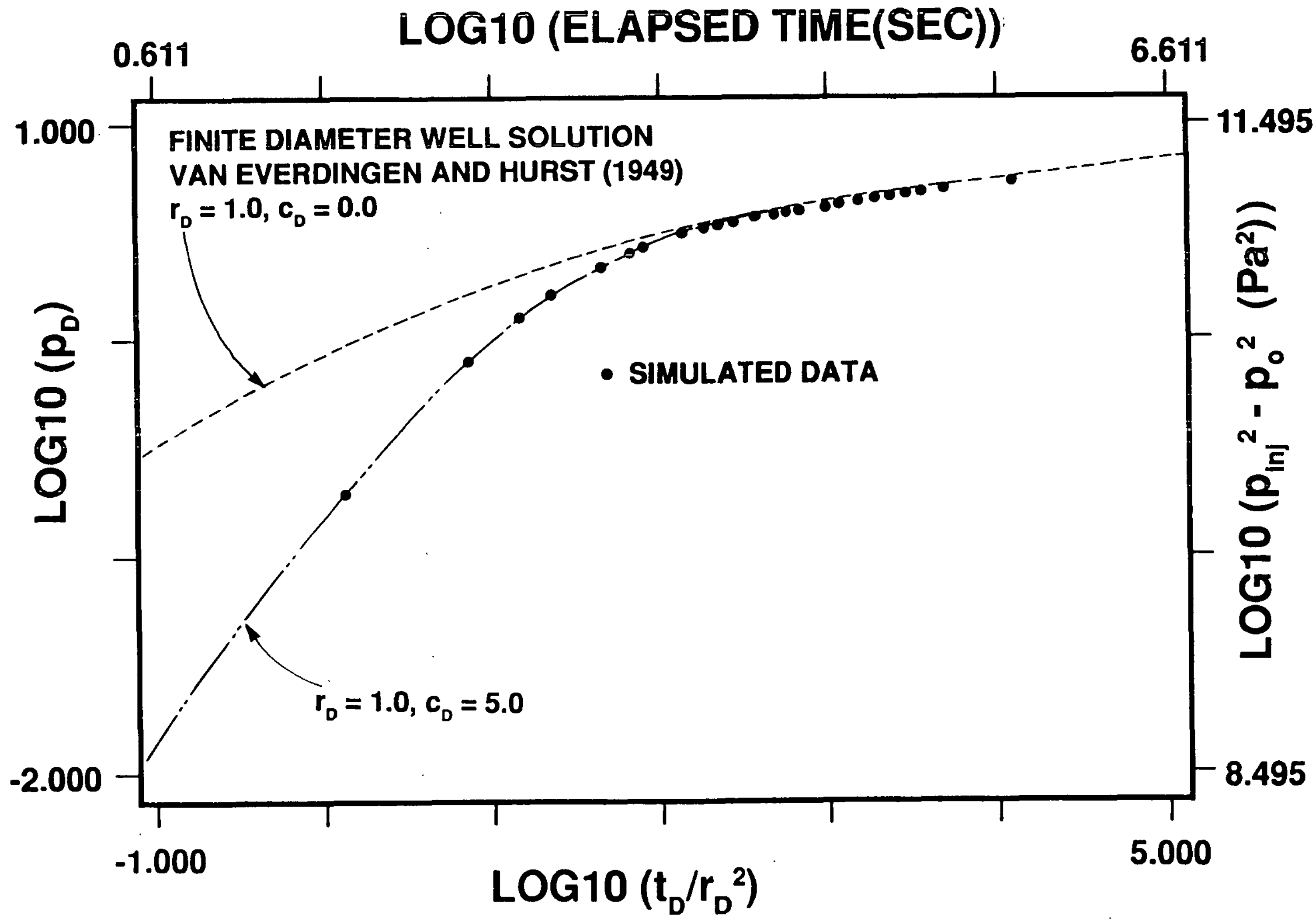
DIMENSIONLESS PRESSURE $= P_D = \frac{\pi k b (p^2 - p_o^2) T_{sc}}{P_{sc} Q_{sc} \mu T}$

RADIAL FLOW EQUATION IN DIMENSIONLESS TERMS

$$\frac{1}{r_D} \frac{\partial}{\partial r_D} \left[r_D \frac{\partial P_D}{\partial r_D} \right] = \frac{\partial P_D}{\partial t_D} \qquad (2)$$


TCURVE. BAT
DATA REDUCTION PROGRAM
RPROG. FOR
MAKE TYPE CURVES
TMAKE.FOR
MATCH TYPE CURVES TO EXPERIMENTAL DATA VISUALLY
TMATCH.PAS
CALCULATE STORATIVITY AND PERMEABILITY
CALC.FOR
AUTOMATED CURVE MATCHING
AMATCH.FOR

SIMULATED DATA SET
(p_f = 4.1E+05 Pa)



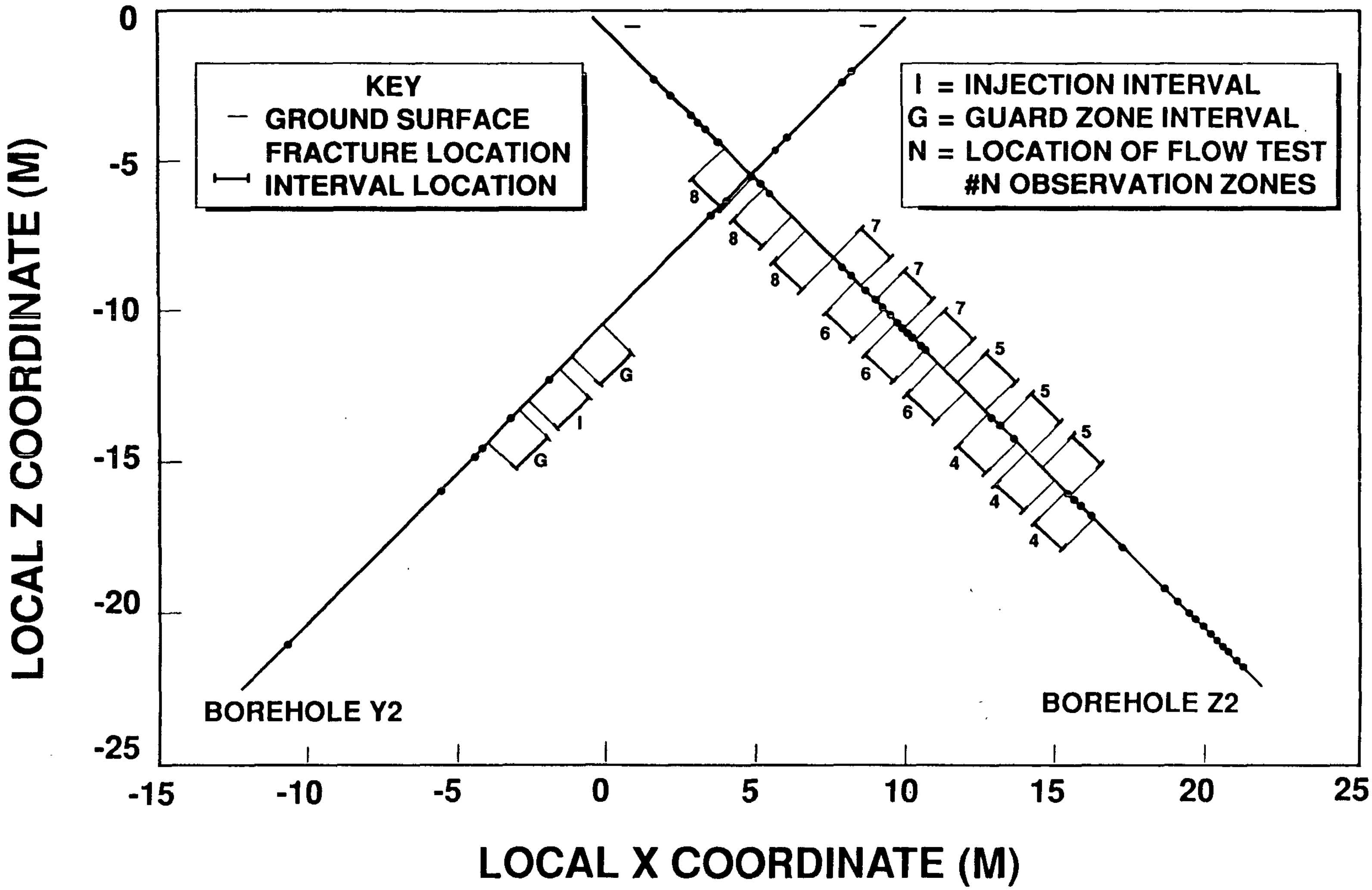
SIMULATED DATA SET

TRUE PERMEABILITY	=	.8000E-15 m^2
TRUE POROSITY (%)	=	17.00

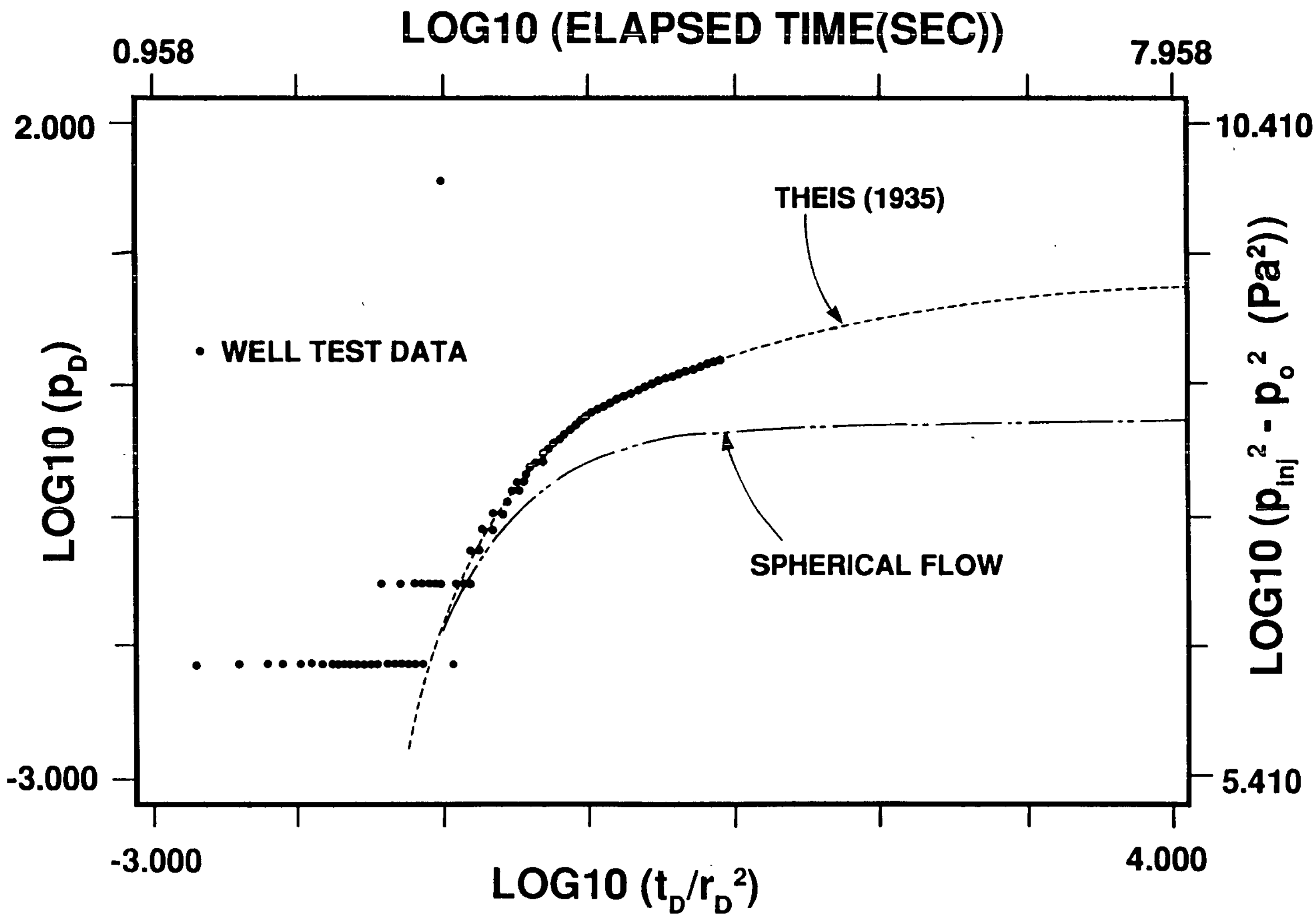
TYPE CURVE MATCHING

PERMEABILITY	=	.8046E-15 m^2
POROSITY (%)	=	18.24

BOREHOLE LOCATIONS
AT APACHE LEAP TUFF SITE, SUPERIOR, ARIZONA



EXPERIMENTAL DATA FILE: A:CFLOW8D.DIF



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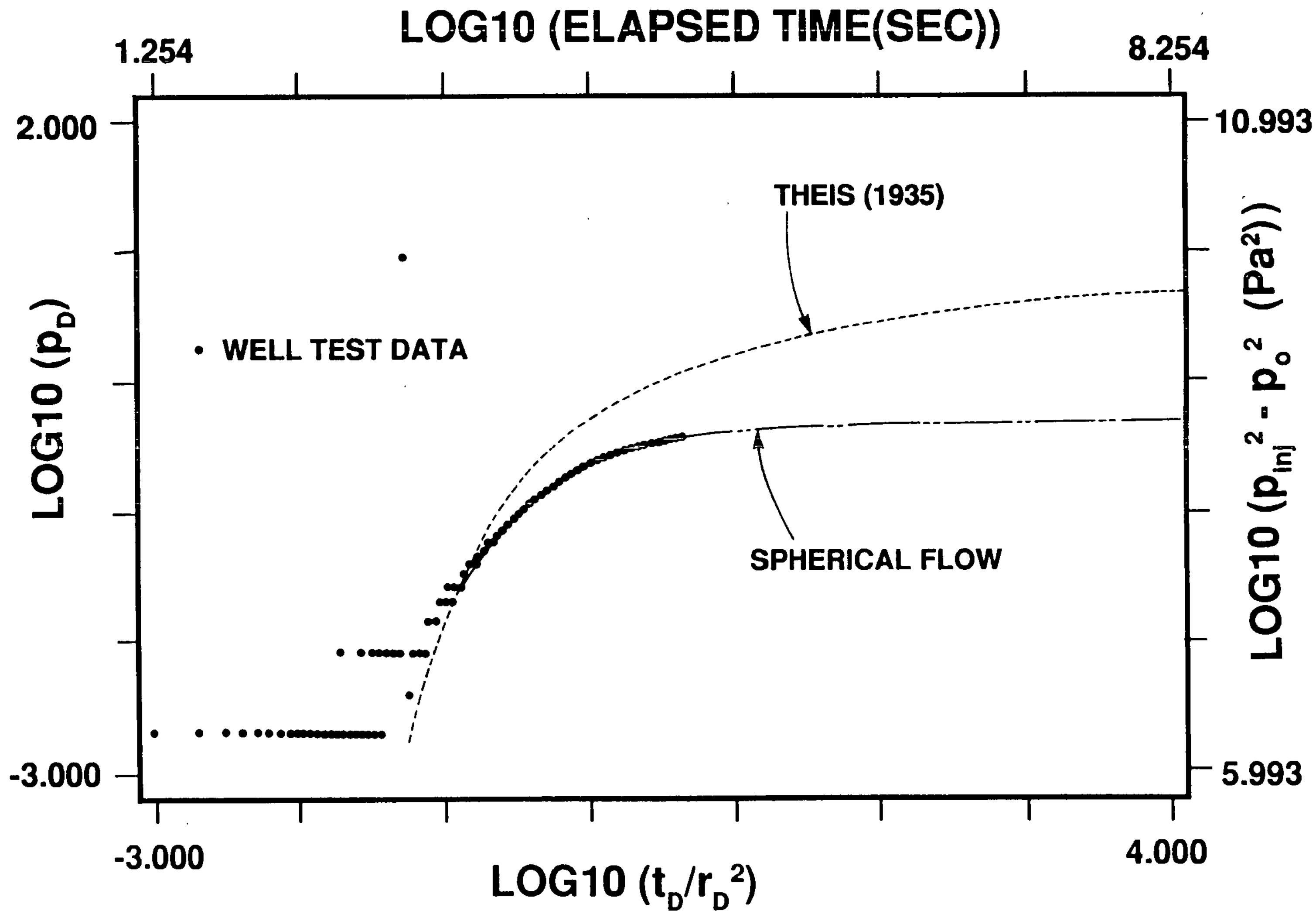

RADIAL FLOW MODEL

PERMEABILITY	=	.3248E-1	m^2
POROSITY (%)	=	123.20	

SPHERICAL FLOW MODEL

PERMEABILITY	=	.9767E-13	m^2
POROSITY (%)	=	7.26	