Field-scale simulations of CO_2 injection in saline aquifer in north Taiwan

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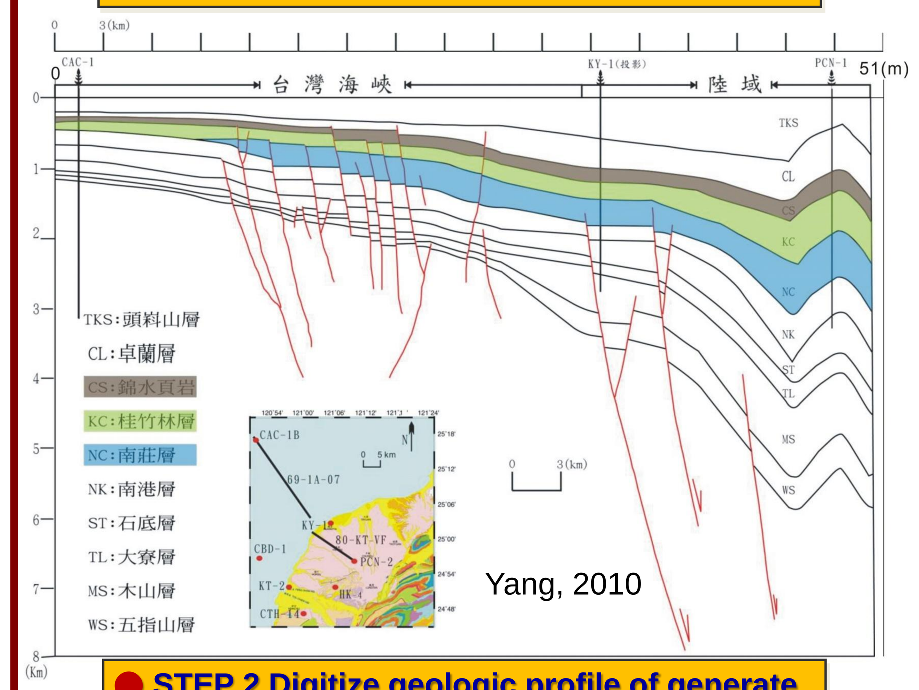
Abstract

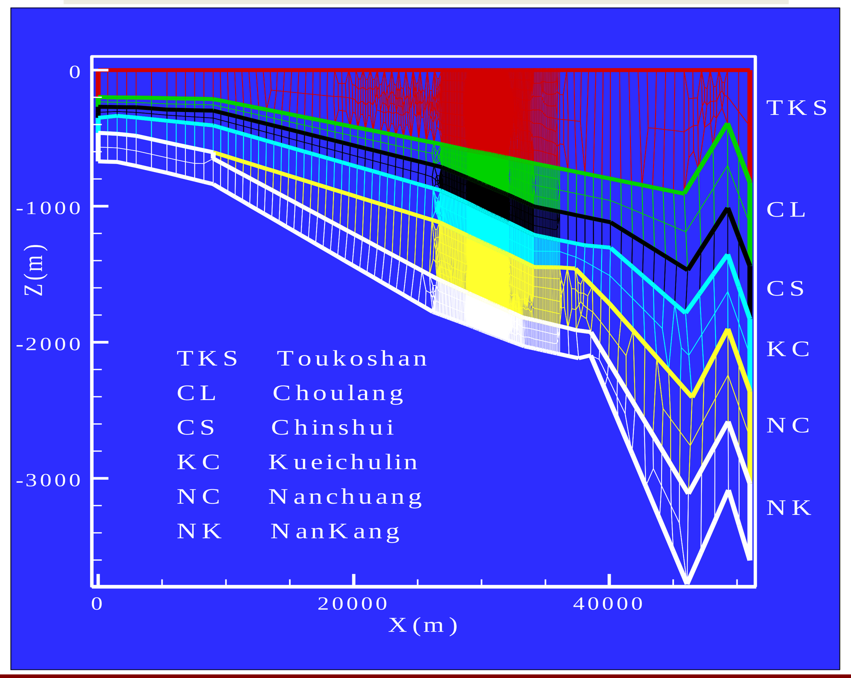
The carbon dioxide capture and storage (CCS) are recognized to be feasible techniques for mitigation of carbon dioxide emission for the earth environment. Due to large capacity and availability of geological formations for most countries, the geological storage methods are well-developed and many sites are on the stage for possible large scale operations. Numerical simulations of CO_2 migration in geological formations can provide key information for predicting CO_2 plume, before field-scale operations and tests are conducted. This study employs TOUGH2 numerical model to predict CO_2 migration in a saline aquifer (Nanchuang and Kueichulin Formations) in north Taiwan. A preprocess computer code for irregular mesh generation is developed to create input information for ECO2N module in the TOUGH2 model. The two-dimensional profile model is 51 km in length and is 3.8 km in depth. However, the aquifer thickness for each formation varies from hundreds to several hundreds of meters. With constant injection of 20 thousand metric ton of CO_2 in Nanchuang formation, the CO_2 plumes with different phases are simulated in 500 years. Simulation results show that the distances of the CO_2 plumes may move 4.2 km for Nanchuang and Kueichulin formations from the injection point. The travel distances in vertical direction of CO_2 plumes may reach 0.42 km(Nanchuang Formation) and 0.1km(Kueichulin Formation) from injection point, respectively.

TOUGH2 Mesh Generation

STEP 1 Geological profile in saline aquifer in north Taiwan

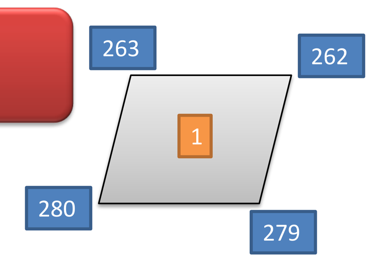


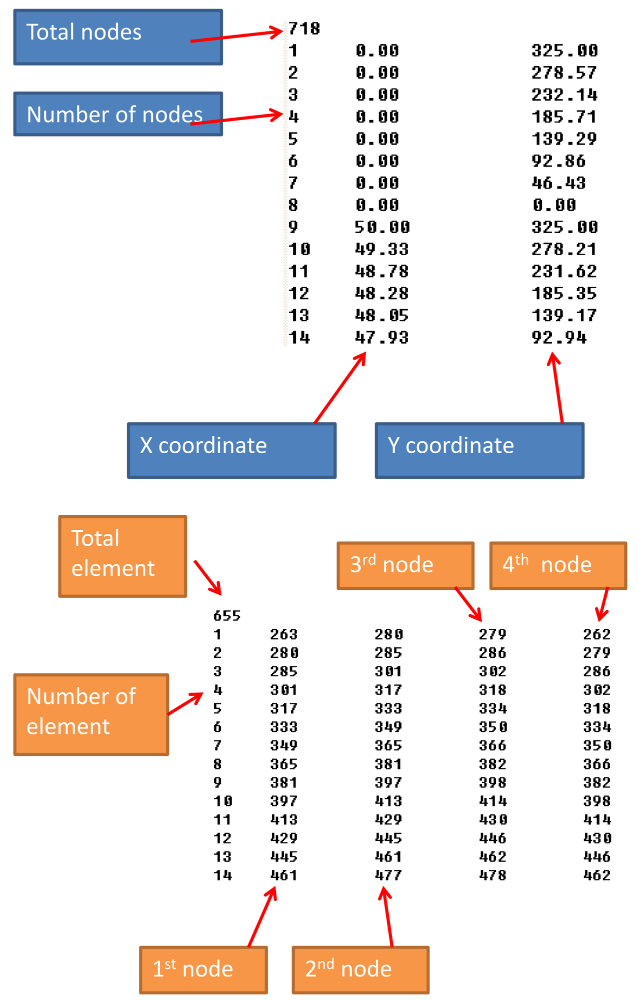
STEP 2 Digitize geologic profile of generate mesh(nodes and elements) by using AUTOMESH-2D（Zhao and Ma ,2003）



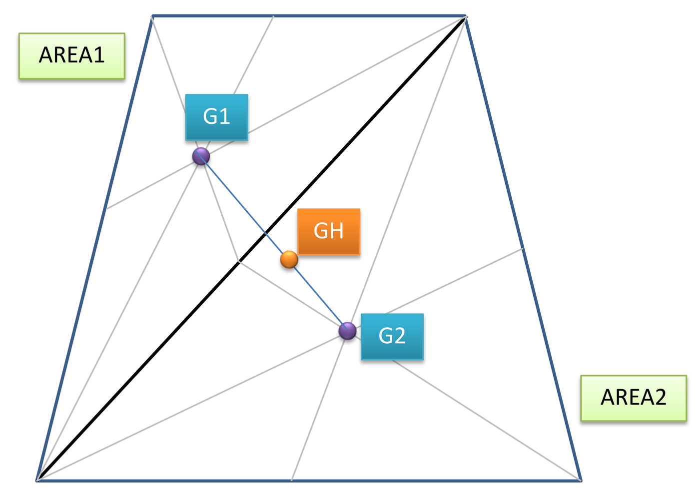
STEP 3 Calculate TOUGH2 mesh data

Step 3-1 Read Automesh-2D data





Step 3-2. Calculate the center of gravity of the element for TOUGH2

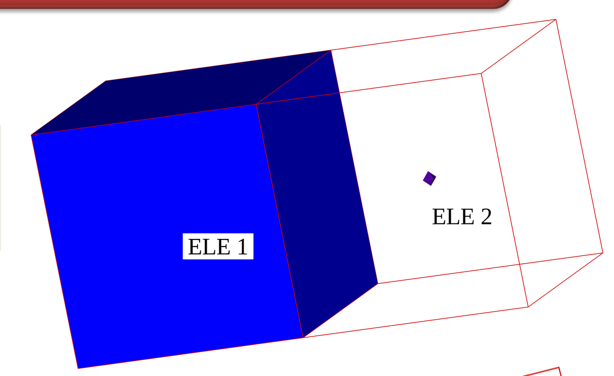


1. Calculate area1 and area2
2. Calculate the center of gravity(G1 and G2) of area1 and area2
   G1(x1,y1), G2(x2,y2)
3. Calculate the center of gravity of the quadrangle.
   GH(x1+(x1-x2)*area2/(area1+area2),
   y1+(y1-y2)*area2/(area1+area2),)

Step 3-3. Calculate the information of the element

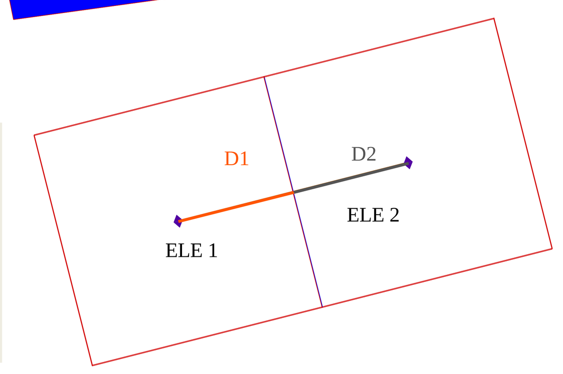
Volume

Calculate the element volume (m³).



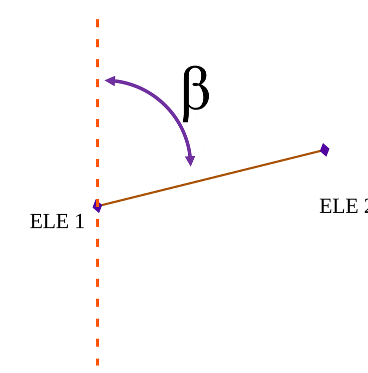
D1 D2

Calculate the distances (m) from the first and second elements to their common interface.



Beta

Calculate the angle between the gravitational acceleration vector and the line between the two elements.



Digitize geologic profile to obtain get geometry of simulation data(X, Z)

Use AUTOMESH-2D to generate mesh(nodes and elements) by geometric data(X and Z)

Use mesh data(nodes and elements) to create TOUGH2 element format

ELEME | **CONNE** | **INCON**

TOUGH2-ECO2N

Governing Equation :

- The basic mass and energy balance equations solved by TOUGH2 can be written in general from:

$$\frac{d}{dt}\int_{V_n} M^{\kappa} dV_n = \int_{\Gamma_n} F^{\kappa} \bullet n d\Gamma_n + \int_{V_n} q^{\kappa} dV_n$$

- The general from of the mass accumulation term is:

$$M^{\kappa} = \phi \sum_{\beta} S_{\beta} \rho_{\beta} X_{\beta}^{\kappa}$$

- Mass flux is a sum over phases:

$$F^{\kappa} = \sum_{\beta} X_{\beta}^{\kappa} F_{\beta}$$

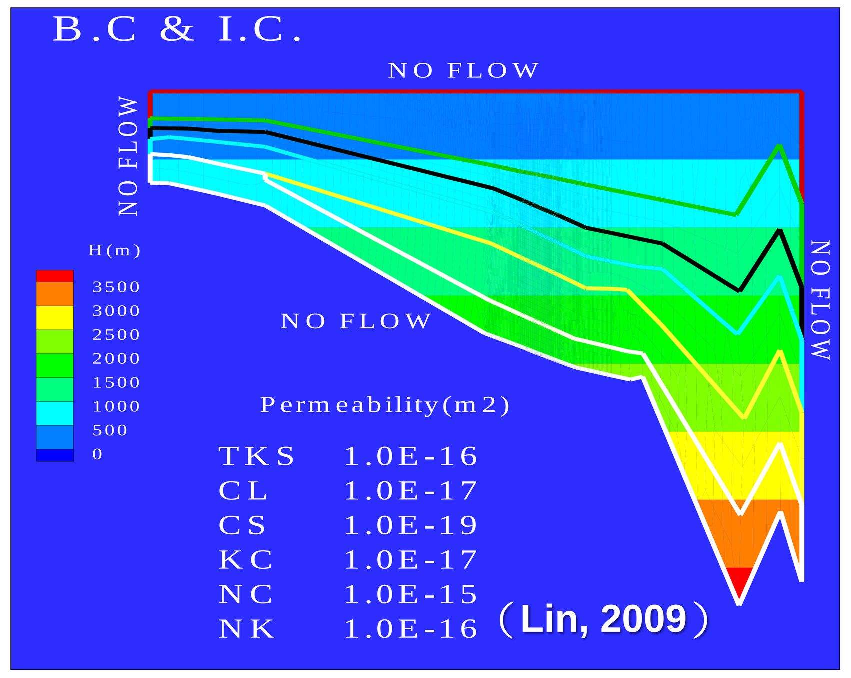
- Individual phase fluxes are given by a multiphase version of Darcy's law:

$$F_{\beta} = \rho_{\beta} u_{\beta}$$

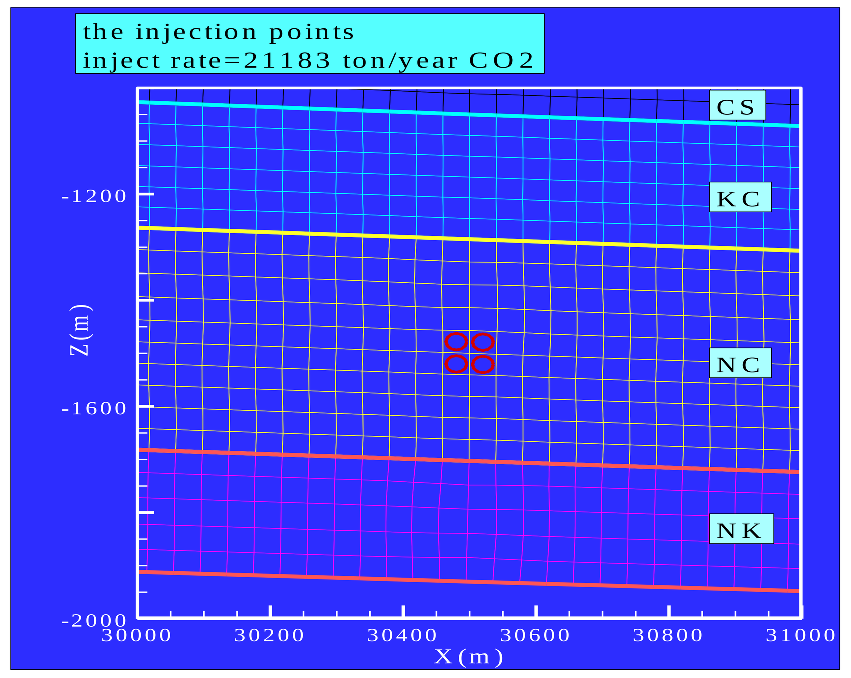
where M in the accumulation term is mass or energy per volume, with κ=1…NK labeling the mass components, F denotes mass or heat flux, and q is sinks and sources. β is fluid phase, S is saturation, ρ is density, φ is porosity, X is the mass fraction, and u is Darcy's velocity.

Simulations of CO2 Injection

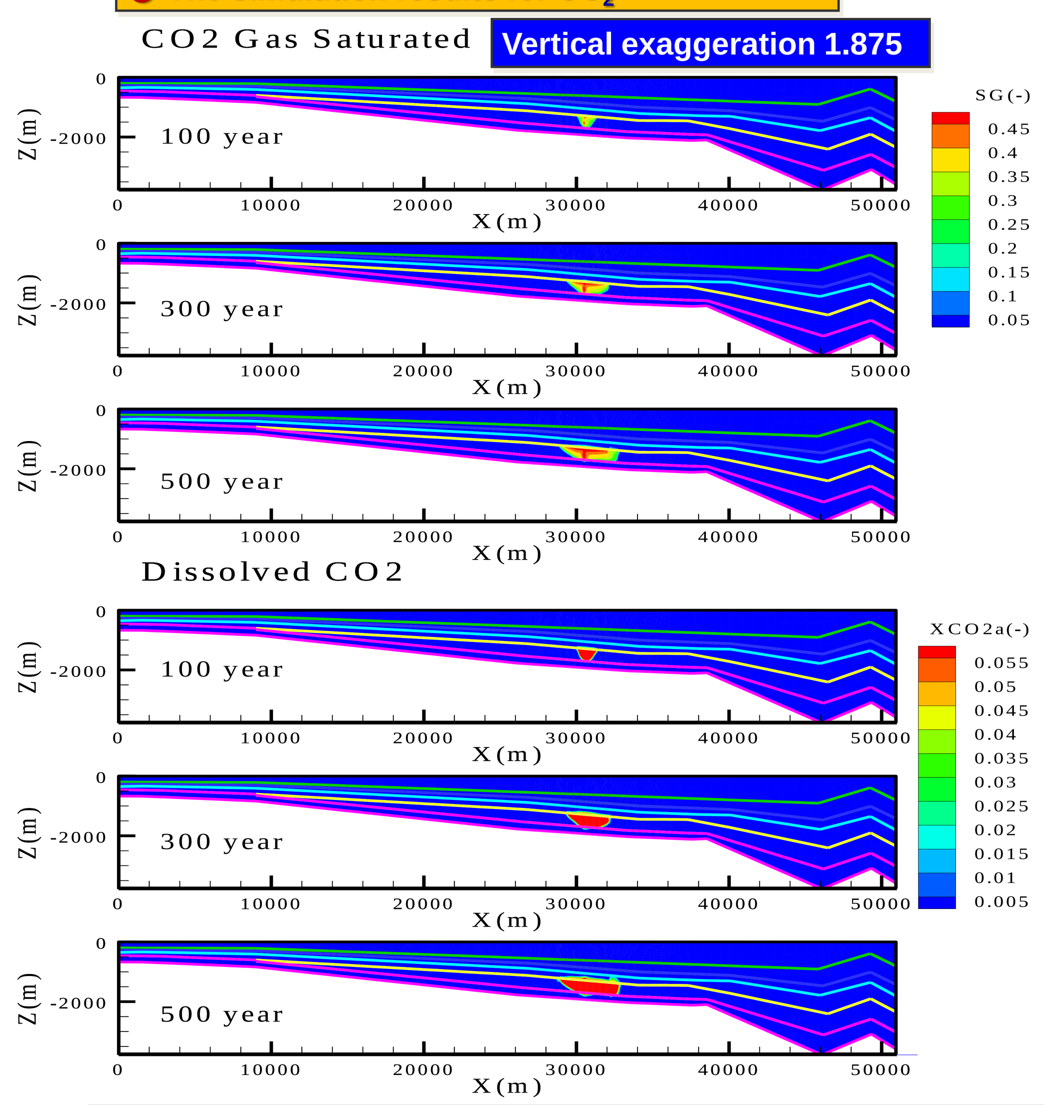
The boundary and initial conditions for simulations



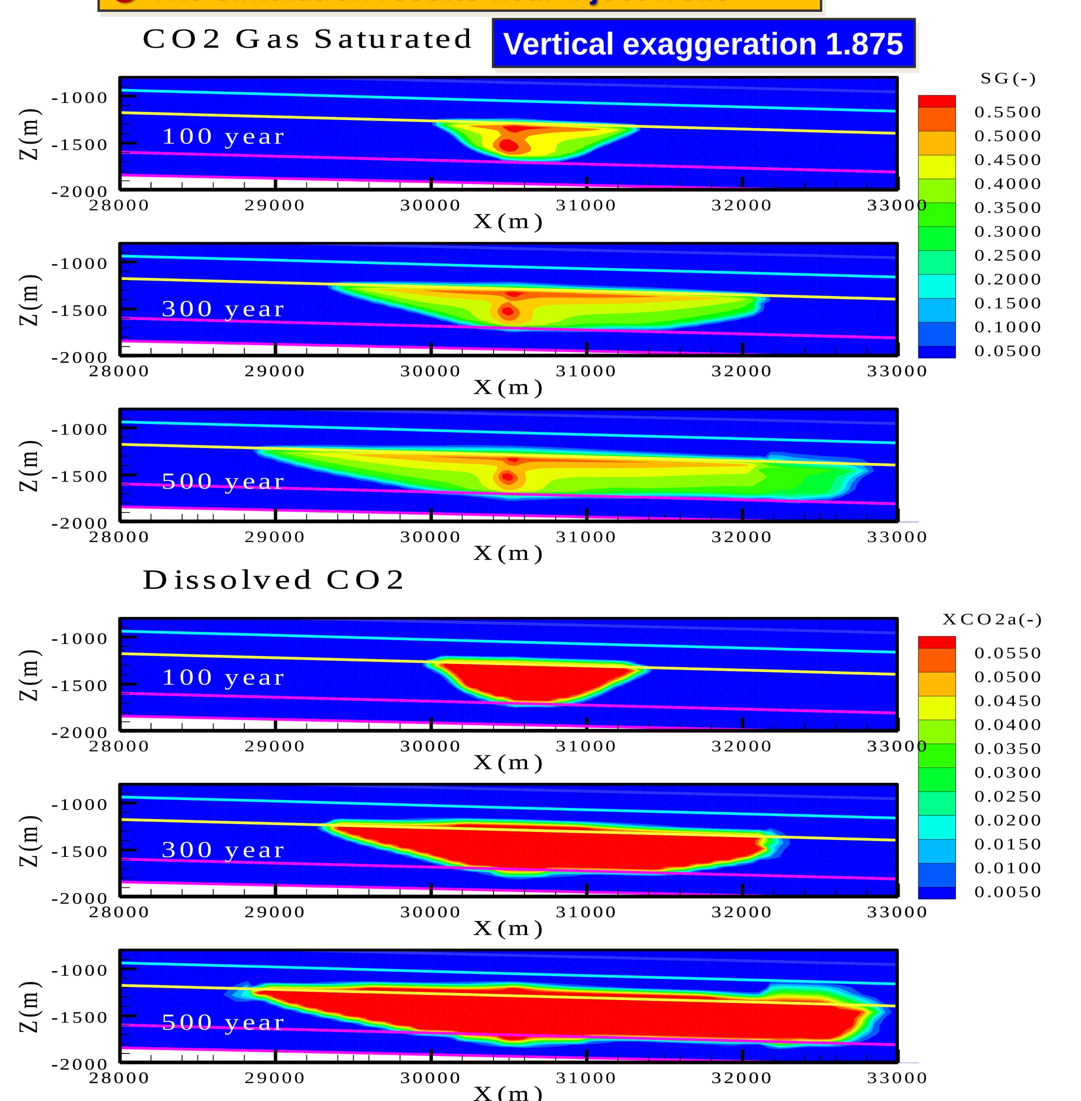
The locations the injection points



The simulation results for CO_2



The simulation results near inject wells



Conclusions

- Simulation results show that the distances of the CO_2 plumes may move 1.4, 3.0 and 4.2 km for Nanchuang formations from the injection point after 100, 300 and 500 years.
- The results show that the CO_2 plumes will migrate 100m to Kueichulin and Nankang formations from the injection point after 300 years. The the plumes will migrate 420m and 130m to Kueichulin and Nankang formations after 500 years.

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