**APPENDIX A**

The modified Hashin-Shtrikman dry-rock moduli are (Dvorkin et al., 1999; Ecker et al., 2000)

, (A1a)

, (A1b)

, (A2a)

, (A2b)

and

, (A3)

where  is the porosity,  is the critical porosity, in the range 0.36~0.4, and  and  are the dry-rock bulk and shear moduli at the critical porosity, respectively,

, (A4)

where  is the average number of contacts per grain,  is the Poisson ratio of the mineral mixture and  is the effective pressure.

, (A5)

where  and  are the densities of the solid and fluid phases, respectively,  is the gravity constant and  is depth below seafloor.

**APPENDIX B**

**Biot-Rayleigh double-porosity theory**

The Biot-Rayleigh double-porosity theory proposed by Ba et al. (2011) is based on the Biot theory and Hamilton principle. The same equations are applied to the two models, but the definitions of some basic variables are different.

 (B1)

 (B2)

 (B3)

 (B4)

where  is the average particle displacement of the solids. , ,  are the corresponding three divergence fields.  is the fluid strain increment caused by the local flow process. In Model 1, ,  are the displacement of fluid phase 1 (formation water), and fluid phase 2 (gas hydrate/free gas). In Model 2,  and  are the displacements of fluid phase 1 (fluid in the host skeleton), and fluid phase 2 (fluid in the inclusions of hydrate), respectively.

**APPENDIX C**

**Model 1 equations**

The five density coefficients in Model 1 are

, (C1a)

, (C1b)

, (C1c)

, (C1d)

, (C1e)

, (C1f)

The dissipation coefficients of the two types of pores are

. (C2)

The stiffness coefficients in Model 1 are

, (C3a)

, (C3b)

, (C3c)

, (C3d)

, (C3f)

. (C3g)

**Model 2 equations**

The five density coefficients in Model 2 are

, (C4a)

, (C4b)

, (C4c)

, (C4d)

. (C4f)

The stiffness coefficients are

, (C5a)

, (C5b)

, (C5c)

, (C5d)

, (C5e)

, (C5f)

. (C5g)

where ,  are the displacement divergence fields of two fluid phases.